ADHIKAANSH ACADEMY

(IITJEE NEET IX X XI XII)

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BIOLOGY NOTES

(CLASS 11TH)

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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.

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

- Photosynthesis is the basis of life on earth because it the primary source of all food on earth and it is responsible for release of O_2 in the atmosphere.
- Chlorophyll, light and CO_2 is required for photosynthesis. It occurs only in green part of leaves in presence of light.

Early Experiments

- Joseph Priestley in 1770, on the basis of his experiments shows the essential role of air in growth of green plants. A mouse kept in closed space could get suffocated and die but if a mint plant is kept in bell jar neither candle will extinguish nor will the mouse die. He concluded that foul air produced by animal is converted into pure air by plants. Priestley discovered Oxygen gas in 1774.

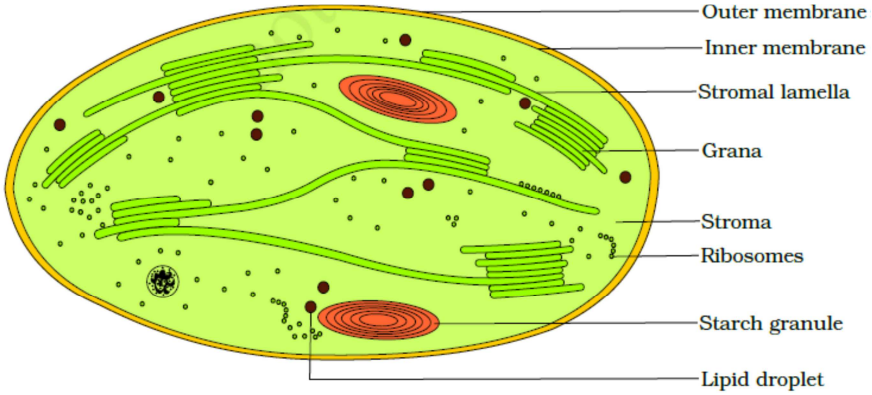
- Julius Van Sachs in 1854 shows that green plant in plants produces glucose which is stored as starch. Starch is the first visible product of photosynthesis.
- T.W.Engelmann (1843-19090 splits light into components by prism and then illuminated Cladophora (an algae) placed in a suspension of aerobic bacteria. He found that bacteria illuminated in blue and red light of the split spectrum. He thus discovered the effect of different wavelength of light on photosynthesis (action spectrum).
- Cornelius Van Neil (1897-1985) 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.

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

In green sulphur bacteria, when H_2S, instead of H_2O was used as hydrogen donor, no O_2 was evolved. He inferred that O_2 evolved by green plants comes from H_2O but not from CO_2 as thought earlier.

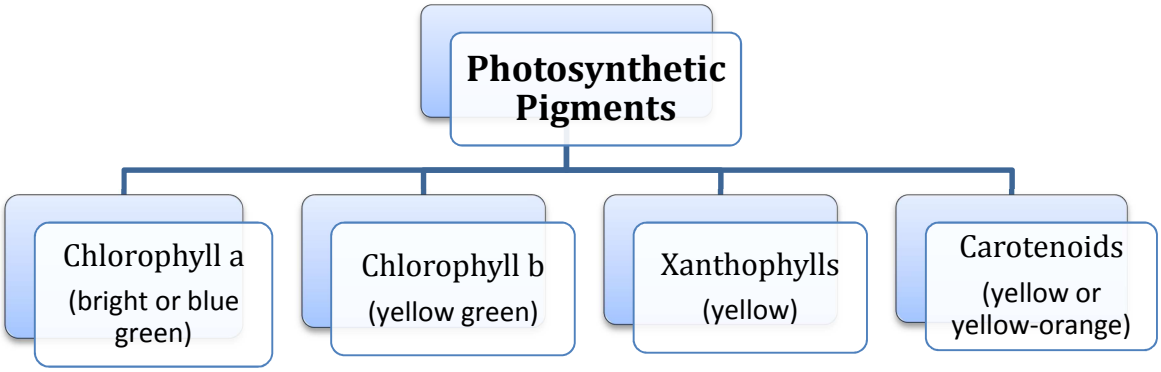
Where Does Photosynthesis Takes Place?

- Chloroplasts are green plastids which function as the site of photosynthesis in eukaryotic photoautotrophs. Inside the leaves, chloroplast is generally present in mesophyll cells along their walls.
- Within the chloroplast there is a membranous system consisting of grana, the stroma lamellae and the fluid stroma.



- The membrane system is responsible for synthesizing light energy for the synthesis of ATP and NADPH. In stroma enzymatic reactions incorporate CO2 in plants leading to synthesis of sugar.
- The reaction in which light energy is absorbed by grana to synthesis ATP and NADPH is called **light reaction**. The later part of photosynthesis in which CO2 is reduced to sugar, in which light is not necessary is called **dark reaction**.

  Pigments involved in Photosynthesis – Chromatographic separation of leaf pigments are as follows-



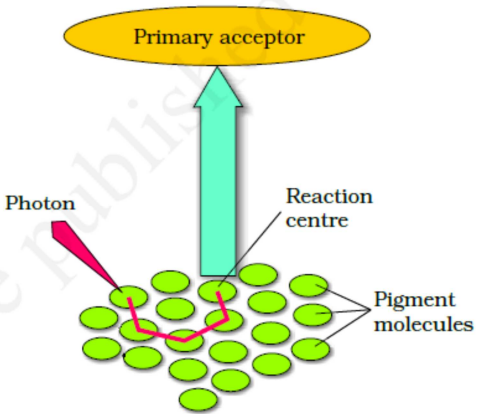
- Maximum absorption by chlorophyll a occurs in blue and red regions having higher rate of photosynthesis. So, chlorophyll a is the chief pigment.
- Other thylakoid pigments like chlorophyll b, xanthophyll and carotenoids are called accessary pigments that absorb light and transfer energy to chlorophyll a and protect them from photo-oxidation.

Light reaction

- Light reaction(photochemical phase) includes

a. Light absorption

b. Water splitting
c. Oxygen release
d. Formation of high energy chemical intermediates (ATP and NADPH).

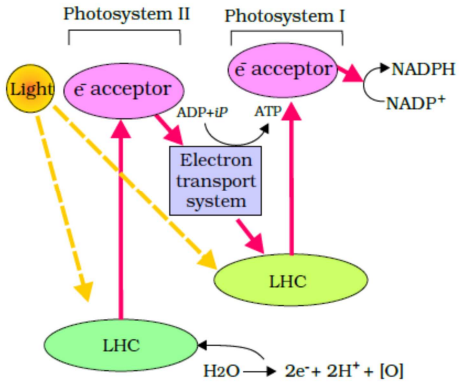


- The pigments are organized into two discrete LHC(light harvesting complex) within photosystem I and photosystem II.
- LHC are made up of hundreds of hundreds of pigments molecules containing all pigments except single chlorophyll a molecules in each PS.

- The pigments in photosystem I and photosystem II absorbs the lights of different wavelength. Single chlorophyll molecules make the reaction centre. In PS I reaction centre has highest peak 700nm, 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 becomes excited. These electrons are picked by electron an electron acceptor which passes to electron transport system consisting of cytochrome.



❖ Electrons passed through electron transport chain and passed on to the pigment of PS I. electron in the PSI also get excited due to light of wavelength 700nm and transferred to higher potential.

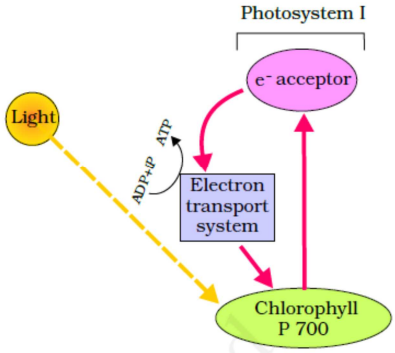
❖ When electron passes in downhill direction, energy is released that reduce the ADP to ATP and $NADP^+$ to NADPH. The whole scheme of transfer of electron is called Z-scheme due to its shape.

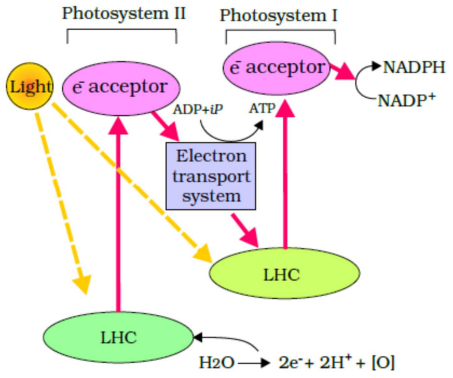
❖ Photolysis of water release electrons that provide electron to PS II. Oxygen is released during photosynthesis due to this also.

$$2H_2O \longrightarrow 4H^+ + O_2 + 4e^-$$

❖ **Difference between cyclic and non-cyclic photophosphorylation**

Cyclic photophosphorylation	Non-
a. It is performed by photosystem I independently.	a. It is performed by collaboration of both PS I and PS II.
b. An external source of electron is not required.	b. The process requires an external electron donar.
c. It synthesizes only ATP.	c. It synthesizes ATP and NADH both.
d. It occurs only in stromal or intergranal thylakoids.	d. It occurs in the granal thylakoids only.

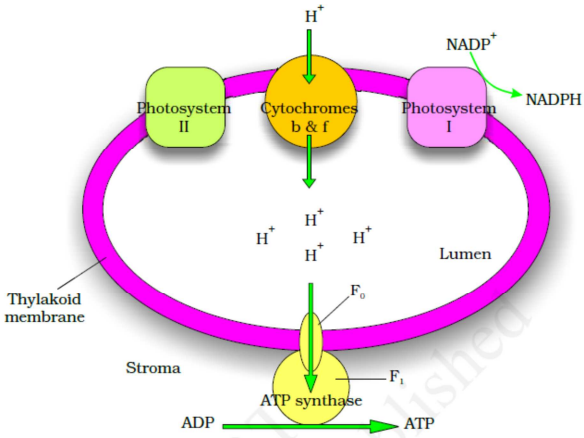




Chemiosmotic Hypothesis of ATP FORMATION

This hypothesis was proposed by Mitchell in 1961. ATP synthesis is linked to development of proton gradient across the membrane of thylakoids and mitochondria.

The process that cause to develop proton gradient across the membrane because-



i. Splitting of water molecules occurs inside the thylakoid to produce hydrogen ion or proton.

ii. As electron passes through the photosystems, protons are transported across the membrane because primary acceptor of electron is located towards the outer side the membrane.

iii. The NADPH reductase enzyme is located in the stroma side of membrane. Electrons come out from the acceptor of electron of PSI, protons are necessary for reduction of $NADP^+$ to NADP + H^+. These protons are also removed from the stroma. This creates proton gradient across the thylakoids membrane along with pH in the lumen.

iv. Gradient is broken down due to movement of proton across the membrane to the stroma through trans-membrane channel of F_0 of ATPase. One part of this enzyme is embedded in membrane to form trans-membrane channel. The other portion is called F_1that protrudes on the outer surface of thylakoid membrane which makes the energy packed ATP.

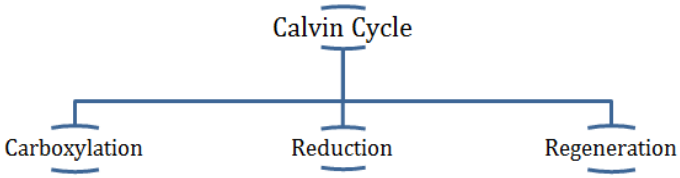
v. ATP and NADPH produced due to movement of electron is used immediately to fix CO_2 to form sugar.

❖ 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 Chlorealla and Scenedesmus algae to discover that first CO2 fixation product is 3-carbon organic compound (3-phosphoglyceric acid) or PGA. Later on a new compound was discovered which contain 4-carbon called Oxaloacetic Acid (AAO). 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 molecules of CO2. Six turn 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 require one molecules of ATP.



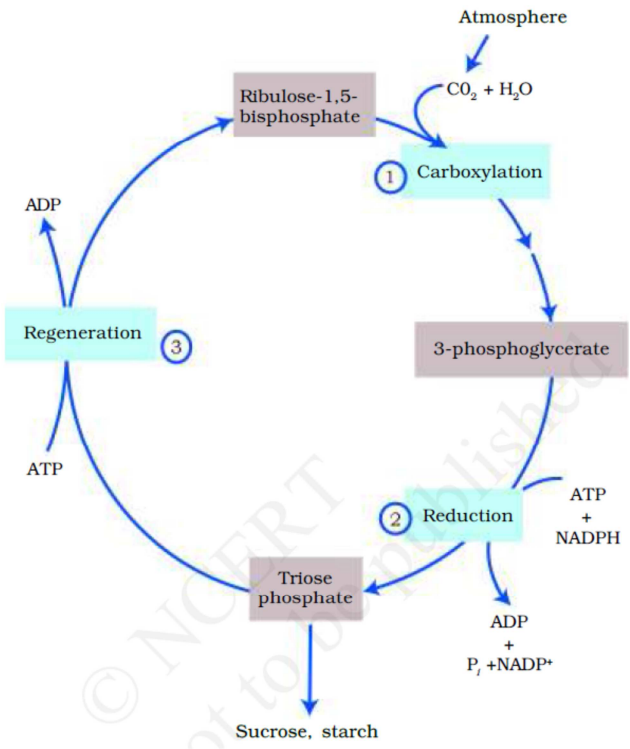


Fig-Calvin Cycle/ C_3 Cycle

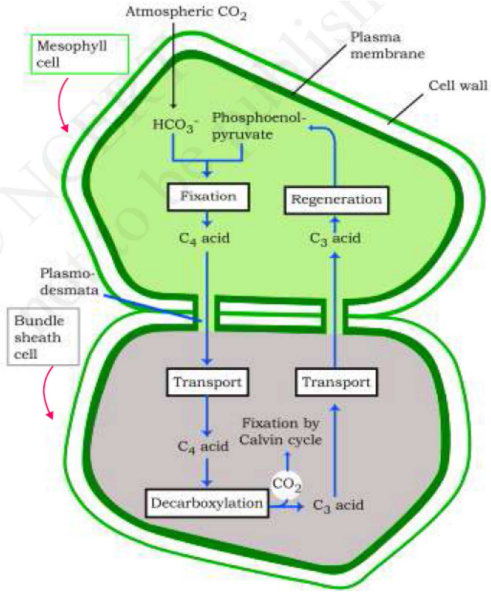
- For every molecules of CO_2 entering the Calvin Cycle, 3 molecules of ATP and 2 molecules of NADPH is required. To make one molecules of glucose 6 turns of cycle is completed so total energy molecule required is

In	Out
Six CO_2	One glucose
18 ATP	18 ADP
12 NADPH	12 NADP

C_4 pathway/Hatch Slack Pathway

- This pathway was worked out by Hatch and Slack (1965, 1967), mainly operational in plants growing in dry tropical region like Maize, Sugarcane, Sorghum etc.
- In this pathway first stable product is a 4-carbon compound Oxaloacetic acid (AAO) so called as C_4 pathway. C_4 plants have Kranz Anatomy (vascular bundles are surrounded by bundle sheath cells arranged in wreath like manner), characterized by large no of chloroplast, thick wall impervious to gases and absence of intercellular spaces.
- The primary CO_2 acceptor is a3-carbon molecule Phosphoenol Pyruvate 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 CO_2 and a 3-carbon molecule. The 3-carbon molecule is returned back to mesophyll cells to form PEP.
- The CO_2 molecules released in bundle sheath cells enters the Calvin cycle, where enzyme RuBisCO is present that forms sugar.



Photorespiration

- ✓ It is a the light dependent process of oxygenation of RuBP and release of carbon dioxide by photosynthetic organs of plants.
- ✓ Photorespiration decrease the rate of photosynthesis when oxygen concentration is increased from 2-3% to 21%.
- ✓ In presence of light and higher concentration of Oxygen results the binding of RubisCO enzyme with O_2 to form.

RubisCO + O_2 → PGA + phosphoglycolate

This pathway involves **Chloroplast, Peroxisome and Mitochondria**. Photorespiration do not occurs in C_4 plants.

a. The leaves do not have Kranz anatomy. b. Photorespiration occurs. c. RuBisCO is the first acceptor of CO_2. d. PGA is the first stable product. e. Plants are adapted to all climates. f. Mesophyll cells perform complete photosynthesis.	a. anatomy in leaves. b. Photorespiration does not occur. c. PEP is the first acceptor of CO_2. d. OAA is the first stable product. e. Plants are adapted to tropical climate. f. Mesophyll cells perform only initial fixation.

Factors affecting photosynthesis

a. **Light** – as light intensity increases, the rate of photosynthesis also increases until light saturation point.

b. **Carbon dioxide concentration**- with increase in concentration of CO_2 rate of photosynthesis increase till the compensation point.

c. **Temperature-** it does not influence the rate of photosynthesis directly but at higher temperature enzyme activity is inhibited due to denaturation to affect the dark reaction.

d. **Water**- increase in temperature, rate of photosynthesis do not increase proportionally as after saturation no more water is required during photosynthesis.

Principle of law of limiting factors states that if a chemical process is affected by more than one factor, then its rate could be determined by the factor which is nearest to its minimal value which directly affects the process if its quality is changed.

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