Chapter 13 Photosynthesis in Higher Plants

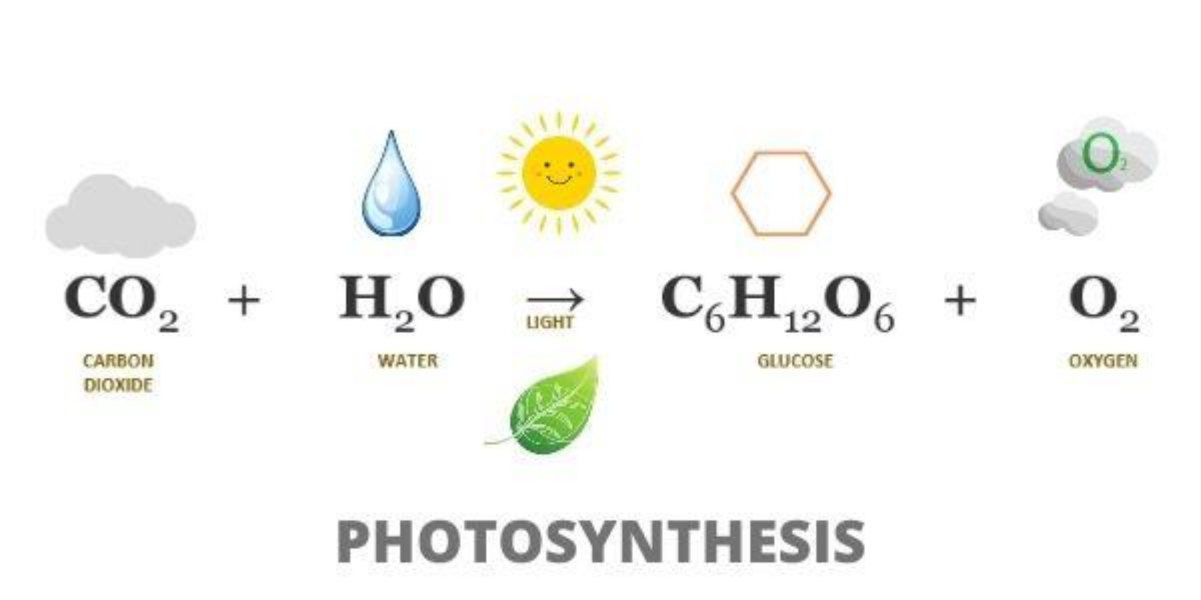
Photosynthesis is the process of using carbon dioxide and water in the presence of sunshine to create organic food, or carbohydrates.

By photosynthesis, all green plants are able to produce food. Since this is the sole source of carbohydrates where solar energy can be transformed into chemical energy, it is the most significant synthesis process on Earth.

The kinetic energy, or light energy, of sunlight is transformed into chemical energy during photosynthesis and is then stored in the molecules of carbohydrates. Our biosphere is sustained and grows thanks to this chemical energy. Plants provide nourishment for all animals, including humans, either directly or indirectly.

What we Know About Photosynthesis

The natural physicochemical process of photosynthesis is essential to life as we know it on Earth. The most significant biological process required for human existence is photosynthesis. The primary ingredients for photosynthesis are carbon dioxide, light, and chlorophyll. Here are a few tests to verify this.



Variegated Leaf Experiment

After being exposed to sunshine, a leaf that has variegated or distorted is examined for starch. Testing revealed that the white spots' absence of chlorophyll is the reason they seem colourless. We deduced from this that chlorophyll is necessary for photosynthesis to occur.

Light Screen Experiment

Photosynthesis requires light, as demonstrated by an experiment with a light screen. Then potted plants were taken and starved. Next, one of the leaves of the starving plant is affixed with a black paper or a Ganong light shade. The light screen on the Ganong is a motion-transmitting device that only permits light to travel through a small portion of the free air. Now, the plant spends many hours in the sun.

After that, the leaf is taken off, and the starch is examined. The non-starchy area stays colourless while the starchy area becomes blue. Furthermore, only leaves that are under direct sunlight become blue.

The portion of the leaf exposed to sunlight had good results for the production of carbohydrates. The portion that is covered and shielded from the sun doesn't produce carbs. This leads us to believe that photosynthesis requires sunshine.

Mohl's Experiment

It was shown through Mohl's experiment that photosynthesis requires carbon dioxide. After being split in half and put through a cork, half of the starving leaves are placed in a jar with cotton that has been slightly soaked in potassium hydroxide.

The leaf's other half is in the air. Next, the leaf is submerged in water in a bowl. After exposing the entire apparatus to sunlight for a while, the starch is examined. It is evident that starch is only generated on the bottle's exterior leaf portions; starch is absent from the interior leaves.

All the conditions for photosynthesis are met by the leaves outside the vase. No starch grows on the leaves inside the bottle because potassium hydroxide absorbs carbon dioxide, proving that carbon dioxide is necessary for photosynthesis.

Early Experiments Based on Photosynthesis

Plants may take in carbon dioxide from the environment and expel oxygen, as Joseph Priestley proved in 1774. He carried out an experiment in which he put a lit candle and a rat inside a glass bell-shaped jar. He removed the rat from it after noticing that the air inside had altered.

Then, he monitored the rat that lived inside with a lighted candle as he put the mint in a container of water inside the same jar. He deduced from this that the vegetation purified the air that had been contaminated by the fire. Priestley proposed that plants replenish the air that animals breathe while candles deplete it, based on the results of this experiment.

He calls the toxic-to-rats air produced by burning candles "PHLOGISTON" and claims that plants transform it into DEPHLOGISTON.

According to Jan Ingenhousz, green leaves produce dephlogisticated air, which is air rich in oxygen, when exposed to sunlight. When exposed to darkness, on the other hand, they produce phlogisticated air, which is air rich in carbon dioxide, and contaminate the air.

In 1854, Julius von Sachs made the discovery that green plants produce glucose, which is often stored as starch.

When TW Engelmann experimented with Cladophora and Spirogyra, he observed that the organisms grouped in blue and red light zones when the light was split by a prism and used to illuminate the algae.

Neil and V conducted experiments with purple and green sulphur bacteria. He attempted to demonstrate that appropriate oxidizable chemicals release hydrogen, which converts carbon dioxide to carbohydrates.

Where Does Photosynthesis Take Place

Green plant cells contain chloroplasts, a semiautonomous endosymbiont cell organelle with three membrane systems. It is composed of three primary components: a thylakoid, a matrix, and an envelope.

An envelope is made up of two membranes: an inner membrane and an outer membrane. Periplasmic space is the region between the outer and inner membranes.

Matrix: Double-stranded circular DNA, the 70S ribosome, the RUBISCO carboxylation enzyme, the PEP carboxylase enzyme, magnesium, CI, and other elements are found in a semi-liquid substrate known as a matrix.

Pigments Involved in Photosynthesis

Photosynthetic unit (PSU)/Light-Harvesting Complex (LHC)/Quantasome

The units of photosynthesis known as quantasomes were identified by Roderick B. Park. They are found in the chloroplast's thylakoid membrane and are made of lipids and proteins.

When light is converted into chemical energy, this is the smallest group of pigment molecules involved.

Their reaction, photo, or trap centres are always made up of a single chlorophyll molecule that consumes pigments that absorb light.

Photosynthetic Pigments:

Three main types of photosynthetic pigments are as follow:

I. Chlorophylls

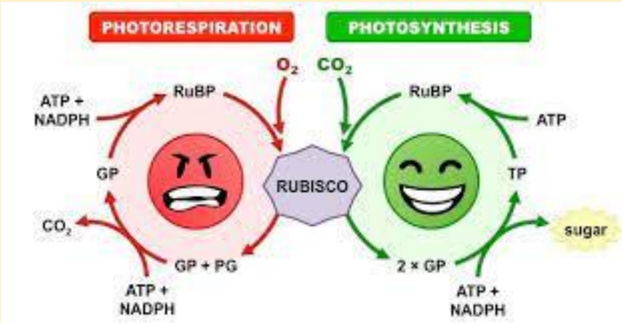
II. Carotenoids

III. Phycobilins

Photorespiration

In a process known as photorespiration, some O2 does bind to RuBisCO in C3 plants, and the RuBP then generates one molecule of phosphoglycerate and phosphoglycolate (2 Carbon).

- This process produces no sugar, ATP, or NADPH.
- C4 plants (increased intracellular concentration of CO2) do not photo respirate.



Factors affecting Photosynthesis

According to Blackman's Law of Limiting Factors, if more than one factor influences a chemical process, the factor that is closest to its minimal value will decide the process's rate since it is the one that has a direct impact on the process when its amount is altered.

- Light: In nature, light is rarely a limiting element (light saturation happens at 10% of full sunlight).
- Concentration of carbon dioxide: One of the main factors impeding photosynthesis.

- Temperature: The photosynthesis-related enzymes are temperature-sensitive.
- Water: Plants under water stress have stomata closure and withering, which hinders photosynthesis.

Absorption Spectrum

The pigments found in chloroplasts are what absorb light.

Different wavelengths of light are absorbed by specific pigments.

For instance, blue and red light in the visible spectrum are absorbed by chlorophyll-a. A pigment's light absorption capacity can be visually depicted.

The absorption spectrum is the peak of the absorption spectrum with respect to wavelength.

Action Spectrum

400–700 nm wavelengths of visible light are used for photosynthesis.

It doesn't happen as quickly as other wavelengths.

The degree of activity is a measurement of the rate of photosynthesis at various wavelengths. (For example, carbon dioxide is used to evolve oxygen). The spectrum of activity is this graph that shows the rate of photosynthesis as a function of wavelength.

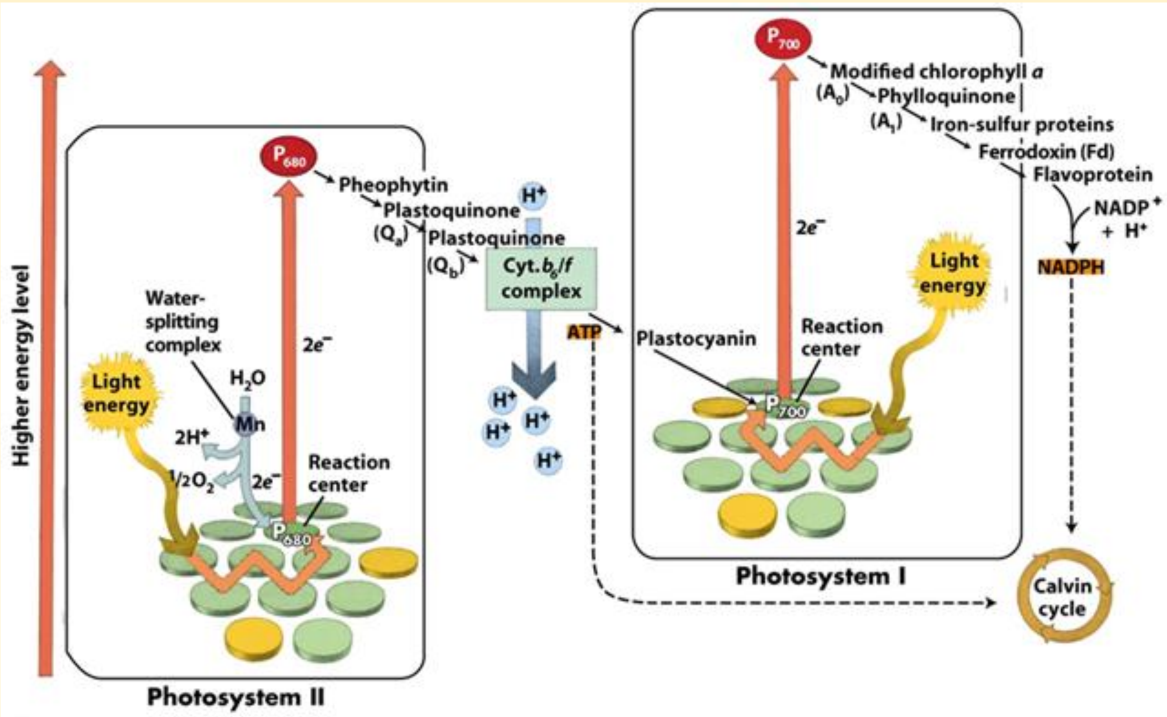
Light Reaction

Using the green algal Cladophora, TW Engelmann created the first photosynthetic activity spectrum in 1882.

The visible spectrum's red light is when photosynthesis is at its fastest. The visible spectrum's blue and red sections are where photosynthesis mostly takes place; other wavelengths do not see the same rate of photosynthesis because the accessory pigments in these regions are limited to absorbing light energy and transferring it to chlorophyll-a.

Only in chlorophyll-a (reaction centre) does the light reaction take place. The process of photosynthesis involves the oxidation of water and reduction of carbon dioxide through a redox reaction.

Electron Transport



Non-Cyclic Photophosphorylation

Another name for it is Z-scheme. It is made up of PS I and PS II. Chlorophyll-a 660, 673, 690, Chlorophyll-b, Chlorophyll-c, or Chlorophyll-d, carotenoids, and phycobilins make up Photosystem II (PS II). Phytoplankton A 680 is the response centre.

In stromal lamellae, it occurs. NADP+ takes the electron instead of it going back to the reaction centre. When water is photolyzed, electrons are used, which results in the production of NADPH2 and ATP.

Advantages of C4 Pathway

Because PEP has a stronger affinity for carbon dioxide, the C4 route is more effective at removing carbon dioxide from the atmosphere and does not include photorespiration.

Due to the bundle sheath cells' proximity to the water supply's surface, the impact of water stress on C4 plants is reduced.

Because it contains organic acids, it can withstand stress.

C4 plants fix the same amount of carbon dioxide in order to minimise water loss.

In terms of carbon dioxide fixation, C4 plants were twice as effective as C3 plants.