

## CSIR NET Life Science Unit 6

### Photosynthesis

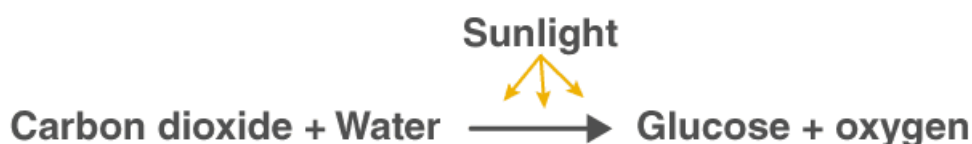
Photosynthesis is a process by which phototrophs convert light energy into chemical energy, which is later used to fuel cellular activities. The chemical energy is stored in the form of sugars, which are created from water and carbon dioxide.

Photosynthesis definition states that the process exclusively takes place in the chloroplasts through photosynthetic pigments such as chlorophyll a, chlorophyll b, carotene and xanthophyll. All green plants and a few other autotrophic organisms utilize photosynthesis to synthesize nutrients by using carbon dioxide, water and sunlight. The by-product of the photosynthesis process is oxygen. Let us have a detailed look at the process, reaction and importance of photosynthesis.

#### **What Is Photosynthesis in Biology?**

The word “**photosynthesis**” is derived from the Greek words *phōs* (pronounced: “fos”) and σύνθεσις (pronounced: “synthesis”). *Phōs* means “light” and σύνθεσις means, “combining together.” This means “**combining together with the help of light.**”

Photosynthesis also applies to other organisms besides green plants. These include several prokaryotes such as cyanobacteria, purple bacteria and green sulfur bacteria. These organisms exhibit photosynthesis just like green plants. The glucose produced during photosynthesis is then used to fuel various cellular activities. The by-product of this physio-chemical process is oxygen.



A visual representation of the photosynthesis reaction

- Photosynthesis is also used by algae to convert solar energy into chemical energy. Oxygen is liberated as a by-product and light is considered as a major factor to complete the process of photosynthesis.

- Photosynthesis occurs when plants use light energy to convert carbon dioxide and water into glucose and oxygen. Leaves contain microscopic cellular organelles known as chloroplasts.
- Each chloroplast contains a green-coloured pigment called chlorophyll. Light energy is absorbed by chlorophyll molecules whereas carbon dioxide and oxygen enter through the tiny pores of stomata located in the epidermis of leaves.
- Another by-product of photosynthesis is sugars such as glucose and fructose.
- These sugars are then sent to the roots, stems, leaves, fruits, flowers and seeds. In other words, these sugars are used by the plants as an energy source, which helps them to grow. These sugar molecules then combine with each other to form more complex carbohydrates like cellulose and starch. The cellulose is considered as the structural material that is used in plant cell walls.

### Where Does This Process Occur?

Chloroplasts are the sites of photosynthesis in plants and blue-green algae. All green parts of a plant, including the green stems, green leaves, and sepals – floral parts comprise of chloroplasts – green colour plastids. These cell organelles are present only in plant cells and are located within the mesophyll cells of leaves.

### Factors Affecting Photosynthesis

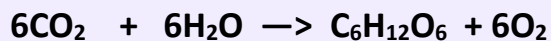
Photosynthesis process requires several factors such as:

- **Light Intensity:** Increased light intensity results in a higher rate of photosynthesis. On the other hand, low light intensity results in a lower rate of photosynthesis.
- **The concentration of CO<sub>2</sub>:** Higher concentration of carbon dioxide helps in increasing the rate of photosynthesis. Usually, carbon dioxide in the range of 300 – 400 PPM is adequate for photosynthesis.
- **Temperature:** For efficient execution of photosynthesis, it is important to have a temperature range between 25° to 35° C.

- **Water:** As water is an important factor in photosynthesis, its deficiency can lead to problems in the intake of carbon dioxide. The scarcity of water leads to the refusal of stomatal opening to retain the amount of water they have stored inside.
- **Pollution:** Industrial pollutants and other particulates may settle on the leaf surface. This can block the pores of stomata which makes it difficult to take in carbon dioxide.

### Photosynthesis Equation

Photosynthesis reaction involves two reactants, carbon dioxide and water. These two reactants yield two products, namely, oxygen and glucose. Hence, the photosynthesis reaction is considered to be an endothermic reaction. Following is the photosynthesis formula:



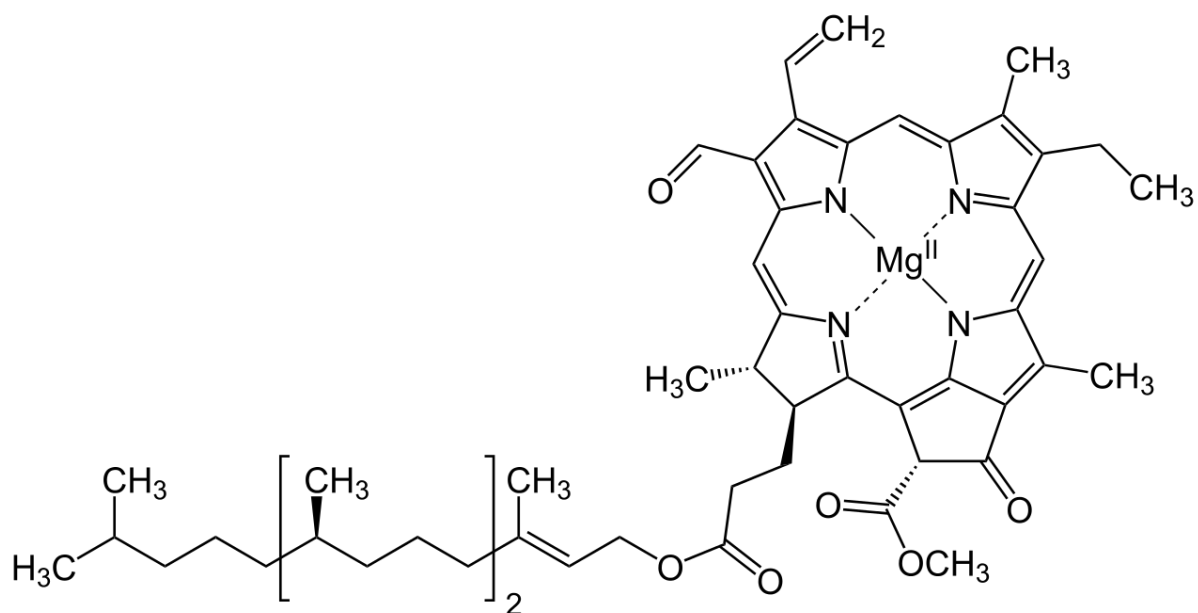
Unlike plants, certain bacteria that perform photosynthesis do not produce oxygen as the by-product of photosynthesis. Such bacteria are called anoxygenic photosynthetic bacteria. The bacteria that do produce oxygen as a by-product of photosynthesis are called oxygenic photosynthetic bacteria.

### Photosynthetic Pigments

There are four different types of pigments present in leaves:

1. Chlorophyll a
2. Chlorophyll b
3. Xanthophylls
4. Carotenoids

### Structure Of Chlorophyll



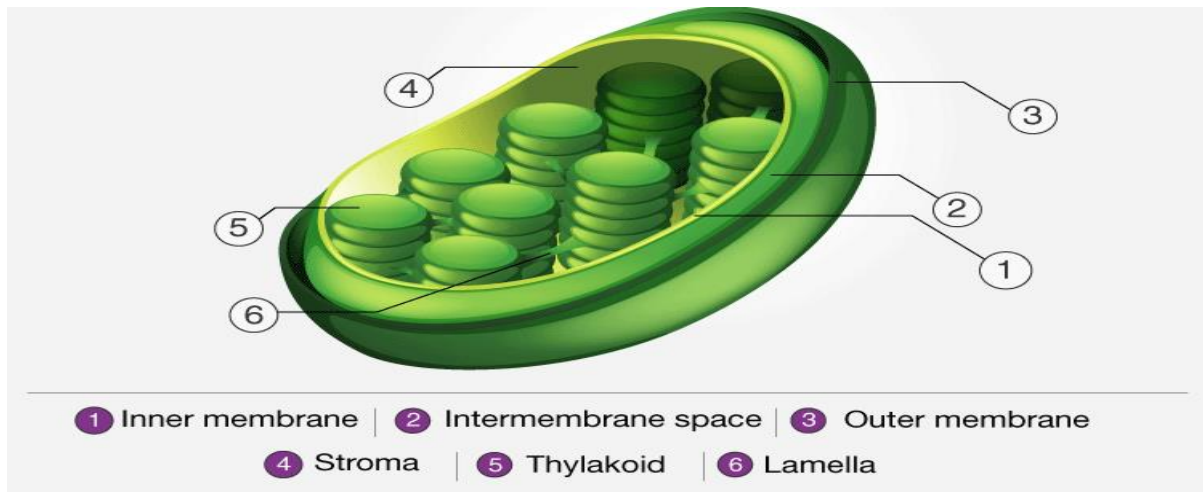
The structure of Chlorophyll consists of 4 nitrogen atoms that surround a magnesium atom. A hydrocarbon tail is also present. Pictured above is chlorophyll-*f*, which is more effective in near-infrared light than chlorophyll-*a*

Chlorophyll is a green pigment found in the chloroplasts of the **plant cell** and in the mesosomes of cyanobacteria. This green colour pigment plays a vital role in the process of photosynthesis by permitting plants to absorb energy from sunlight. Chlorophyll is a mixture of chlorophyll-*a* and chlorophyll-*b*. Besides green plants, other organisms that perform photosynthesis contain various other forms of chlorophyll such as chlorophyll-*c1*, chlorophyll-*c2*, chlorophyll-*d* and chlorophyll-*f*.

### Process Of Photosynthesis

At the cellular level, the photosynthesis process takes place in cell organelles called chloroplasts. These organelles contain a green-coloured pigment called chlorophyll, which is responsible for the characteristic green colouration of the leaves.

As already stated, photosynthesis occurs in the leaves and the specialized cell organelles responsible for this process is called the chloroplast. Structurally, a leaf comprises a petiole, epidermis and a lamina. The lamina is used for absorption of sunlight and carbon dioxide during photosynthesis.



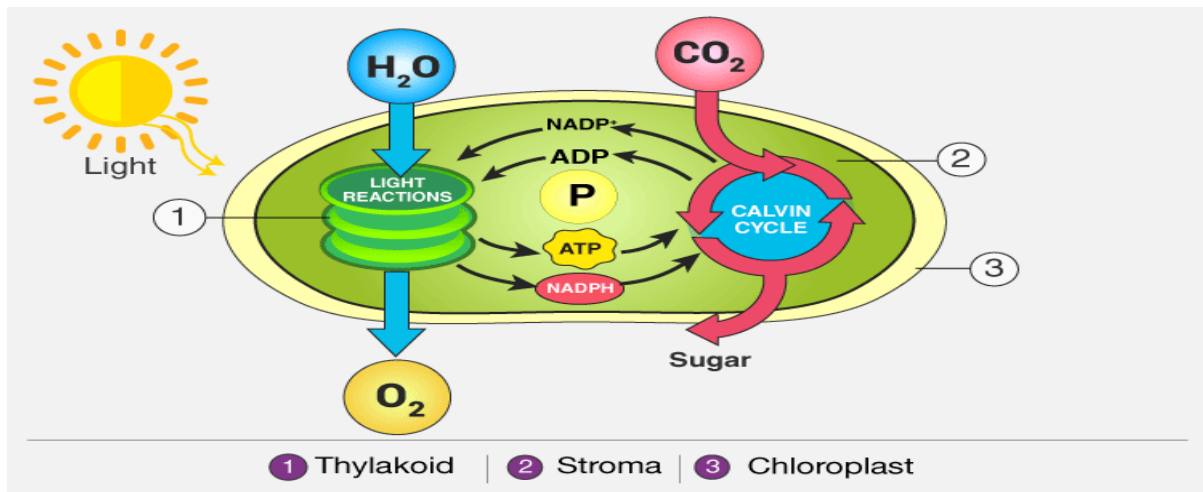
Structure of Chloroplast. Note the presence of the thylakoid

### ***“Photosynthesis Steps:”***

- During the process of photosynthesis, carbon dioxide enters through the stomata, water is absorbed by the root hairs from the soil and is carried to the leaves through the xylem vessels. Chlorophyll absorbs the light energy from the sun to split water molecules into hydrogen and oxygen.
- The hydrogen from water molecules and carbon dioxide absorbed from the air are used in the production of glucose. Furthermore, oxygen is liberated out into the atmosphere through the leaves as a waste product.
- Glucose is a source of food for plants that provide energy for **growth and development**, while the rest is stored in the roots, leaves and fruits, for their later use.
- Pigments are other fundamental cellular components of photosynthesis. They are the molecules that impart colour and they absorb light at some specific wavelength and reflect back the unabsorbed light. All green plants mainly contain chlorophyll a, chlorophyll b and carotenoids which are present in the thylakoids of chloroplasts. It is primarily used to capture light energy. Chlorophyll-a is the main pigment.

The **process of photosynthesis** occurs in two stages:

- Light-dependent reaction or light reaction
- Light independent reaction or dark reaction



Stages of Photosynthesis in Plants depicting the two phases – Light reaction and Dark reaction

### Light Reaction of Photosynthesis (or) Light-dependent Reaction

- Photosynthesis begins with the light reaction which is carried out only during the day in the presence of sunlight. In plants, the light-dependent reaction takes place in the thylakoid membranes of chloroplasts.
- The Grana, membrane-bound sacs like structures present inside the thylakoid functions by gathering light and is called photosystems.
- These photosystems have large complexes of pigment and proteins molecules present within the plant cells, which play the primary role during the process of light reactions of photosynthesis.
- There are two types of photosystems: photosystem I and photosystem II.
- Under the light-dependent reactions, the light energy is converted to ATP and NADPH, which are used in the second phase of photosynthesis.
- During the light reactions, ATP and NADPH are generated by two electron-transport chains, water is used and oxygen is produced.

The chemical equation in the light reaction of photosynthesis can be reduced to:



### Dark Reaction of Photosynthesis (or) Light-independent Reaction

- Dark reaction is also called carbon-fixing reaction.
- It is a light-independent process in which sugar molecules are formed from the water and carbon dioxide molecules.

- The dark reaction occurs in the stroma of the chloroplast where they utilize the NADPH and ATP products of the light reaction.
- Plants capture the carbon dioxide from the atmosphere through stomata and proceed to the Calvin photosynthesis cycle.
- In the **Calvin cycle**, the ATP and NADPH formed during light reaction drive the reaction and convert 6 molecules of carbon dioxide into one sugar molecule or glucose.

The chemical equation for the dark reaction can be reduced to:



\* G3P – glyceraldehyde-3-phosphate

