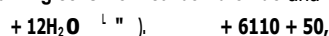


PHOTOSYNTHESIS IN HIGHER PLANTS

Photosynthesis is an enzyme regulated anabolic process of manufacture of organic compounds inside the chlorophyll containing cells from carbon dioxide and water with the help of sunlight as source of energy.



For photosynthesis, light and CO_2 is required. It occurs only in green part of leaves in presence of light.

Early Experiment

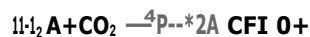
Joseph Priestley in 1770s concluded that foul air produced by animal is converted into pure air by plants.

Priestley discovered Oxygen gas in 1774.

Julius Van Sachs in 1854 shows that green plant in plants produces glucose which is stored as starch. Starch is the first visible product of photosynthesis.

T.W. Engelmann (1843-1913) discovered the effect of different wavelength of light on photosynthesis (action spectrum).

Cornelius Van Niel (1897-1935) on the basis of studies with purple and green sulphur bacteria shows that photosynthesis is a light dependent reaction in which hydrogen from an oxidisable compound reduces CO_2 to form sugar.



In green sulphur bacteria, when H_2S instead of H_2O was used as hydrogen donor, no O_2 was evolved. He

inferred that oxygen from green plants comes from H_2O but not from CO_2 as thought earlier.

Where Does Photosynthesis Takes Place?

- Chloroplasts are green plastids which function as the site of photosynthesis in eukaryotic phototrophs.
- Within the chloroplast there is a membranous system consisting of grana, the stroma lamellae and the fluid matrix.

The reaction in which light energy is absorbed by grana to synthesize ATP and NADPH is called light reaction. The later part of photosynthesis in which CO_2 is reduced to sugar, in which light is not necessary is called dark reaction.

Pigments involved in photosynthesis - The plant pigments are found in chloroplasts on the thylakoids.

The 4 Plant Pigments are-

- Chlorophyll a: Light to medium green. Main photosynthetic pigment.
- Chlorophyll b: Blue-green, Accessory Pigment.
- Carotene: Yellow. Orange. Accessory Pigment.
- Xanthophyll: Yellow. Accessory Pigment.

Maximum absorption by chlorophyll a occurs in blue and red regions having higher rate of photosynthesis. So, chlorophyll a is the chief pigment.

Light reaction

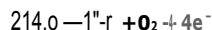
- Light reaction (photochemical phase) includes

- Light absorption
- Water splitting
- Oxygen release
- Formation of high energy chemical intermediates (ATP and NADPH).

- The pigments are organized into two discrete LHC (light harvesting complex) within photosystem I and photosystem II.
- LHC Ant made up of hundreds of hundreds of pigment molecules containing all pigments except single chlorophyll a molecules in each PS.
- * The pigments in photosystem I and photosystem II absorb the lights of different wavelength. Single chlorophyll molecules make the reaction centre. In PS I reaction centre has highest peak 700 nm, hence called P700. And PS II reaction centre has highest peak at 680 nm, so called P680.

The Electron Transport System

- Reaction centre of photosystem II absorbs light of 680 nm in red region and causing electron to become excited. These electrons are picked by electron acceptor which passes to electron transport system consisting of cytochrome.
- Electrons passed through electron transport chain and passed on to the pigment of PSI. Electron in the PSI also get excited due to light of wavelength 700 nm and transferred to higher potential.
- + When electron pass in downhill direction, energy is released that reduce the ADP to ATP and NADP⁺ to NADH. The whole scheme of transfer of electron is called Z-scheme due to its shape.
- Photolysis of water release electrons that provide electron to PS II. Oxygen is released during photosynthesis due to this also.



Difference between Cyclic and non-cyclic photophosphorylation

Cyclic photophosphorylation

- It is performed by photosystem I independently.
- An external source of electron is not required.
- It synthesizes only ATP.
- It occurs only in stroma or intergranal thylakoids.

Non-cyclic photophosphorylation

- It is performed by collaboration of both PS I and PS II.
- The process requires an external electron donor.
- It synthesizes ATP and NADH both.
- It occurs in the granal thylakoid only.

Chemiosmotic Hypothesis ATP formation was proposed by Mitchell in 1961.

The product of light reaction is used to drive the process leading to synthesis of sugar are called biosynthetic phase of photosynthesis.

Calvin Cycle/C3 cycle/Reductive Pentose Sugar Phosphate Pathway

Malvin Calvin, Benson and their colleagues used radioactive ¹⁴C and Chlorella and Scenedesmus algae to discover that first CO₂ fixation product is 3-carbon organic compound 3-phosphoglyceric acid or 3-PGA. Later on a new compound was discovered which contain 4-carbon called Oxaloacetic Acid (4C). On the basis of number of carbon atoms in first stable product they are named C₃ and C₄ pathway.

- **Carboxylation** is the fixation of CO₂ into 3-phosphoglyceric acid (3-PGA). Carboxylation of RuBP occurs in presence of enzyme RuBP carboxylase (RuBisCO) which results in the formation of two molecules of 3-PGA.
- **Reduction** is series of reaction that leads to formation of glucose. Two molecules of ATP and two molecules of NADPH are required for reduction of one molecule of CO₂. Six turns of this cycle are required for removal of one molecule of glucose molecules from pathway.
- * **Regeneration** is the generation of RuBP molecules for the continuation of cycle. This process requires one molecule of ATP.

Fig-Calvin Cycle/ C3/ C4 Cycle

For every molecules of CO₂ entering the Calvin Cycle, 3 molecules of ATP are required.

C4 pathway/Hatch Slack Pathway

- This pathway was worked out by Hatch and Slack in 1967, mainly operational in plants growing in arid tropical region like Maize, Sugarcane, Sorghum etc,
- In this pathway first stable product is a 4-carbon compound Oxaloacetic acid, so called as C₄ pathway. C₄ plants have Kranz Anatomy (vascular bundles are surrounded by bundle sheath cells, arranged in wreath like manner), characterized by large no. of chloroplasts, thick wall in bundle sheath cells and absence of intercellular spaces.
- The primary CO₂ acceptor is a 3-carbon molecule Phosphoenolpyruvate present in mesophyll cells and enzyme involved is PEP carboxylase.
- OAA formed in mesophyll cell forms 4-carbon compound like malic acid or aspartic acid which is transported to bundle sheath cells.
- In bundle sheath cell, it is broken into CO₂ and a 3-carbon molecule. The 3-carbon molecule is returned back to mesophyll cells to form PEP.
- The CO₂ molecules released in bundle sheath cells enter the Calvin cycle, when enzyme RuBisCO is present that forms sugar.

Photorespiration

It is a light dependent process of oxygenation of RuBP and release of carbon dioxide by photosynthetic organs of plants.

Photorespiration decreases the rate of photosynthesis when oxygen concentration is increased from 2-3% to 21%.

This pathway involves Chloroplast, Peroxisome and Mitochondria. Photorespiration does not occur in C₄ plants.

Factors affecting photorespiration:

- Light
- Carbon dioxide concentration
- Temperature - It does not influence the rate of photosynthesis directly. High temperature can inhibit it due to denaturation of enzymes involved in the dark reaction.
- Water