6 Photosynthesis — Provider of Food for All

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 & chlorophyll and also the formation of starch and the output of oxygen ; carbon cycle.*

Scope of syllabus : 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, 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 photosynthesis and experiments with regard to the factors essential for the process should be discussed.

Photosynthesis, in a way, is the most significant life process – it provides food for all animal life including humans, and also the life supporting free oxygen gas in the atmosphere for breathing. A whole series of experiments on photosynthesis are worth performing. Hopefully, you will be able to see them THROUGH demonstrations.

6.1 PLANTS — SELF FOOD PRODUCERS

All living organisms need food. Animals obtain food from plants but plants prepare it for themselves by the process of photosynthesis.

6.2 WHAT IS PHOTOSYNTHESIS ?

Photosynthesis is an important activity of all green plants which are able to **synthesise food from carbon dioxide and water in the presence of chlorophyll and light energy**. The essential chemical steps in this process are the same in all green plants.

Photosynthesis is the process by which living plant cells, containing chlorophyll, produce food substances (glucose and starch), from carbon dioxide and water, by using light energy. Plants release oxygen as a waste product during photosynthesis.

Importance of photosynthesis

(1) ***Food for all.*** Photosynthesis is ultimately the source of energy and food for all living beings— directly for plants and indirectly for animals and humans who eat the plants or the plant-eating animals.

(2) ***Oxygen to breathe in.*** Photosynthesis is the only biological process which releases oxygen into the atmosphere. The oxygen supports all life on the earth.

6.3 CHLOROPHYLL – THE VITAL PLANT PIGMENT

Chlorophyll (*chloro* : green, *phyll* : leaf) is the green colouring matter found in plants. It is contained in microscopic cell organelles called chloroplasts (Fig. 1.1 B page 2).

Chloroplasts are minute oval bodies bounded by a double membrane, and their interior contains closely packed flattened sacs (**thylakoids**) arranged in piles (**grana**) lying in a colourless ground substance called

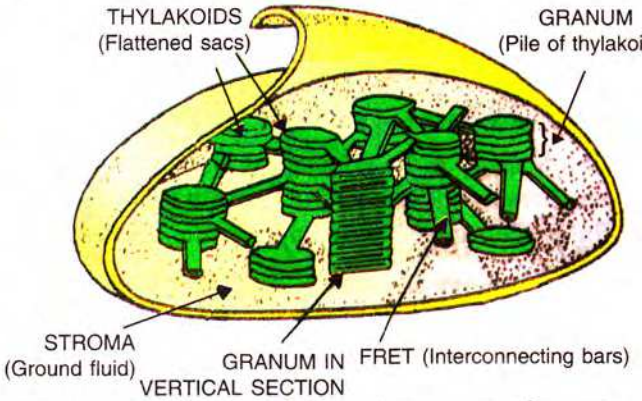


Fig. 6.1 : A chloroplast. Internal structure as revealed by electron microscope. (Highly diagrammatic)

stroma (Fig. 6.1). Ordinarily, there may be 40-50 chloroplasts in a cell. *The pigment **chlorophyll** is contained in the walls of **thylakoids**.* It is a highly complex substance, composed of carbon, hydrogen, oxygen, nitrogen and magnesium. Chloroplasts are mainly contained in the mesophyll cells located between the upper epidermis and the lower epidermis (*i.e.* in palisade cells and spongy cells) of leaves. These are also found in the guard cells of stomata and in the outer layers of young green stems.

There may be more than 500,000 chloroplasts per sq. mm. of leaf surface.

You will be surprised to know that there are nine types of chlorophyll. Two out of these, **chlorophyll-a** and **chlorophyll-b**, are best known and most abundant.

Chlorophylls absorb light at both ends of the visible spectrum - i.e. BLUE and RED light, and reflect away the green light. That is why, chlorophyll appears green. The absorbed blue and red lights are most effective for photosynthesis.

Too much light destroys chlorophyll

Chlorophyll is highly sensitive to light, so too much light may destroy it. However, the formation of chlorophyll itself depends on the exposure of the plant to light. The grass growing in the shade under a stone turns yellowish due to the non-formation of new chlorophyll and due to the disintegration of the older one in the absence of light.

6.4 REGULATION OF STOMATAL OPENING FOR LETTING IN CO_2

Stomata are minute openings occurring in large numbers on the lower surface of a leaf. The main function of the stomata is to let in CO_2 from the atmosphere for photosynthesis. When stomata are not in use for photosynthesis, *i.e.* when it is dark, they tend to close their openings so that water loss is minimised from the leaves through transpiration. When there is light, as after sunrise, they reopen to allow CO_2 to diffuse in. Transpiration occurs along with photosynthesis. Due to this process, one can say that ***transpiration is the price which the plant pays for photosynthesis***.

The closing and opening of the stomata are on account of the movement of water in and out of the guard cells. They have a **thick inner wall** facing the opening and a **thin outer wall** on the opposite side (Fig. 6.2); their cytoplasm contains chloroplasts.

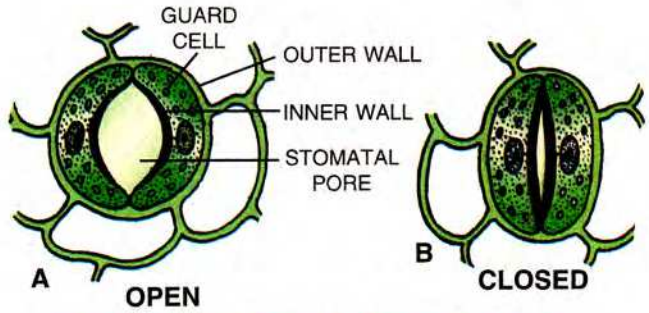


Fig. 6.2 The opening and closing of stomata.
A – Guard cells turgid, the stoma (mouth) opens,
B – Guard cells flaccid, the stoma closes.

Opening and Closing of Stomata

There are two theories about the opening and closing of stomata.

(1) Sugar concentration theory (old)

(2) K^+ ion concentration theory (recent)

(1) *Sugar concentration theory :*

According to the old sugar concentration theory, during daytime, the guard cells begin photosynthesis and the sugar (glucose) produced during the process increases the osmotic pressure which draws in water from the adjoining cells due to endosmosis. Hence, the guard cells **become turgid and bulge outwards** due to their thin outer wall, thus widening the stomatal opening lying in between (Fig. 6.2A). As the stomata open, the diffusion of gases in and out begins for fulfilling the need for photosynthesis and for allowing transpiration.

Closing of the stomata : If for any reason, the water content of the leaf is falling short, the water is drawn out of the guard cells due to exosmosis making them flaccid. As a result, their inner thick walls straighten to close the stomata.

(2) *K^+ ion concentration theory :*

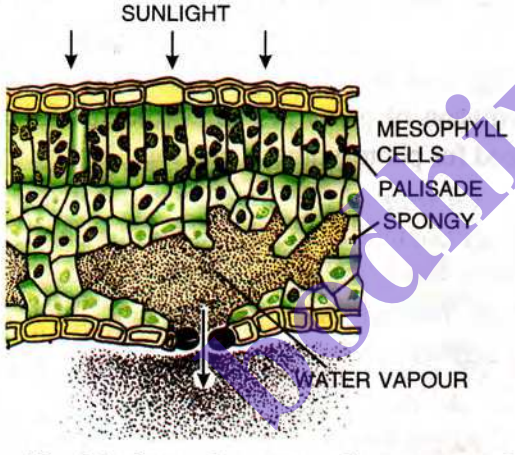
According to the recent K^+ ion concentration theory, the stomatal opening and closing depend on the generation of potassium ion (K^+) gradient. During daytime, the chloroplasts in the guard cells photosynthesise which leads to the production of ATP. **This ATP is used to actively pump the potassium ions of the adjacent cells into the guard cells.** Increased K^+ concentration in the guard cells makes them hypertonic, so, more water from the adjacent cells is drawn in and the cells become more turgid and they move outwards to open out the stomatal pore. Reverse happens at night. The K^+ ions leak out thus reducing the turgor of guard cells and the stomatal pore closes.

PROGRESS CHECK

1. Answer the following in "Yes" or "No"
   (i) All parts of a green plant carry out photosynthesis. Yes/No
   (ii) Photosynthesis is the only biological process that releases oxygen into the air. Yes/No
   (iii) Out of nine types of chlorophyll, chlorophyll a and b are most abundant. Yes/No
   (iv) Too much light destroys chlorophyll. Yes/No
   (v) No transpiration occurs during photosynthesis. Yes/No
   (vi) During sunlight, the guard cells turn flaccid to open the stomata. Yes/No

6.5 PROCESS OF PHOTOSYNTHESIS

Mesophyll cells (both **palisade** and **spongy**) in a leaf are the principal centres of this activity. During daytime, when sunlight falls on the leaf, the **light energy** is trapped by the chlorophyll of the upper layers of mesophyll, especially the palisade cells. This energy is utilized in chemical processes involved in the manufacture of food, where the raw materials used are carbon dioxide and water.



- **Carbon dioxide** from the atmosphere enters the leaf by diffusion down a concentration gradient (higher concentration outside the leaf, and less concentration inside) through the stomata.
- **Water** from the soil is taken up by the roots, sent up through the stem and finally to the leaves where it is distributed in the mesophyll tissue.

The chemical equation to represent this process is as follows :

$$6CO_2 + 12H_2O \xrightarrow[\text{chlorophyll}]{\text{light energy}} C_6H_{12}O_6 + 6H_2O + 6O_2 \uparrow$$

The glucose molecule $C_6H_{12}O_6$ is a simple sugar readily soluble in water.

The 6 molecules of H_2O liberated at the end of the process are those that are **re-formed** during a chain of reactions and not out of the original ones.

6.6 TWO MAIN PHASES OF PHOTOSYNTHESIS — (A) LIGHT-DEPENDENT PHASE AND (B) LIGHT-INDEPENDENT (DARK) PHASE

(A) LIGHT-DEPENDENT PHASE (PHOTO-CHEMICAL PHASE)

In this phase, light plays the key role. A series of chemical reactions occur in very quick succession, initiated by light and therefore, the phase is called the photochemical phase. The light reaction takes place in **thylakoids** (containing chlorophyll) of the chloroplasts.

The light reaction (photochemical phase) occurs in two main steps.

Step I. *Activation of chlorophyll.* The chlorophyll on exposure to light energy becomes activated by absorbing **photons** (photon is the smallest unit of light energy).

Step II. *Splitting of water.* The absorbed energy is used in splitting the water molecule (H_2O) into its two components (Hydrogen and Oxygen) and releasing electrons.

$$2H_2O \xrightarrow{\text{energy of 4 photons}} 4H^+ + 4e^- + O_2$$

The reaction is known as **photolysis**, which means ***splitting by light*** (*photo* = light, *lysis* = breaking).

> Photolysis is defined as the splitting of H_2O molecules into hydrogen ions and oxygen in the presence of **light** and **grana**.

End result of the products of photolysis

(1) The **hydrogen** ions (H^+) are picked up by a compound **NADP** (Nicotinamide adenine dinucleotide phosphate) to form **NADPH.**

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

(2) The **oxygen** (O) component is given out as molecular oxygen (O_2).

$$2O \rightarrow O_2$$

(3) The **electrons** (e^-) are used in converting ADP (adenosine diphosphate) into energy-rich compound ATP (adenosine triphosphate) by adding one phosphate group P_i (inorganic phosphate).

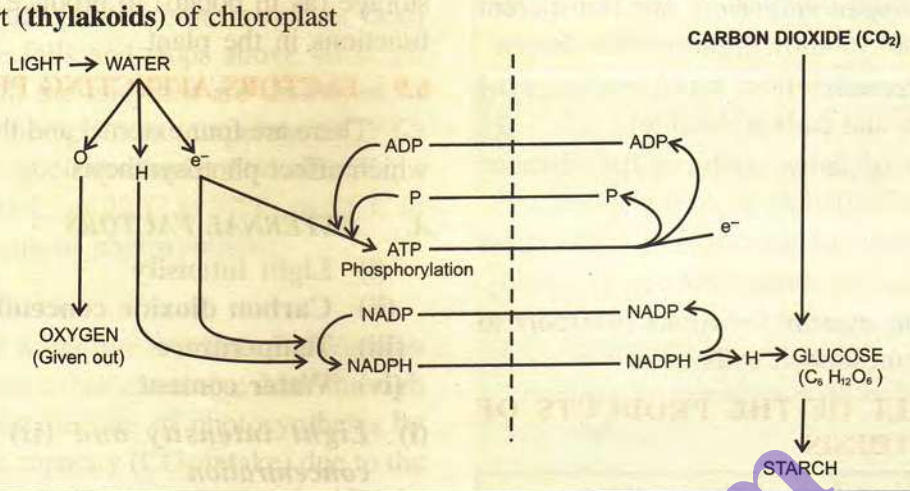
$$ADP + \underset{\text{(inorganic)}}{\text{Phosphate}} \rightarrow ATP$$

[This process is called **phosphorylation** (addition of phosphate) and since the energy used in

HIGHLY SIMPLIFIED SUMMARY OF THE EVENTS IN LIGHT REACTION AND LIGHT-INDEPENDENT REACTION OF PHOTOSYNTHESIS

LIGHT-DEPENDENT REACTIONS
Occur in chlorophyll-containing part (**thylakoids**) of chloroplast

LIGHT-INDEPENDENT REACTIONS
Occur in other part (**stroma**) of chloroplast



the process comes from light (photons), the process is termed as **photophosphorylation**]

(B) LIGHT-INDEPENDENT (DARK) PHASE also called *Biosynthetic phase*

The new term Light Independent Phase

The old term "dark phase" did not mean that it occurs when it is dark i.e. at night. It only meant that the reactions are not dependent on light. That is why, it is now better to call it "light independent phase."

The reactions in this phase do not require light energy, and occur simultaneously with the light reaction (time gap between the two being less than even one-thousandth of a second).

EXTRA **Not in syllabus**

Some details of the chemical steps during dark phase are as follows :

- The hydrogen of NADPH is used to combine it with CO_2 by utilising ATP energy to ultimately produce glucose ($C_6H_{12}O_6$).
- This fixation of CO_2 occurs in a number of steps using a special CO_2 acceptor compound RuBP (ribulose bisphosphate). [**Note :** Some write it wrongly as "..... biphosphate"].
- This fixation is catalysed by the enzyme **Rubisco** (Ribulose bisphosphate carboxylase).

Conversion of glucose into starch and other chemicals. Most green plants convert glucose into **starch** as soon as it is formed during photosynthesis. Several glucose molecules are transformed to produce one molecule of starch; this process is called **polymerisation.** Some plants change glucose to sucrose (cane sugar, which chemically is called disaccharide or double sugar), or some into oils, etc.

PROGRESS CHECK

1. Write the overall summary chemical equation of photo-synthesis. .....
2. Which single substance in the above equation is repeated in raw material as well as reproduced as an the end products? .....
3. What is the source of oxygen released in photo-synthesis — CO_2 or H_2O? .....
4. What happens in photolysis? .....
5. Dark reaction involves utilisation of CO_2 in producing $C_6H_{12}O_6$ (glucose). Why is this phase called dark reaction ? .....
6. Glucose produced during photosynthesis is soon polymerised into starch. What does polymerisation mean? .....
7. Why is it better to call the dark phase of photo-synthesis as "light-independent phase"?

.....

6.7 ADAPTATIONS IN LEAF FOR PHOTO-SYNTHESIS

1. ***Large surface area*** for *maximum light absorption.* (Narrowing of leaves in certain

plants is to minimise transpiration in order to conserve water, as in oleander and pine).

2. ***Leaf arrangement*** *at the right angle to the light source to obtain maximum light.*
3. ***Cuticle and upper epidermis*** are transparent and water proof to allow light to enter freely.
4. ***Numerous stomata*** allow rapid exchange of gases (oxygen and carbon dioxide).
5. ***The thinness of leaves*** reduces the distance between cells facilitating rapid transport.
6. ***The chloroplasts*** are concentrated in the upper layers of the leaf to obtain light energy quickly.
7. ***Extensive vein system*** *for rapid transport* to and from the mesophyll cells.

6.8 END RESULT OF THE PRODUCTS OF PHOTOSYNTHESIS

There are three end-products of photosynthesis :
1. **Glucose ($C_6 H_{12} O_6$)**
2. **Water**
3. **Oxygen.**

1. *Glucose :* The **simple sugar glucose** is used in four different ways as required by the plant :

(i) immediately consumed by the plant cells
(ii) stored in the form of insoluble starch
(iii) converted into sucrose
(iv) used in synthesising fats, proteins, etc.

2. *Water :* The water produced in the process may be re-utilized in the continuance of photosynthesis.

3. *Oxygen :* Some of the oxygen may be used in respiration in the leaf cells (the phenomenon is called photorespiration), but the major portion of it is not required and it **diffuses out** into the atmosphere through the stomata. In a sense, even **this oxygen is not a waste**, because all organisms require it for their existence including the plants which require it at night.

Utilisation of Synthesised Food and its Translocation. Food manufactured in the leaf is required for use by all other parts of the plant. The glucose is formed in the leaf very rapidly during photosynthesis and it cannot be transported to other parts with the same rapidity. So, it is converted into **insoluble starch for temporary storage** in the leaf. At night, the starch is reconverted into soluble sugar which is transported in solution through the veins of the leaf and down through the phloem of the stem. In this way, it gets transported **(translocated)** to different parts of the plant where it may be reconverted into starch for storage (as in potato) to produce energy for various functions in the plant.

6.9 FACTORS AFFECTING PHOTOSYNTHESIS

There are four external and three internal factors which affect photosynthesis :

A. *EXTERNAL FACTORS*

(i) Light intensity
(ii) Carbon dioxide concentration
(iii) Temperature
(iv) Water content

(i) *Light intensity and* (ii) *Carbon dioxide concentration*

One would easily think that the rate of photosynthesis will increase with light intensity. To some extent, it is true (Fig. 6.3A). Photosynthesis increases with the light intensity up to a certain limit only, and then it gets stabilised at the point S′(0.02% CO_2). But if, at this point, the carbon dioxide concentration is increased, the photosynthesis also increases further (Fig. 6.3 B) and again gets stabilised at a point S″ = (0.05% CO_2) for the two factors together.

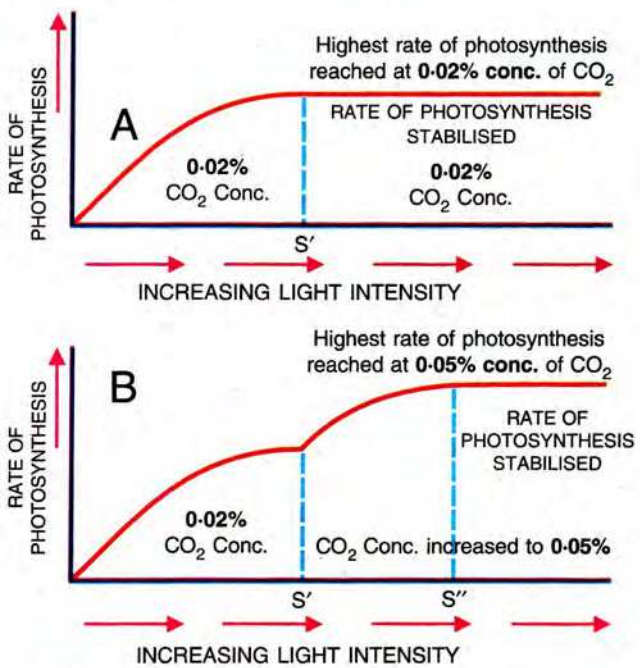


Fig. 6.3 : Photosynthesis at increasing light intensities and CO_2 concentrations

(iii) ***Temperature***

With the rise in temperature, the rate of photosynthesis rises. This rise occurs up to the optimum temperature of 35°C (maximum suitable temperature when the photosynthesis occurs best) after which the rate falls and stops above 40°C. At this uppermost limit, the enzymes are destroyed. A rise of 10°C up to the optimum temperature (35°C) doubles the rate of photosynthesis. *For example*, a rise from 20°C to 30°C, or 22°C to 32°C, or 25°C to 35°C, doubles the rate of photosynthesis.

(iv) ***Water Content***

The scarcity of water due to reduced absorption from the soil or due to an excessive loss through transpiration reduces the rate of photosynthesis by decreasing diffusive capacity (CO_2 intake) due to the closure of stomata. Only 1% of water absorbed by the root is utilised in photosynthesis.

B. INTERNAL FACTORS

(i) ***Chlorophyll*** – Nutritional deficiencies of minerals cause loss of chlorophyll, and hence the drop in trapping solar energy.

(ii) ***Protoplasm*** – Dehydration of protoplasm for some reason reduces the rate of photosynthesis. Similarly, the accumulation of carbohydrates (sugar and starch) also reduces the rate of photosynthesis.

(iii) ***Structure of leaf*** – The thickness of cuticle, the distribution of stomata and the size of the leaf influence the amount of light and the amount of CO_2 entering the leaf.

Dawn-to-Dusk natural changes in environmental conditions & photosynthesis

In every period of twenty-four hours, plants are subjected to a regular cycle of changes in light intensity, and the rate of photosynthesis increases from dawn to midday and declines as dusk approaches. Plants, like other organisms, respire, taking in oxygen and giving out carbon dioxide. **In light**, the effects of this respiratory activity are masked by those of photosynthesis and there is a net output of oxygen. In **darkness**, respiration alone is responsible for changes in the gaseous composition of a plant's surrounding atmosphere.

"Photosynthesis at night"???

Some people believe that PEEPAL tree is the only plant which gives out oxygen even during the night. Neither the release of such oxygen has been demonstrated practically nor such a view can stand scientific reasoning as at present.

PROGRESS CHECK

1. How do the following favour increased photosynthesis?
   (i) Large surface area of the leaf .....
   (ii) Thinness of the leaf .....
   (iii) More numerous stomata .....
2. Name the three end-products of photosynthesis and mention the fate of each of them in the plant.
   (i) Name .....
   Fate .....
   (ii) Name .....
   Fate .....
   (iii) Name .....
   Fate .....
3. If we keep on increasing CO_2 concentration in the air, will the rate of photosynthesis also keep on increasing in direct proportion ?
   Yes/No .....
   Explain : .....

6.10 EXPERIMENTS ON PHOTOSYNTHESIS

A number of experiments can be performed for proving the various conditions and requirements necessary for photosynthesis.

Destarching (Removal of starch). A plant used for experiments on photosynthesis should initially be placed in the dark for 24 to 48 hours to destarch the leaves. During this period, all the starch from the leaves will be removed, to the storage organs and the leaves will not show the presence of starch.

A destarched plant is one whose **leaves** are free from starch.

A plant is destarched by placing it in the dark for 24 to 48 hours.

To test a leaf for starch (Iodine test).

- Dip the leaf in **boiling water** for a minute **to kill the cells**.
- Boil the leaf in methylated spirit over a water bath till it becomes pale-white due to the

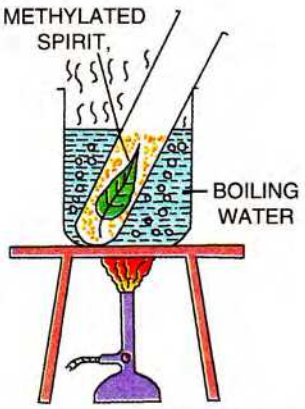


Fig. 6.4 : Removal of chlorophyll from a leaf

removal of chlorophyll (Fig. 6.4). The leaf now becomes hard and brittle.

- Place it again in hot water to **soften it**.
- Spread the leaf in a dish and pour **iodine solution*** on it. The presence of starch will be indicated by a **blue-black colour**. A leaf without starch will show brown colouration.

Experiment 1 : To show that chlorophyll is necessary for photosynthesis : Take a plant with variegated leaves having some green and some non-green areas. Examples : Coleus, Geranium and Croton.

- Destarch the leaves by keeping the plant in a dark room for a few days.
- Place the plant in the sun.
- After a few hours, pluck one leaf.
- Make its outline on paper and mark the green and non-green areas on the outline.
- Test the leaf for starch. Only the green parts of the leaf turn bluish, showing the presence of starch (Fig. 6.5).

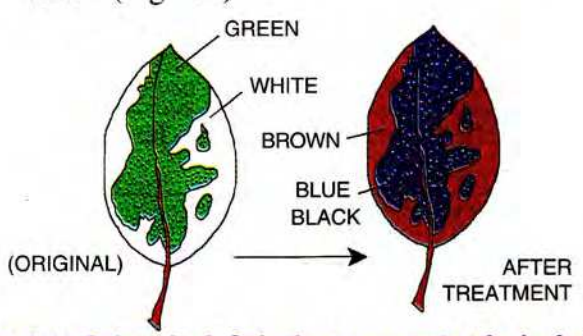


Fig. 6.5 : Coleus leaf. Only the green parts of a leaf give iodine test for the presence of starch proving that chlorophyll is necessary for photosynthesis

*** Composition of iodine solution is as follows :**
Iodine = 0.3 g; Potassium iodide = 1.5 g; Water = 100 ml

Experiment 2 : To show that sunlight is necessary for photosynthesis.

- Take a plant with destarched leaves.
- Cover one of its leaves with black paper on which a design is cut.
- Place this plant in the sun.
- After a few hours, test the leaf which is covered by black paper for the presence of starch.

It will be observed that only the parts of the leaf, which could get light through the cut out design as well as those that were left uncovered by the paper, turn blue-black, showing the presence of starch (Fig. 6.6).

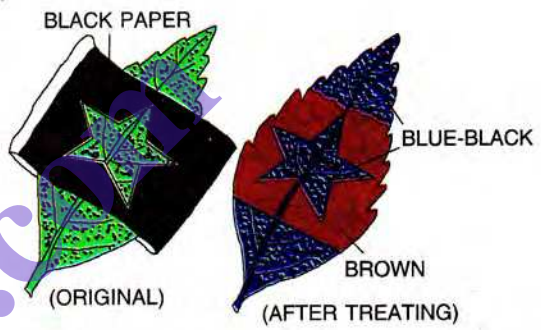


Fig. 6.6 : Only the parts of the leaf exposed to sunlight give the Iodine test, proving that light is necessary for photosynthesis

Experiment 3 : To show that carbon dioxide is necessary for photosynthesis.

- Take a plant with **destarched** leaves.
- Insert a part (half) of one of its leaves (through a split cork) into a conical flask containing potassium hydroxide (Fig. 6.7A). (Potassium hydroxide absorbs carbon dioxide).
- Leave the plant in sunlight.
- After a few hours, test the leaf for starch.

The part of the leaf which was exposed to the atmospheric air becomes blue-black, and the part of the leaf inside the flask containing potassium hydroxide does not become blue-black, showing that carbon dioxide is necessary for photosynthesis. The part of the leaf outside the flask becomes the control experiment.

Note : The same experiment can be modified as given in Fig. 6.7 B. Half of the leaf outside the bottle will show the presence of starch while the other half will not.

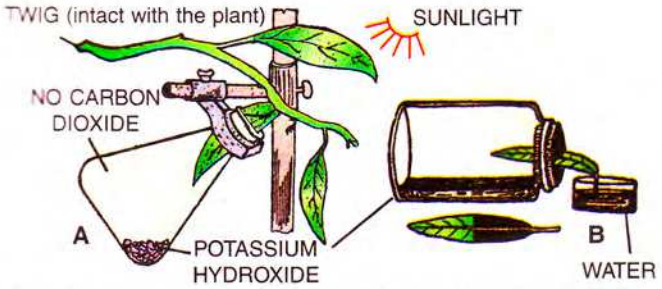


Fig. 6.7 : Experiment to prove that carbon dioxide is necessary for photosynthesis

Experiment 4 : To show that oxygen is produced during photosynthesis.

- Place some water plants (*Elodea* or *Hydrilla*) in a beaker containing pond water and cover them by a short-stemmed funnel.
- Invert a test-tube full of water over the stem of the funnel. (Ensure that the level of water in the beaker is above the level of stem of the inverted funnel).
- Place the apparatus in the sun for a few hours (Fig. 6.8). Bubbles of the gas will collect in the test-tube.
- Test the gas in the test-tube. A glowing splinter bursts into flame which shows the presence of oxygen.

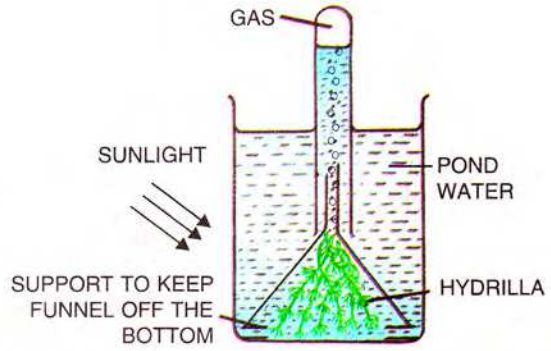


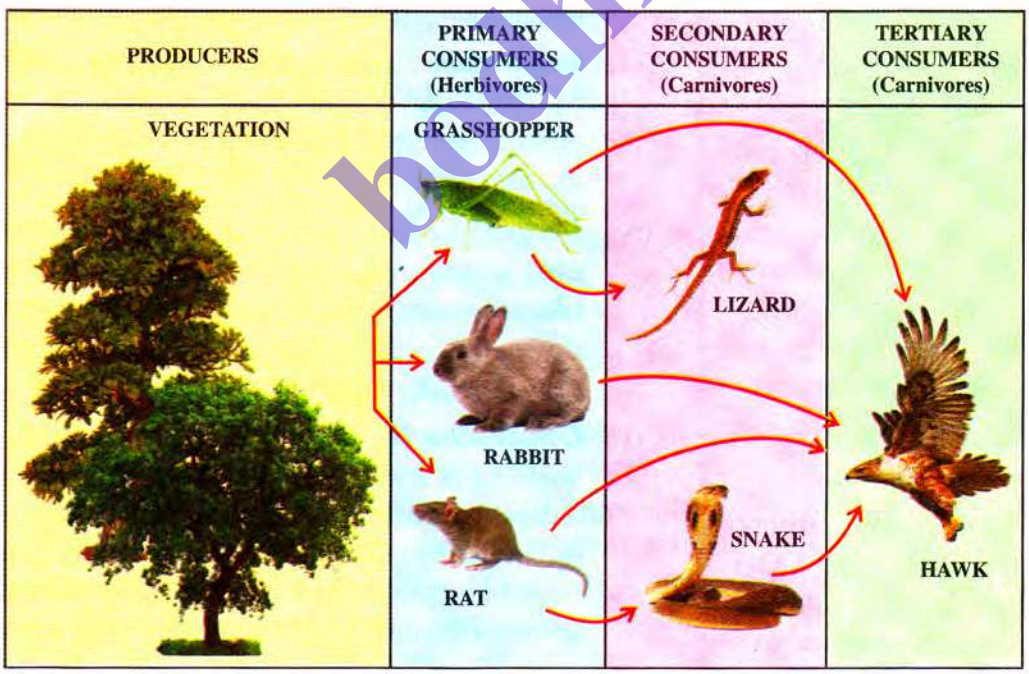
Fig. 6.8 : An experiment to show that oxygen is given out during photosynthesis

6.11 IMPORTANCE OF PHOTOSYNTHESIS

(The process supporting all life on the earth)

If there were no green plants, all life on the earth would come to an end.

1. *Provides food :* All animals, including humans, ultimately depend on plants for food. A herbivore (plant-eater) consumes the plant parts directly, while a carnivore (flesh-eater) eats flesh of an animal which in turn was a herbivore. This chain of food-dependence is called the **food chain** (Fig. 6.9). The food chain may have a number of intervening stages but the **starting point is always a plant** (producer) which produces its own food through photosynthesis.



How many food chains in all are shown here ?

3, 4, 5, 6, 7 or 9

Answer

Fig. 6.9 : Some examples of the food chain : Green plants (producers) provide food for all herbivores (primary consumers), herbivores are eaten up by carnivores (secondary consumers), the carnivores may be further eaten up by tertiary consumers (again called carnivores)

You can imagine several food chains, *for example* :

Corn → Rat → Snake → Hawk

Grass → Rabbit → Tiger

Grass → Grasshopper → Lizard → Kite

Grass → Insects → Frog → Snake → Peacock

Wheat → Man → Mosquito

Non-green plants such as **fungi** and **bacteria** obtain their nourishment from decaying organic matter in their environment. This matter comes from dead animals and plants, which in their own turn were dependent on photosynthesis.

2. ***Provides oxygen :*** The life-supporting gas, oxygen, is present in the atmosphere in a free state only because of photosynthesis. Scientists strongly believe that about 2 billion years ago, when there was no life on the earth in any form, there was no free oxygen in the atmosphere. Appearance of green plants set the stage for the animals to appear. Almost all organisms need oxygen for respiration.

PROGRESS CHECK

1. Why is it necessary to destarch a plant before performing an experiment on photosynthesis?
.....
2. Why do we perform the iodine-test ?
.....
3. What chemical do you use to remove CO_2 from inside a flask in certain experiments on photosynthesis ?
.....
4. All food chains start with a plant. Why is this so?
.....
5. The honey bee produces honey. In terms of the food chain, is the honey bee a producer or a consumer?
.....

6.12 CARBON CYCLE (Fig. 6.10)

The carbon cycle is a series of chemical reactions in which carbon as a chemical element (in CO_2) is removed from the air, used by living organisms in their body processes and is finally returned to the air.

The essential steps in the carbon cycle are as follows :

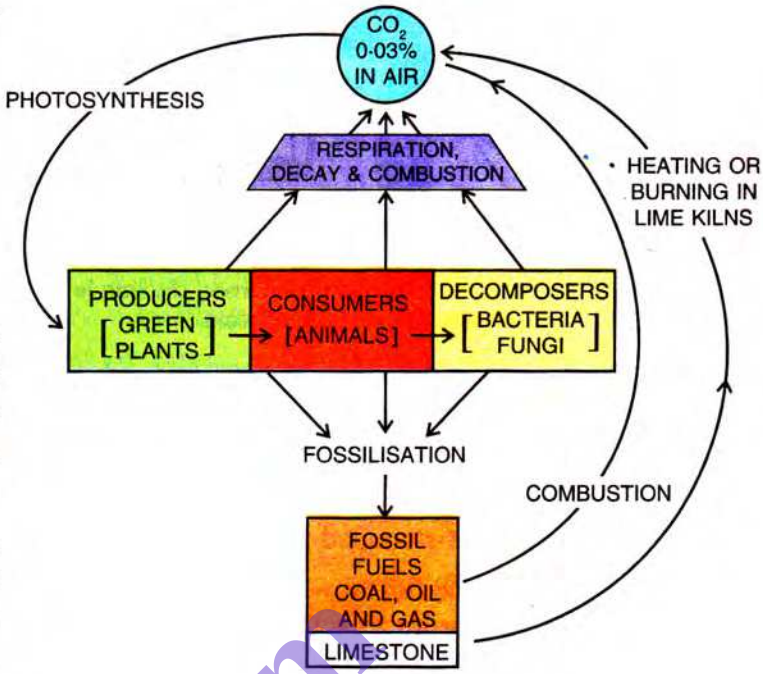


Fig. 6.10 : Carbon cycle

(i) ***Photosynthesis:*** Green plants **(producers)** use carbon dioxide of the air to produce carbohydrates (sugar, starch, etc.).

(ii) ***Food chains :*** Through food chains, the food (containing carbon in the carbohydrates and other products) passes on from plants to animals **(consumers)**. Carbon is an essential element of all body tissues of both plants and animals.

(iii) ***Respiration :*** All plants and animals, respire by oxidising carbohydrates in their cells to produce energy and give out carbon dioxide into the atmosphere.

(iv) ***Decay :*** The dead remains of plants and animals are consumed by bacteria and fungi (**decomposers**), and in the process, they break down the organic matter, releasing carbon dioxide back into the atmosphere.

(v) ***Combustion (burning) :*** When a fuel such as wood or a fossil fuel like coal, petroleum or natural gas, is burnt, the carbon contained in it is oxidised to carbon dioxide, which is given back into the atmosphere. All the fuels named above originally come from living organisms.

(vi) A certain amount of carbon dioxide is released during heating or **burning of limestone** in lime kilns.

REVIEW QUESTIONS

A. MULTIPLE CHOICE TYPE

(Select the most appropriate option in each case)

1. The production of starch, and not glucose, is often used as a **measure of photosynthesis** in leaves because
   (a) starch is the immediate product of photosynthesis.
   (b) glucose formed in photosynthesis soon gets converted into starch.
   (c) starch is soluble in water.
   (d) sugar cannot be tested.

2. The **number of water molecules** required in the chemical reactions to produce one molecule of glucose during photosynthesis is.
   (a) six (b) twelve
   (c) eighteen (d) twenty-four

3. The **rate of photosynthesis** is NOT affected by.
   (a) light intensity (b) humidity
   (c) temperature (d) CO_2 concentration

4. Chlorophyll in a leaf is **required for**
   (a) breaking down water into hydrogen and oxygen.
   (b) emitting green light. (c) trapping light energy.
   (d) storing starch in the leaves.

5. If the **rate of respiration** becomes more than the rate of photosynthesis, plants will :
   (a) continue to live, but will not be able to store food.
   (b) be killed instantly.
   (c) grow more vigorously because more energy will be available.
   (d) stop growing and die gradually of starvation.

6. Which one **chemical reaction** occurs during photosynthesis?
   (a) Carbon dioxide is reduced and water is oxidised.
   (b) Water is reduced and carbon dioxide is oxidised.
   (c) Both carbon dioxide and water are oxidised.
   (d) Both carbon dioxide and water are reduced.

7. The **specific function** of light energy in the process of photosynthesis is to
   (a) reduce carbon dioxide. (b) synthesise glucose.
   (c) activate chlorophyll. (d) split water molecule.

8. A plant is kept in a dark cupboard for about 48 hours before conducting any **experiment on photosynthesis** in order to
   (a) remove chlorophyll from the leaves.
   (b) remove starch from the leaves.
   (c) ensure that no photosynthesis occurred.
   (d) ensure that the leaves are free from starch.

9. During photosynthesis, the **oxygen** in glucose comes from
   (a) CO_2 (b) water
   (c) both CO_2 and water (d) oxygen via air

B. VERY SHORT ANSWER TYPE

1. **Name** the following :
   (a) The category of organisms that prepare their own food from basic raw materials.
   (b) The kind of plastids found in the mesophyll cells of the leaf.
   (c) The compound which stores energy in the cells.
   (d) The first form of food substance produced during photosynthesis.
   (e) The organisms that can be called "natural purifiers" of the air.
   (f) The source of CO_2 for aquatic plants.
   (g) The part of chloroplast where the dark reaction of photosynthesis takes place
   (h) The tissue that transports manufactured type of starch from leaves to all parts of the plants.

C. SHORT ANSWER TYPE

1. **Mention one difference** between the following on the basis of what is given in brackets.
   (a) Respiration and photosynthesis (gas released).
   (b) Light and dark reactions (products formed).
   (c) Producers and consumers (mode of nutrition).
   (d) Grass and grasshopper (mode of nutrition).
   (e) Chlorophyll and chloroplast (part of plant cell).

2. **Identify** the **false statements** and **rewrite** them correctly by changing the first or the last word only.
   (a) Dark reaction of photosynthesis occurs during night time.
   (b) Immediate product of photosynthesis is glucose.
   (c) Starch produced in a leaf remains stored in it for 2-3 weeks before it is used by other parts of the plant.
   (d) Photosynthesis requires enzymes.
   (e) Green plants are consumers.
   (f) Photosynthesis results in loss of dry weight of the plants.
   (g) Photosynthesis stops at a temperature of about 35°C.
   (h) Photosynthesis occurs only in cells containing chloroplasts.
   (i) Green plants perform photosynthesis.
   (j) Algae are autotrophs.

3. **Fill in the blanks** with the appropriate answer from the choices given in the brackets.
   (a) The site of light reaction in the cells of a leaf is ..... (cytoplasm, stroma, grana).
   (b) The chemical substance used to test the presence of starch in the cell of a leaf is ..... ($CaCl_2$, iodine solution, Benedict solution).
   (c) Stroma is the ground substance in ..... (cytoplasm, chloroplast, ribosomes).
   (d) The dark reaction of photosynthesis is known as ..... (Hill reaction, cyclic phosphorylation, Calvin cycle).
   (e) In the flowering plants, food is transported in the form of ..... (sucrose, glucose, starch).

4. Are the following statements ***true*** or ***false***? **Give reason** in support of your answer.
   (a) The rate of photosynthesis continues to rise as long as the intensity of light rises.
   (b) The outside atmospheric temperature has no effect on the rate of photosynthesis.
   (c) If you immerse a leaf intact on the plant in ice cold water, it will continue to photosynthesise in bright sunshine.
   (d) Destarching of the leaves of a potted plant can occur only at night.
   (e) The starting point of carbon cycle is the release of CO_2 by animals during respiration.
   (f) If a plant is kept in bright light all the 24 hours for a few days, the dark reaction (biosynthetic phase) will fail to occur.
   (g) Photosynthesis is considered as a process supporting all life on earth.

5. Given below are five terms. **Rewrite the terms** in the **correct order** so as to be in logical sequence with regard to photosynthesis: *(i) water molecules, (ii) oxygen, (iii) grana, (iv) hydrogen and hydroxyl ions, (v) photons.*

6. **State** any *four* differences between photosynthesis and respiration.

7. "Oxygen is a waste product of photosynthesis." **Comment**.

8. Why is it necessary to place a plant in the dark before starting an experiment on photosynthesis? **Explain**.

9. In most of the experiments on photosynthesis, we use a de-starched leaf or plant. **What** is the purpose of de-starching?

10. **Why** is it not possible to demonstrate respiration in a green plant kept in sunlight ?

11. Most leaves have the upper surface more green and shiny than the lower one. **Why** ?

12. **How** would you **demonstrate** that green plants release oxygen when exposed to light?

13. **Describe** the main chemical changes which occur during photosynthesis in
   (i) Light reaction (ii) Dark reaction.

14. **Complete** the following food chains by writing the names of appropriate organisms in the blanks.
   (i) Grass → ..... → Snake → .....
   (ii) ..... → Mouse ..... → Peacock

15. **How** do non-green plants such as fungi and bacteria obtain their nourishment ?

16. All life owes its existence to chlorophyll. **Give reason**.

17. Complete the following by filling the blanks 1 to 5 with appropriate words/terms/phrases:
   To test the leaf for starch, the leaf is boiled in water to ..... (1). It is next boiled in methylated spirit to ..... (2). The leaf is placed in warm water to soften it. It is then placed in a dish and ..... (3) solution is added. The region, which contains starch, turns ..... (4) and the region, which does not contain starch, turns .....(5).

D. STRUCTURED/APPLICATION/SKILL TYPE

1. A candidate studied the importance of certain factors in photosynthesis. He took a potted plant and kept it in the dark for over 24 hours. In the early hours of the next morning, he covered one of the leaves with dark paper in the centre only. Then he placed the plant in sunlight for a few hours and tested the leaf which was covered with black paper for starch.
   (a) **What** aspect of photosynthesis was being investigated?
   (b) Is there any control in this experiment? If so, **state** it.
   (c) **Why** was the plant kept in the dark before the experiment?
   (d) **Describe** step by step, how the candidate proceeded to test the leaf for the presence of starch.

2. Photosynthesis in green plants is directly and indirectly dependent on so many plant structures. Explain briefly the role of the following structures in this process.
   (a) Guard cells.....

(b) Cuticle .....

(c) Mesophyll cells .....

(d) Xylem tissue in the leaf veins .....

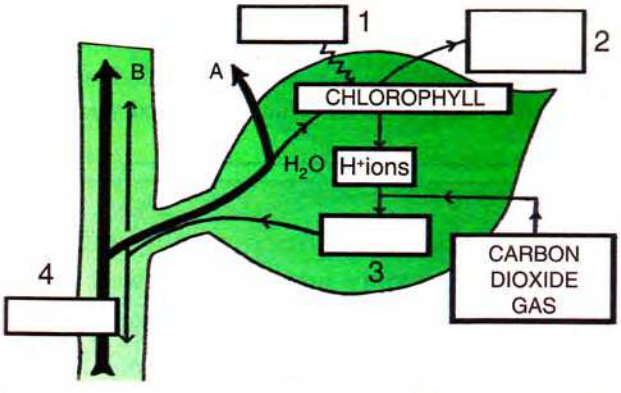
(e) Phloem tissue in the leaf veins .....

(f) Stomata .....

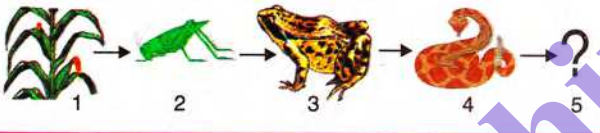
3. Given below is a schematic diagram to illustrate some aspects of photosynthesis.

(a) **Fill up** the gaps, in blank spaces (1-4), by writing the names of the correct items.

(b) **What phenomenon** do the thick arrows A and B indicate respectively ?



4. Given below is the representation of a certain phenomenon in nature. with four organisms 1-4.



(a) Name the phenomenon represented.

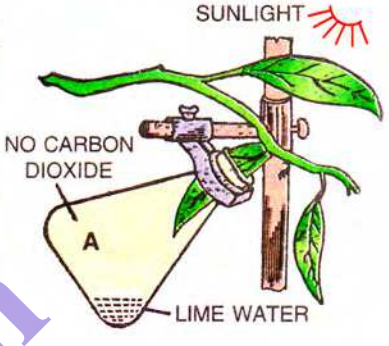
(b) Name any one organism that could be shown at No. 5.

(c) Name the **biological process** which was the starting point of the whole chain.

(d) Name one natural element which all the organisms 2-4 and even 5 are getting from No. 1 for their survival.

5. **Enumerate** the steps involved in testing a green leaf for the presence of starch.

6. Given alongside is the diagram of an experimental set-up :



(a) What is the objective of this experiment ?

(b) Will it work satisfactorily? Give reason.

(c) What alteration(s) will you make in it for obtaining expected result?

(d) Would you take any step before starting the experiment? Describe this step and explain its necessity.

7. **Draw** a neat diagram of the stomatal apparatus found in the epidermis of leaves and label the Stoma, Guard cells, Chloroplast, Epidermal cells, Cell wall and Nucleus.

ANSWER THE FOLLOWING SIMPLY IN "YES" OR "NO"

1. Chloroplast and chlorophyll are one and the same thing. .....
2. Oxygen given out in photosynthesis comes from the atmosphere. .....
3. The dark reaction of photosynthesis occurs during nighttime. .....
4. The immediate product of photosynthesis is glucose. .....
5. Photosynthesis can also occur in artificial light such as that of a 100 Watt electric lamp. .....
6. All the starch produced in a leaf remains stored in it for 2-3 weeks before it is used by other parts of the plant. .....
7. Photosynthesis requires involvement of enzymes. .....
8. Plants require several nutrients such as nitrogen, sulphur and iron. .....
9. Every green plant produces glucose as well as proteins and many other compounds. .....
10. All green plants are categorised as consumers. .....

Check your Answers 1-NO, 2-NO, 3-NO, 4-YES, 5-YES, 6-NO, 7-YES, 8-YES, 9-YES, 10-NO

Can we say —

"Chloroplasts are the kitchen of a cell!"?

NO! Not at all

The kitchen only cooks the food but does not produce it. It is the agricultural farms and orchards that produce it, and there again it is the chloroplasts in their cells which produce it.

A better analogy could be :

Chloroplasts are starch producing "factories", which need

— **raw materials :** CO_2 and H_2O

— **energy :** sunlight

— **labourers :** enzymes

Why the name "Stoma" (singular of "stomata") ?

Is this the "mouth" of an old bearded toothless man ? If so, are there two "lips" **guarding** the "mouth opening"?

Yes, this is "mouth"! But not of a human. It is one of the hundreds of "mouths" called "stomata" present on the lower surface of green leaves. The Greek word "stoma" means "mouth" and its pleural form is "stomata".