Ratna Sagar

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Education, Our Mission

As per the latest ICSE syllabus 2022

Ratna Sagar
Education, Our Mission!

Revised and Updated

LIVING SCIENCE BIOLOGY

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EDUCATION, OUR MISSION

ICSE
Living Science
Biology

Class 10

Chapter 6 Photosynthesis

LEARNING OBJECTIVES

What is photosynthesis?

- **Raw materials for photosynthesis**

Opening and closing of stomata

- **How are the leaves adapted for photosynthesis?**

The mechanism of photosynthesis

- **Phases of photosynthesis**

Factors affecting photosynthesis

- **External factors**
- **Internal factors**

Carbon cycle

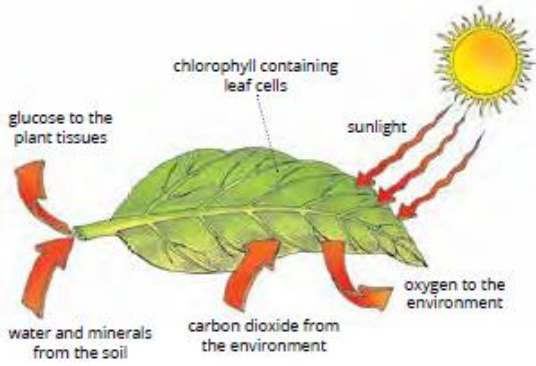
Experiments on photosynthesis

What is autotrophic nutrition?

All green plants can synthesize their own food from simple inorganic raw materials through **photosynthesis**. Hence, green plants are called **producers** or **autotrophs** and the mode of nutrition in green plants is called **autotrophic nutrition**.

What is photosynthesis?

Photosynthesis is a biochemical process by which living cells of plants containing chlorophyll manufacture their own food (glucose and starch) using carbon dioxide and water as raw materials in the presence of light energy. Oxygen is released as a by-product of photosynthesis.



Significance of photosynthesis

1. Photosynthesis provides food for all. The process of photosynthesis occurs in green plants which are the primary producers in a food chain.

2. Photosynthesis is ultimate biological source of oxygen and energy for all living beings on earth. It is essential for sustaining life.

3. It is necessary for synthesis of organic compounds from inorganic compounds.

4. It converts atmospheric carbon dioxide to oxygen.

Raw materials for photosynthesis

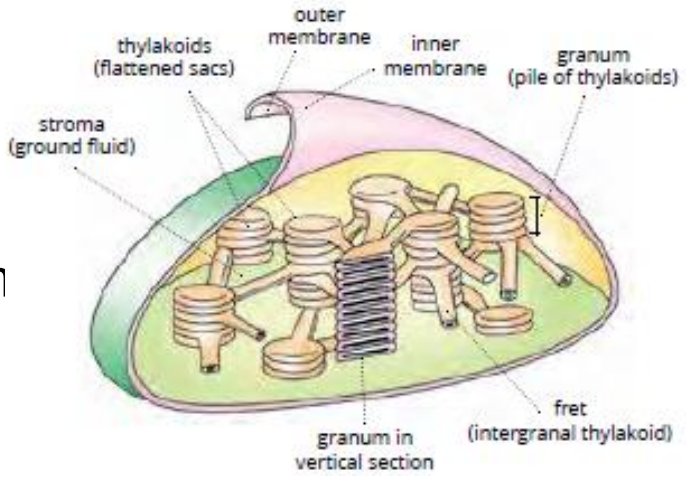
To perform photosynthesis, plants require carbon dioxide (CO_2), water (H_2O), light energy and chlorophyll. CO_2 and H_2O serve as raw materials and sunlight serves as a source of light energy. The process of photosynthesis takes place in chloroplasts.

- Two main processes, photosynthesis and respiration, take place side by side but photosynthesis does not take place in the absence of light whereas respiration continues throughout the day and night.
- Water rarely serves as a limiting factor in photosynthesis because less than 1 per cent of the water absorbed by a plant is used in photosynthesis.
- The rate of photosynthesis is affected both by the quality as well as the quantity (intensity and duration) of light. Too much light intensity may destroy chlorophyll. In red-coloured light, the rate of photosynthesis is maximum whereas in green-coloured light photosynthesis does not occur.

Chlorophyll – The photoreceptor to trap solar energy

Leaves contain chlorophyll which is a photoreceptor molecule. Chlorophyll absorbs photons – unit of sunlight. Chlorophyll is present in the chloroplast.

Chloroplast are green-coloured plastids containing chlorophyll pigments and are mostly present in leaves. The green colour of plants is due to the chlorophyll.



Internal structure of a chloroplast

Structure of chloroplasts

A Chloroplast has three parts:

1. A double membrane envelope that links each chloroplast. There is a minute space available between the membranes. The membranes are selectively permeable.

2. Stroma: At inside, the lumen of chloroplast is filled with colourless ground substance or matrix called stroma.

3. Thylakoids: Thylakoids are flattened membranous sac-like structures present in stroma. These thylakoids are stacked over one another like stack of coins. A pile of thylakoid is called grana

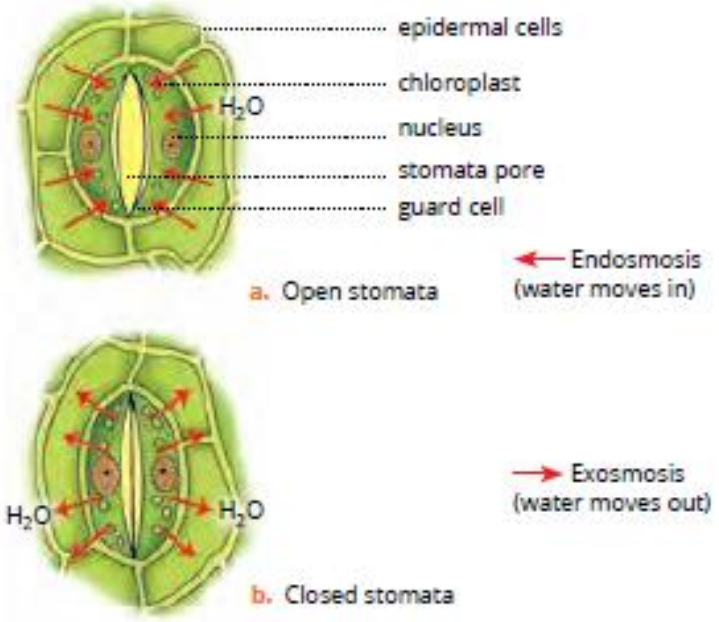
Opening and closing of stomata

Stomata are minute pores present either on the lower or both the surfaces of the leaf to facilitate exchange of gases (CO_2 and O_2) between the leaf and the atmosphere. Each stoma consists of a **stomatal aperture** and two surrounding **guard cells**. The guard cells are kidney-shaped and contain chloroplasts. The inner wall of each guard cell is thick and outer wall is thin.

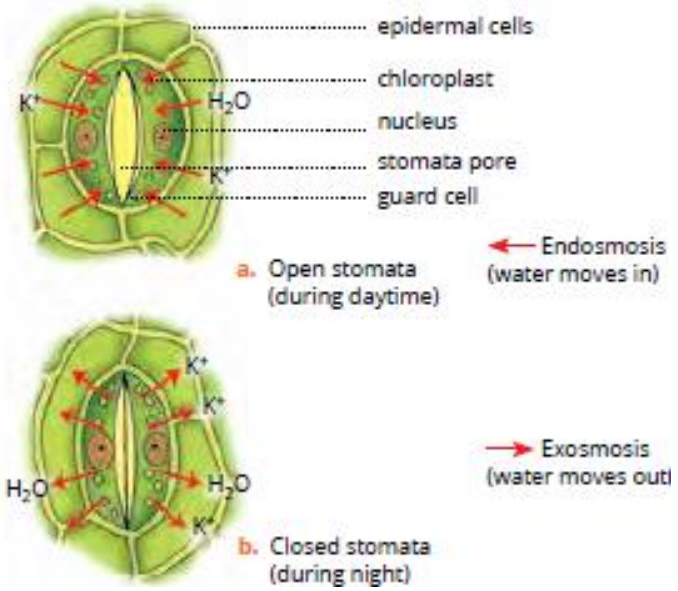
There are two theories for opening and closing of stomata, namely

1. sugar concentration theory and

2. K+ ion concentration theory.



Stomatal apparatus showing opening and closing of stomatal pore



Mechanism of opening and closing of stomata as explained by K+ concentration theory

Note: For detailed description refer to pages 71-72 of the book

How are the leaves adapted for photosynthesis?

1. Large surface area: Leaves have large surface area for maximum absorption of light.

2. More number of stomata: The leaves have more number of stomata to allow rapid exchange of O2 and CO2 gases.

3. Arrangement of leaves at right angles: The leaves are arranged at right angles to light source so as to trap maximum light.

4. Concentration of chloroplasts on upper epidermis: The chloroplasts are more concentrated on the upper epidermis of leaf so as to obtain maximum light energy.

5. Extensive vein system: The vein system is extensively developed for rapid transport of water to and from mesophyll cells.

6. Thinning of leaves: This reduces distance between cells for faster transport of gases and water. epidermal cells

The mechanism of photosynthesis

By using light energy from sunlight, carbon dioxide and water are combined in the chloroplast with the help of a number of enzymes to yield sugar (glucose). It is readily converted into a storable form, starch. The oxygen evolved in the process is given out in the atmosphere through stomata.

The overall chemical equation of photosynthesis is as follows:

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

The six molecules of H_2O liberated at the end of the reaction are those that have been re-formed during chain of reactions in the process.

Phases of photosynthesis

There are two phases of photosynthesis:

1. the light-dependent phase and

2. the light-independent phase (dark phase).

Light-dependent phase or reaction – Hill's reaction : This reaction takes place in the **thylakoids** of the chloroplasts. A series of chemical reactions occur in quick succession, initiated by light. The main steps of this reaction are:

Step 1: Excitation or activation of chlorophyll

❖ The photosynthetic pigments (chlorophyll) absorb light energy in the form of **photons** (smallest unit of light energy).

❖ After being exposed to photons, the chlorophyll molecule gets activated and emits electrons, which travel through electron transport chain in chloroplasts.

Step 2: Splitting of water (Photolysis)

The splitting of water also known as **photolysis** takes place in light reaction during which, water is broken down into highly reactive hydrogen (H^+) ions and oxygen and electrons (e^-) are emitted. These electrons travel through electron transport chain in chloroplasts.

$2H_2O \xrightarrow{\text{energy of 4 photons}} 4H^+ + O_2 + 4e^-$ The free oxygen is the oxygen gas given off during photosynthesis.

Step 3: Formation of ATP from ADP (Photophosphorylation)

The above mentioned reactions in step 1 is mediated by electron acceptors, and adenosine triphosphate (ATP) is synthesized from adenosine diphosphate (ADP) and inorganic phosphate (Pi). In other words, electrons are used to convert ADP into ATP by adding one inorganic phosphate, Pi. **This is known as photophosphorylation.** This ATP is used during dark reaction.

End products of photolysis

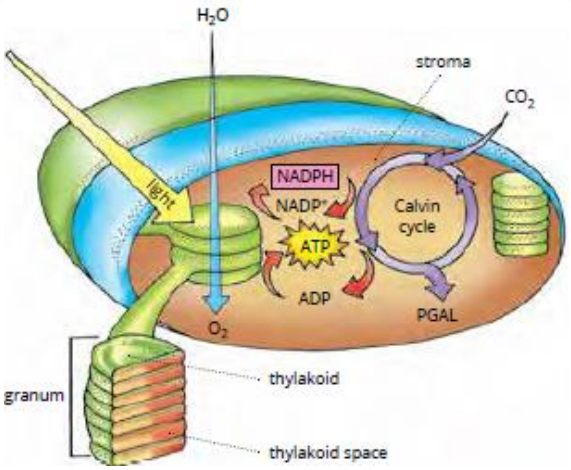
1. NADP is reduced to NADPH: The released H^+ (hydrogen ions) are picked up by NADP molecule (Nicotinamide Adenine dinucleotide phosphate) to form NADPH (reduced form of NADP).
2. The oxygen (O) is given out as molecular oxygen (O_2).

Light-independent phase – Calvin cycle

This is the **biosynthetic phase** of photosynthesis. The dark reaction occurs in the **stroma** of chloroplasts. This reaction does not require light energy, but it does not mean that it occurs during dark only. This is a **light-independent reaction**. The dark reaction occurs simultaneously with the light reaction and the time gap between the two is less than one-thousandth of a second.

In the dark reaction, following steps take place:

1. NADPH molecules and ATP molecules, both produced during light reaction are utilized to produce sugar ($C_6H_{12}O_6$) from carbon dioxide.



2. Reduction of carbon dioxide occurs in the stroma of the chloroplast by means of a series of reactions known as the **Calvin cycle** during which fixation and reduction of carbon dioxide take place. The fixation of CO2 is catalyzed by the enzyme Rubisco (Ribulose-1, 5-bisphosphate carboxylase).

Summary of light and dark reactions. The light reactions occur in thylakoids of chloroplasts where sunlight is captured, water is split and oxygen is given out, and ATP and NADPH are produced. The dark reactions occur in stroma of chloroplasts, where carbon dioxide is fixed and reduced after being incorporated into the Calvin cycle. Reduction uses the ATP and NADPH from the light reactions. granum

Factors affecting photosynthesis

There are a number of factors affecting the rate of photosynthesis. These factors are categorized as follows:

1. external factors:

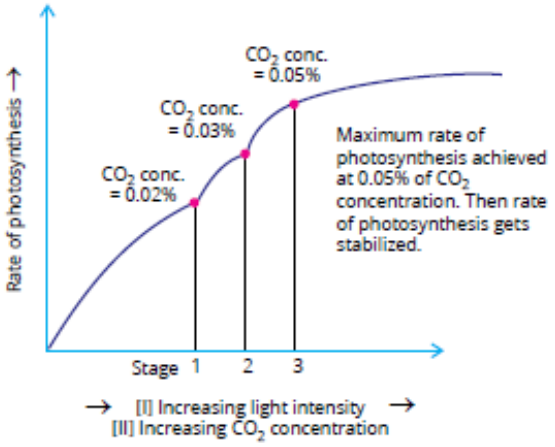
(i) light intensity (ii) carbon dioxide concentration (iii) temperature (iv) water availability

2. internal factors:

(i) Chlorophyll (ii) leaf structure (iii) protoplasm

External factors

❖ **Light intensity:** The rate of photosynthesis increases linearly with an increase in the intensity of light and then stabilizes at a point of 0.02% of CO_2. Very strong light intensity may bleach chlorophyll and retard photosynthesis.

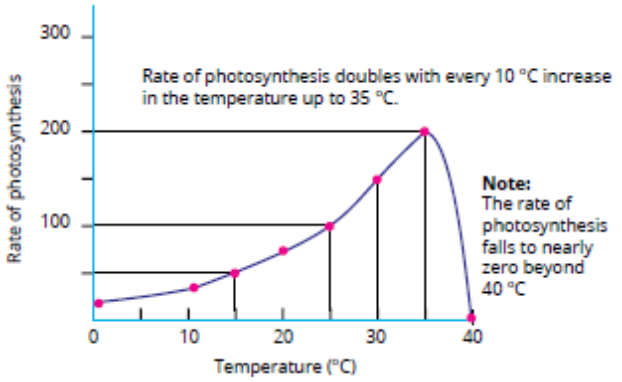


❖ **Carbon dioxide concentration:** In normal conditions, carbon dioxide is the major limiting factor in photosynthesis. The rate of photosynthesis increases with an increase in the CO_2 concentration.

❖ **Temperature:** In general, increase in temperature results in an increase in the rate of photosynthesis when other factors are not limiting.

The maximum suitable temperature when photosynthesis occurs best is about 35 ° C above which the rate falls. The process of photosynthesis falls and stops above 40 ° C as the enzymes get destroyed.

❖ **Water:** Less than 1 per cent of the total water absorbed by plants is utilized as a raw material in photosynthesis. **Water rarely becomes a limiting factor in photosynthesis.**



Effect of temperature on rate of photosynthesis

Internal factors

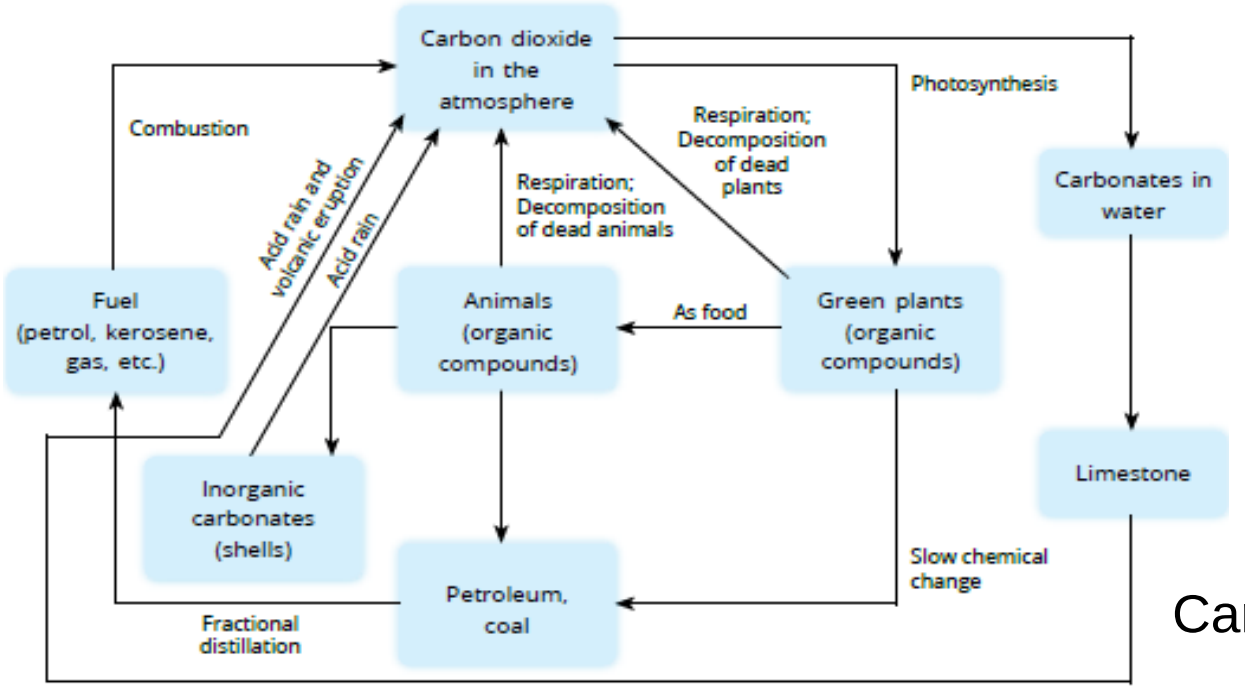
1. Chlorophyll: Inadequate amount of nutrients like minerals causes loss of chlorophyll in leaves thereby reducing the trapping of solar energy. As a result the rate of photosynthesis is reduced.

2. Structure of leaf: Size and thickness of leaf, and distribution of stomata influences the amount of CO_2 and light entering the leaf.

3. Protoplasm: Dehydration of protoplasm and accumulation of sugar and starch in the leaves reduces the rate of photosynthesis.

Carbon cycle

The cyclic process in which carbon element is circulated continuously through the living and non-living components of the biosphere is called carbon cycle.



Carbon cycle in nature

In fact, carbon is the most essential constituent of all the organic compounds present in the living organisms. Carbon dioxide present in the atmosphere is the main reservoir of carbon.

The main steps of the carbon cycle in nature are:

1. Photosynthesis: Carbon is present as carbon dioxide gas in the atmosphere. Green plants use this carbon dioxide and prepare their food (as carbohydrate) by the process of photosynthesis. When animals eat the plant, plant carbohydrate is converted into animal carbohydrate.

2. Respiration: When plants and animals respire by oxidizing carbohydrates in their cells to release energy, they give out carbon dioxide, which is returned to the atmosphere.

When animals and plants die, their bodies are decomposed by decomposers and carbon dioxide is returned to the atmosphere.

3. Burning of fossil fuels: Some of the dead plants and animals get buried deep under the earth. They change into fossil fuels like coal and petroleum through slow chemical changes. Petroleum gives us fuel like kerosene, petrol, diesel, petroleum gas, etc. When these fuels burn, they give out carbon dioxide which goes into the atmosphere.

4. Weathering of rocks: Some carbon dioxide is present in the dissolved state in water. This gets converted into calcium carbonate ($CaCO_3$) in limestone and other carbonate rocks.

Weathering of carbonate containing rocks or treatment of their minerals gives out carbon dioxide. When acid rain falls on these rocks, then carbon dioxide is released.

5. Volcanic eruptions: Volcanic eruptions and hot springs also release carbon dioxide into the atmosphere.

Thus, there is a continuous exchange of carbon dioxide between atmosphere, water bodies and living beings.

Experiments on photosynthesis

Destarching (removing starch)

Since the presence of starch is regarded as an evidence of photosynthesis, the experimental plant should not have starch in its leaves, before the experiment is started.

The leaves of a potted plant may be destarched (devoid of starch) by leaving it in a dark place for 2–3 days (48 to 72 hours).

To conduct experiments on plants in open, the selected leaves on a plant must be destarched by wrapping in aluminium foil for 2 days and then experimented upon.

Note: Refer to Experiments 1 to 5 P 78-79 for the following tests:

Experiment 1: To test a leaf for presence of starch (Iodine test)

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

Experiment 3: To show that sunlight is necessary for photosynthesis.

Experiment 4: To show that oxygen is given out during photosynthesis.

Experiment 5 : To show that carbon dioxide (CO_2) is necessary for photosynthesis (Moll's half leaf experiment).

SUMMARY...

- All green plants prepare their own food, hence, they are called producers or autotrophs.
- The process by which living cells of plants containing chlorophyll manufacture their own food (glucose and starch) using CO_2 and water as raw materials in the presence of sunlight is called photosynthesis. Oxygen is released as a by-product during photosynthesis.
- Photosynthesis provides food for living beings directly or indirectly, and produces oxygen.
- Chlorophyll *a* and chlorophyll *b* are most important as they receive light energy from the sun to bring about splitting of water molecule during photosynthesis.
- Chlorophyll pigment is present in chloroplast. Chloroplasts contain two main parts – stroma and grana.
- Photosynthesis occurs in two phases – light-dependent reaction and light-independent (dark) reaction.
- Light-dependent reaction (also called photochemical phase) occurs in thylakoids of grana of chloroplasts.
- Light reaction includes trapping of light energy by chlorophyll, splitting of water and formation of ATP from ADP.

- Hydrogen ions produced due to splitting of water combine with NADP to produce NADPH.
- Light-independent (dark) reaction is a biosynthetic phase which occurs in the stroma of chloroplasts. This reaction does not require light energy.
- During dark reaction, NADPH molecules and ATP molecules both produced during light reaction, are utilized to produce sugar ($C_6H_{12}O_6$) from carbon dioxide.
- Dark reaction occurs simultaneously with light reaction and the time gap between the two is less than 1/1000 of a second.
- As a result of photosynthesis, glucose, water and oxygen are produced. Glucose is either immediately used up by cell or is stored in the form of starch, sucrose and cellulose. Oxygen diffuses out into atmosphere which is used by living beings for respiration.
- Light intensity, CO_2 concentration and temperature affect rate of photosynthesis.
- Carbon cycle involves a series of chemical reactions through which carbon dioxide is circulated in nature.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