According to the Latest Syllabus

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BIOLOGY

Class-11 (Part-II)

For the Students of Rajasthan Board of Secondary Education

By

Dr. B. S. Kumawat
M.Sc., Ph.D.
Ex. Deputy Director,
College Education, Rajasthan
Jaipur

Ashwini Kumar Sharma
M.Sc., B.Ed., NET, SLET

Sanjiv Arora
M.Sc., M.Phil. Gold Medalist

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Email : sanjeevprakashanjaipur@gmail.com
Postal Address : Publication Department
Sanjiv Prakashan,
Dhamani Market, Chaura Rasta,
Jaipur-302003

❖ *Your suggestions shall be taken care of in our next edition.*

Preface

We are extremely pleased to present this book according to latest syllabus of NCERT. The book has been written in easy and simple language so that students may assimilate the subject easily. We hope that students will get benefitted from it and teachers will appreciate our efforts. In comparison to other books available in market, this book has many such features which make it a unique book :

1. Theoretical subject-material is given in adequate and accurate description along with pictures.
2. The latest syllabus of NCERT is followed thoroughly.
3. Complete solutions of all the questions given at the end of the chapter in the textbook are given in easy language.
4. Topic wise summary is also given in each chapter for the revision of the chapter.
5. In every chapter, all types of questions that can be asked in the exam (Objective, Fill in the blanks, Very short, Short, Numerical and Long answer type questions) are given.
6. At the end of every chapter, multiple choice questions asked in various competitive exams are also given with solutions.

Valuable suggestions received from subject experts, teachers and students have also been given appropriate place in the book.

We wholeheartedly bow to the Almighty God, whose continuous inspiration and blessings have made the writing of this book possible.

We express our heartfelt gratitude to the publisher – Mr. Pradeep Mittal and Manoj Mittal of Sanjiv Prakashan, all their staff, laser type center and printer for publishing this book in an attractive format on time and making it reach the hands of the students.

Although utmost care has been taken in publishing the book, human errors are still possible, hence, valuable suggestions are always welcome to make the book more useful.

In anticipation of cooperation!

Authors

Dr. B.S. Kumawat

Ashwini Kumar Sharma

Sanjiv Arora

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CHAPTER 11

PHOTOSYNTHESIS IN HIGHER PLANTS

Chapter Overview

Introduction : All living beings require energy to complete their biological activities. They get this energy as a result of oxidation of food. There is a difference in the method of obtaining energy between plants and animals because plants are capable of converting sunlight directly into chemical energy, whereas animals depend directly or indirectly on plants for the energy required to carry out their biological activities. Green plants prepare their own food in the presence of green pigment called **chlorophyll**, in the presence of water absorbed by the soil, CO_2 obtained from the atmosphere and light energy obtained from the Sun and convert them into carbohydrates in the form of **chemical energy**. Therefore, on the basis of the above explanation, photosynthesis can be defined as follows: The conversion of CO_2 from the atmosphere and water absorbed by the soil into chemical energy in the form of carbohydrates by green plants in the presence of sunlight is called **photosynthesis**. This can be described by the following equation:

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

In the process of photosynthesis, oxygen is released as a by-product.

11.1 What do we Know?

In earlier classes, some simple experiments are done to know about photosynthesis. From which it is known that chlorophyll (green pigment of leaves), light and CO_2 are necessary for photosynthesis. In the experiment, if a variegated leaf like Croton or Coleus is kept in light, on testing these leaves for the presence of starch it was clear that photosynthesis occurred only in the green parts of the leaves in the presence of light. Variegated leaves have white and red spots. They do not contain chlorophyll and starch is not formed at these places. Similarly, another experiment is done in this regard which is called **Moll's** experiment. In this experiment, we take a wide mouth bottle, in which a little caustic potash (KOH) is kept. The mouth of the bottle is closed with a cork, cut from the middle of starch free leaves in a pot (this pot is kept in the dark for 48 hours so that the leaves become starch free). Half of it is inserted inside the bottle through the cork and the remaining half of the leaf remains outside the bottle. After keeping it in light for a few hours, the starch test shows that starch is not formed in the part of the leaf which was in the bottle and starch is formed in the part which was outside in light. The KOH in the bottle absorbs CO_2, due to which the inner part of the leaf did not receive CO_2. Therefore, this experiment proves that CO_2 is necessary for photosynthesis.

11.2 Early Experiments

The process of photosynthesis has evolved gradually.

- **Joseph Priestley** (1733-1804) conducted several experiments in the 1770s. Priestley told that in the process of photosynthesis, exchange of gases takes place. On the basis of his experiments, he tried to show that plants purify the air polluted by animals. Priestley made the air polluted by burning candles in the bell jar clean and suitable for animals to breathe through the mint plant (Fig. 11.1).

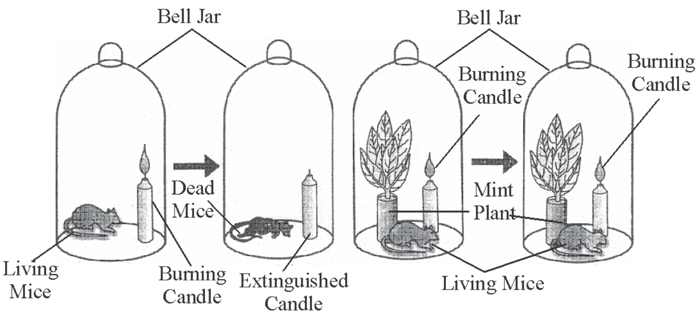

Fig. 11.1 : Priestley's experiment

- **Jan Ingenhousz** (1730-1799) was the first to show in 1779 that the green parts of plants (leaves and petioles) purify the air in the presence of light and impure it in the dark (i.e. in the presence of light plants release O_2 into the atmosphere and release CO_2 in darkness). Therefore, **Jan Ingenhousz** first explained the importance of green pigment and light in the process of photosynthesis. In his experiments with an aquatic plant, Jan Ingenhousz showed that small bubbles formed around the green part of the plant in bright sunlight, while no bubbles were formed around the plant kept in darkness. These bubbles were later identified as 0_2. Hence he said that only the green part of the plant can release O_2.
- **Julius von Sachs** (1854) told that when a plant grows, glucose (sugar) is formed. Glucose is usually stored as starch.
- **T.W. Engelmann** (1843-1909) using a prism split light into its spectral components and then illuminated a green alga, Cladophora, placed in a suspension of aerobic bacteria. The bacteria were used to detect the sites of O_2 evolution. He observed that the bacteria accumulated mainly in the region of blue and red light of the split spectrum. A first action spectrum of photosynthesis was thus described. It resembles roughly the absorption spectra of chlorophyll *a* and *b*.

By the middle of the 19th century, all the main features of plant photosynthesis were known, namely, that plants could use light energy to make **carbohydrates** from CO_2 and water. The empirical equation representing the total process of photosynthesis for oxygen evolving organisms was then understood as :

$$CO_2 + H_2O \xrightarrow{\text{Light}} [CH_2O] + O_2$$

- **Cornelis Bernardsu van Niel's** (1897-1985) experiment served as a milestone in understanding photosynthesis. His study was based on purple and green bacteria. He explained that photosynthesis is a light-dependent reaction in which hydrogen from a suitable oxidisable compound reduces carbon dioxide to carbohydrates. This can be described by the following equation :

$$2H_2A + CO_2 \xrightarrow{\text{Light}} 2A + CH_2O + H_2O$$

In green plants H_2O is the hydrogen donor and is oxidised to O_2. Some organisms do not release O_2 during photosynthesis. When H_2S, instead is the hydrogen donor for purple and green sulphur bacteria, the 'oxidation' product is sulphur or sulphate depending on the organism and not O_2. Hence, he inferred that the O_2 evolved by the green plant comes from H_2O, not from carbon dioxide. This was later proved by using radioisotopic techniques. The correct equation, that would represent the overall process of photosynthesis is therefore :

$$6CO_2 + 12H_2O \xrightarrow{\text{Light}} C_6H_{12}O_6 + 6H_2O + 6O_2$$

- **Ruben, Kemen and Hassid** (1941) proved by radio tracer method using radioactive O_2 called O^{18} that during photosynthesis, O_2 originates from H_2O, not from CO_2.

$$6CO_2 + 12H_2O^{18} \xrightarrow[\text{Chlorophyll}]{\text{Light}} C_6H_{12}O_6^{16} + 6H_2O + 6O_2^{18}$$

11.3 Where does Photosynthesis takes place?

Photosynthesis occurs in the green parts of plants. This green colour is due to the pigment chlorophyll. Chlorophyll is found in chloroplasts. The mesophyll tissues of leaves contain abundant amounts of chloroplasts. Chloroplasts have a membrane system consisting of grana, stroma lamellae and stroma fluid (Fig. 11.2). Well-defined division of labor in chloroplast absorbs the membrane system of chloroplast light energy and produces ATP and synthesises NADPH. Enzymatic reactions occur in the stroma that synthesise sugars from CO_2 which are then converted into starch. The first reaction is called **light reaction**, because it is completely based on light. The second reaction depends on the product of light reaction, i.e. ATP and NADPH, which takes place in darkness, hence it is called **dark reaction**.

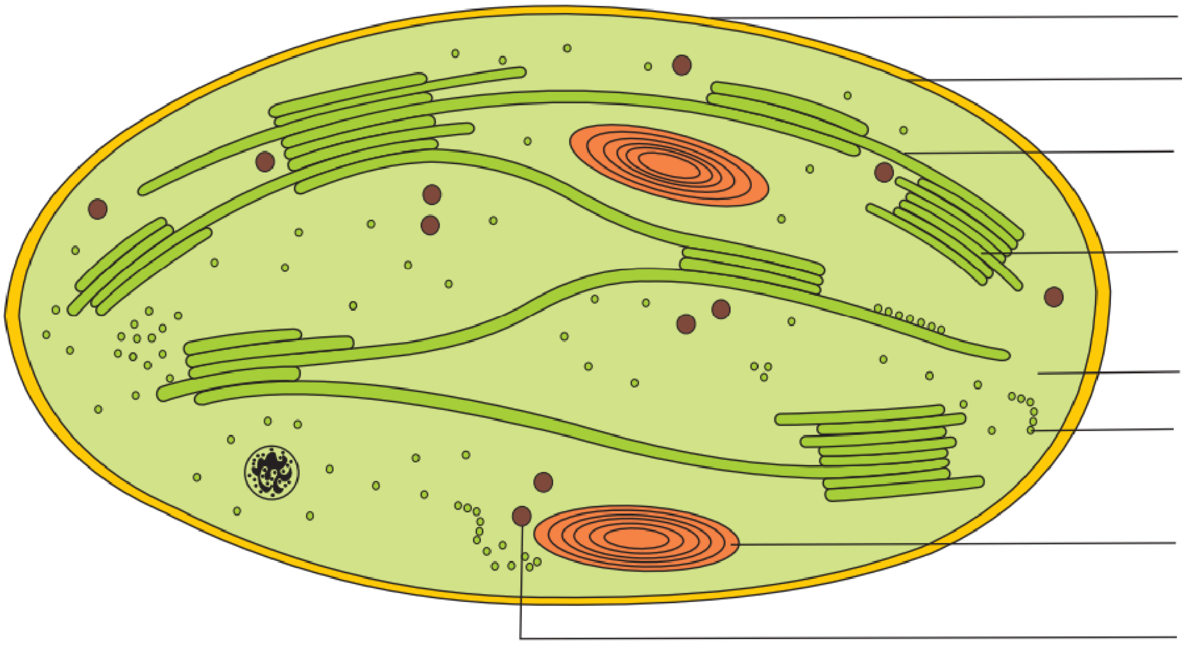

Fig. 11.2 : Diagrammatic representation of an electron micrograph of a section of chloroplast

11.4 How many Types of Pigments are Involved in Photosynthesis?

If we look at the leaves of a plant, we realise that all the leaves of that plant are not equally green but some subtle differences are found in them. This subtle difference can be evaluated by the method of **chromatography** (paper chromatogram). Chromatography shows that the leaves are green due to the pigments present in them, but this is not due to just one pigment but due to four pigments. These four pigments are as follows :

(i) **Chlorophyll *a*** (bright or blue-green in chromatography)
(ii) **Chlorophyll *b*** (yellow, green)
(iii) **Xanthophyll** (yellow)
(iv) **Carotenoids** (yellow to orange yellow)

Pigments are substances that have the ability to absorb specific wavelengths of light. Visible light is made up of waves of wavelength of only 390-810 nm 'micron'. Our eyes cannot see rays of wavelength shorter or longer than this. Visible light also consists of waves of many wavelengths. Those longer than 390 nm microns are in the order violet, blue, green, yellow, orange and red = **VIBGYOR**. Waves longer than red rays are called **infra-red** and waves shorter than violet are called **ultra-violet**. The process of photosynthesis occurs maximum in red and blue light waves. Green waves are absorbed in the least amount by leaves (that is why leaves appear green to us). Fig. 11.3 (a) shows the absorption of light by three types of pigments, chlorophyll *a*, *b* and carotene (carotenoids).

Fig. 11.3 (b) shows the wavelengths where maximum photosynthesis occurs in plants. In this, chlorophyll absorbs in the wavelength '*a*' i.e. blue and red region, the rate of photosynthesis is also maximum in that region. Hence, it can be said that chlorophyll '*a*' is a major pigment for photosynthesis. Fig. 11.3 (c) shows the rate of photosynthesis and light absorption.

These graphs make it clear that maximum photosynthesis takes place in the blue and red regions of the spectrum and some photosynthesis also takes place at other wavelengths of the visible spectrum. Although chlorophyll '*a*' is the main pigment to absorb light. However, other pigments present in chloroplasts like chlorophyll '*b*', xanthophyll and carotenoids, which are called accessory pigments, absorb light and transfer the absorbed energy to chlorophyll '*a*'.

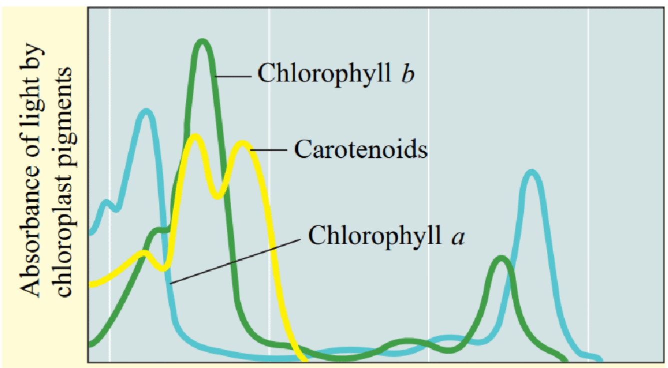

Fig. 11.3 (a) : Graph showing the absorption spectrum of chlorophyll *a, b* and the carotenoids

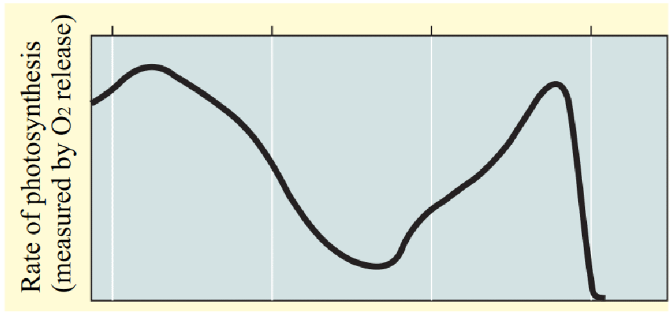

Fig. 11.3 (b) : Graph showing action spectrum of photosynthesis

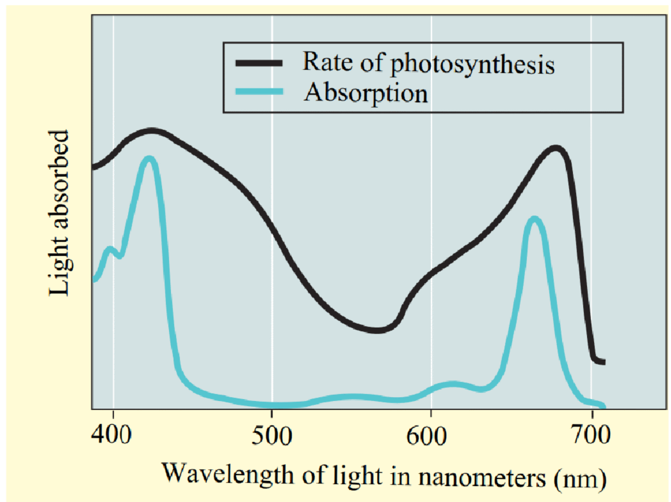

Fig. 11.3 (c) : Graph showing action spectrum of photosynthesis superimposed on absorption spectrum of chlorophyll *a*

11.5 What is Light Reaction?

The light reaction or photochemical steps include light absorption, water splitting, oxygen release, and the formation of high-energy chemical intermediates, such as ATP and NADPH. Here the pigments are present in two distinct **light harvesting complexes** (light harvesting complex = LHC) which are called Photosystem-I (Photo System I or PS-I) and Photosystem-II (Photo System II or PS-II). These have been named according to the order of discovery. LHCs are composed of thousands of pigment molecules bound to proteins. 300 to 400 pigment molecules are found in each photosystem. In every photosystem, there is a **reaction centre** and auxiliary pigments surrounded by it. These auxiliary pigments absorb light energy and pass it to the reaction centre. These molecules are called **antennae** (Fig. 11.4). A single molecule of chlorophyll '*a*' forms the **reaction centre**. The reaction centres are separate in both the photosystems. In PS-I the absorption peak of the reaction centre chlorophyll '*a*' occurs at 700 nm. Hence, it is called P_{700}. In PS-II the absorption peak is at 680 nm, hence it is called P_{680} (P = Pigment).

Both P_{700} and P_{680} are pigments of chlorophyll '*a*'. The molecule of chlorophyll '*a*' which absorbs light of 700 nm wavelength is called P_{700} and the molecule of chlorophyll 'a' which absorbs light of 680 nm wavelength is called P_{680}.