PHOTOSYNTHESIS IN HIGHER PLANTS

- Photosynthesis is the primary source for energy in earth
- it is responsible for production of oxygen

Half leaf experiment

Here a part of a leaf is enclosed in a test tube containing some KOH soaked cotton (which absorbs CO2), while the other half is exposed to air. The set up is then placed in light for some time. Starch is formed at exposed part while the part inside the test tube do not produce starch. This is because of absence of starch.

Early experiments relate with photosynthesis and scientists

1. Joseph preistely
   He observed that a burning candle will be extinguished in a closed space(inside the bell jar) and a mice will die inside the closed space.
   But if a mint plant is taken with mice and candle inside the bell jar the air is restored by plant.
2. Jan Ingenhouesz
   He took the above experiment of Joseph preistely ; one in dark and another in sunlight and found that sunlight is required for the purification of air.
   He also found that some bubbles are produced in water plants during the process and said it is oxygen.
3. Julius Von sachs
   provided the evidence of production of glucose during the process and it is produced in green bodies
4. T.W Engelmann
   He split the light into its components and illuminated the alga cladophora, taken in a suspension of aerobic bacteria. The bacteria detected the places where the oxygen is evolved and concentrated there. He observed that the bacteria accumulated at the light of blue and red.
5. Van Neil- observed that carbon dioxide is reduced by hydrogen comes from a suitable oxidisable compound.

- Photosynthesis is an oxidation reduction reaction; because here CO_2 is reduced and H_2O gets oxidised
- In photosynthesis Glucose is the main product and $O_2$is bye product
- here solar energy converted into chemical energy
- photosynthesis completes in two phases; light reaction and Dark reaction

Light reaction	Dark reaction
1. takes place in grana 2. ATP and NADPH are formed 3. light dependent phase	1. takes place in stroma 2. glucose is formed 3. light independent

Photosynthetic pigments

Chlorophyll a (bright or blue green) , chlorophyll b (yellow green), xanthophylls (yellow) and carotenoids (yellow to yellow-orange) are the various pigments of photosynthesis. They absorb light, of specific wavelengths. They present in grana.

Chlorophyll a is the major pigment responsible for trapping light, other pigments like chlorophyll b, xanthophylls and carotenoids, also absorb light and transfer the energy to chlorophyll a.
the pigments other than chlorophyll a is called accessory pigments.

The accessory pigments also protect the chlorophyll a from photo oxidation

Action spectrum and absorption spectrum

Absorption spectrum: it is the graph showing the absorption of different wavelength of light by pigments. More absorption takes place blue and red light

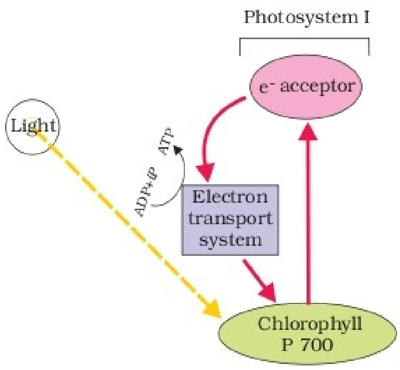
Action spectrum: graph showing the rate of photosynthesis in different wavelength of light .More photosynthesis takes place blue and red light

light harvesting complexes(LHC)

The LHC are made up of hundreds of molecules pigment molecules bound to proteins. these pigments absorb light and transfer energy to chlorophyll a ; the reaction centre. The other pigments(except chlorophyll a) are called antenna pigments.

The LHC is the part of Photosystems. Two photosystems are there . Photosystem I and Photosystem II (PS I and PS II)
Both PS I and PS II show the reaction centre of chlorophyll a.
The reaction centre of PS I absorb 700 nm avelength of light while the reaction centre of PS II absorb 680 nm avelength of light

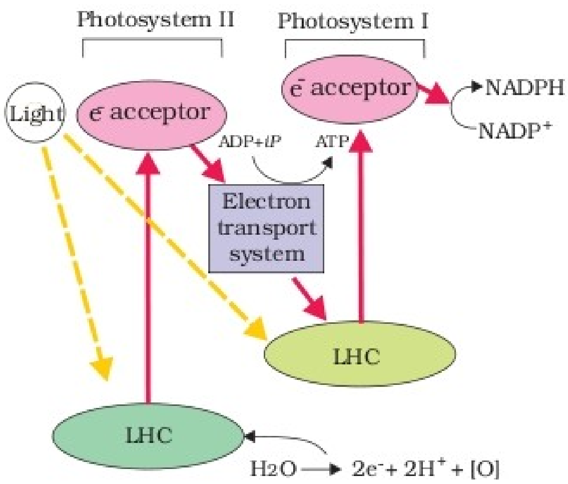
Cyclic photophosphorylation



The reaction centre(P700) gets energy and it is excited . Then an electron is emitted. This electron is accepted by an electron acceptor. Then the electron is passed through a series of electron carriers (ETS). Finally reach at reaction centre itself. During the transport through ETS an ATP is produced from ADP.

The production of ATP from ADP is called as Phosphorylation. I.e addition of inorganic phosphate with ADP and the formation of ATP

Non Cyclic photophosphorylation



The reaction centre(P700) of PS I gets energy and it is excited . Then an electron is emitted. This electron is accepted by an electron acceptor. Then the electron is passed to NADP+.
Then NADP+ is reduced to NADPH + H+.

At the same time the The reaction centre(P680) of PS II gets energy and it is excited . Then an electron is emitted. This electron is accepted by an electron acceptor. Then the electron is passed through a series of electron carriers (ETS). Finally reach at reaction centre (P700) of PS I. During the transport through ETS an ATP is produced from ADP.

Non cyclic is also called Z scheme, because of the shape of movement of electron.
In Non cyclic photophosphorylation Splitting of Water take place. The splitting of water is associated with the PS II; water is split into H+, [O] and electrons. these electrons reached at PSII.

Difference between cyclic and noncyclic

cyclic photophosphorylation	Noncyclic photophosphorylation
• Only photosystem I is involved • electrons travel in cyclic manner • only ATP is synthesised • no photolysis of water • no oxygen evolution • it is predominant in bacteria	• Both photosystem I and photosystem II are involved • electrons travel in non cyclic manner • ATP and NADPH are synthesised • photolysis of water occur • oxygen evolution takes place • it is predominant in green plants

- The production of ATP from ADP is called as Phosphorylation. i.e addition of inorganic phosphate with ADP and the formation of ATP.

<u>How ATP is synthesised in grana?</u>

It can be explained by Chemiosmotic Hypothesis . ATP synthesis takes place due to proton gradient across a membrane. Here emembrane is thylakoid membrane. Inside the thylakoid lumen H+ ions are accumulated. Then they move to stroma ; across the membrane. Then the phosphorylation takes place.

The concentration of H+ ions are increased inside the lumen by following ways....

(a) Hydrogen ions that are produced by the splitting of water accumulate within the lumen of the thylakoids.

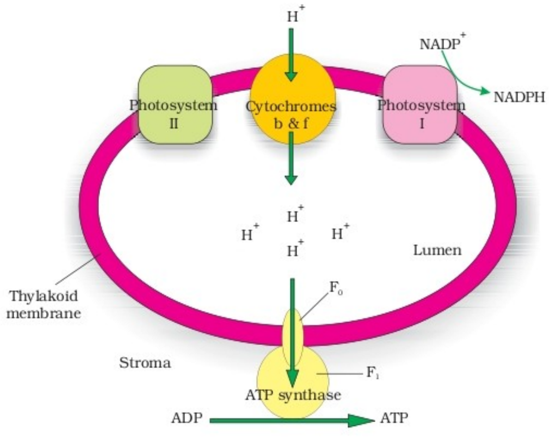


Figure 13.7 ATP synthesis through chemiosmosis

(b) As electrons move through the photosystems, protons are transported to lumen from stroma.
(c) The H+ ions ae taken from stroma for reduction of NADP .

These creates a proton gradient across the thylakoid membrane and they move out of lumen through ATP synthase. It results in the production of ATP.

<u>DARK REACTION</u>

The ATP and NADPH produced in light reaction are used here and the synthesis of glucose occur. This is the **biosynthetic phase** of photosynthesis. This process does not directly depend on the presence of light.

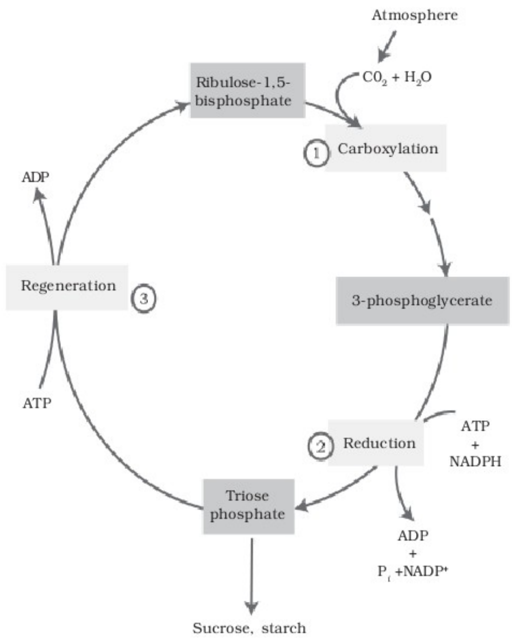
Melvin calvin identified and explained the process of dark reaction.

<u>Calvin cycle</u>

The whole pathway is operated in a cyclic manner. Calvin cycle can be described under three stages: carboxylation, reduction and regeneration.

<u>1. Carboxylation</u>

- Carboxylation is the fixation of CO2 into a stable organic intermediate.
- RuBP (5 carbon compound) accept CO2 and two molecules of 3-PGA are formed.
- It is catalysed by the enzyme RuBP carboxylase.
- Since this enzyme also has an oxygenation activity in addition to the carboxylation it is called RuBP carboxylase-oxygenase or RuBisCO.



<u>2. Reduction –</u> These are a series of reactions that lead to the formation of glucose.
The steps utilise 2 molecules of ATP for phosphorylation and two of NADPH.

<u>3. Regeneration</u> – Regeneration of the RuBP (CO2 acceptor molecule) . The regeneration steps require one ATP.

To make one molecule of glucose 6 turns of the cycle are required.
So in Calvin cycle 18 ATP and 12 NADPH are required for the synthesis of 1 glucose molecule.

Also called C3 cycle as its first stable compound is a 3 carbon compound.(3PGA)

<u>Hatch and Slack Pathway</u>
Plants that are adapted to dry tropical regions have the C4 pathway to fix CO_2

***<u>C4 plants are special</u>*:**	**<u>Special anatomy</u>**
➢ They have a special type of leaf anatomy ➢ they tolerate higher temperatures ➢ they show a response to highlight intensities, ➢ they lack a process called photorespiration and have greater productivity of biomass one.	The leaves show special anatomy called 'Kranz' anatomy. 'Kranz' means 'wreath' and is a reflection of the arrangement of cells. The bundle sheath cells may form several layers around the vascular bundles

- The pathway completes in mesophyll and bundle sheath cells.
- Traced out by Hatch and Slack.
- It is also a cyclic process.
- phosphoenol pyruvate (PEP) accepts CO_2 and OAA ((Oxalo Acetic Acid) is formed in the mesophyll.
- PEP is a 3-carbon molecule and OAA is 4-carbon molecule
- The enzyme responsible for this fixation is PEP carboxylase or PEPcase.

- Mesophyll cells lack RuBisCO enzyme.
- OAA then forms other 4-carbon compounds like **malic acid or aspartic acid** in the mesophyll cells, which are transported to the bundle sheath cells.
- In the bundle sheath cells these C4 acids are broken down to release CO_2 and Pyruvic Acid (3C)
- The 3-carbon molecule is transported back to the mesophyll where it is converted to PEP again.
- The CO_2 released in the bundle sheath cells enters the Calvin pathway.

Also called C4 cycle as the forst stable compound is a 4 carbon compound(OAA)

<u>PHOTORESPIRATION</u>
If the O_2 concentration is more than that of CO_2 the RuBP combines with O_2 to form 1 molecule of 3PGA and one molecule and phosphoglycolate. It is common in C3 plants.

In the photorespiration there is no synthesis of ATP or NADPH. Therefore, photorespiration is a wasteful process.

In C4 plants photorespiration does not occur. Because the RuBisCO s seen in bundle sheath cells; there is enough supply of CO_2 .

<u>FACTORS AFFECTING PHOTOSYNTHESIS</u>
Photosynthesis is under the influence of several factors, both internal (plant) and external

<u>Internal factors</u>
leaf number, leaf size, leaf age and orientation of leaves,
orientation of mesophyll cells,orientation of chloroplasts,
internal CO_2 concentration and the amount of chlorophyll.
<u>External factors</u>
Many factors like availability of sunlight, temperature, CO_2 concentration and water ,all affect the rate of photosynthesises,

1. Light: light afect in various ways
a) light quality: photosynthesis is maximum in red and blue light
b) light intensity: photosynthesis is maximum in intensed light than dim light.
c) duration: photosynthesis is maximum in intermittent light than continouus light.

2. Carbon dioxide Concentration

The concentration of CO2 is very low in the atmosphere (between 0.03 and 0.04 per cent).
Increase in concentration upto 0.05 per cent can cause an increase photosynthesis; beyond this the levels can become damaging .
The current availability of CO2 levels is limiting to the C3 plants. The fact that C3 plants respond to higher CO2 concentration by showing increased rates of photosynthesis leading to higher productivity .

3. Temperature

The dark reactions being enzymatic are temperature controlled. The C4 plants respond to higher temperatures and show higher rate of photosynthesis while C3 plants have a much lower temperature optimum.

4.Water

water is necessary for photosynthesis.
Water stress causes the stomata to close hence reducing the CO2 availability.

Blackman's Law of Limiting Factors can be applicable here as several factors affect the rate simutaneousely.
This states that- If a chemical process is affected by more than one factor, then its rate will be determined by the factor which is nearest to its minimal value.

Difference between C3 and C4 cycle

C3 cycle	C4 cycle
Traced out by Melvin Calvin	Traced out by Hatch and Slack
Co2 acceptor is RuBp	Co2 acceptor is PEP
First stable compound is 3-PGA	First stable compound is OAA
RuBisCo is the carboxylation enzyme	PEP Case is the carboxylation enzyme
Leaves have no Kranz anatomy	Leaves show Kranz anatomy
Bundle sheath cells do not show chloroplasts	Bundle sheath cells show chloroplasts
Only mesophyll cells involved	Both mesophyll and Bundle sheath cells involved
Optimum temperature is low	Optimum temperature is high
Photorespiration is high	No Photorespiration
Co2 compensation point is high(50ppm)	Co2 compensation point is low (2-5ppm)
Eg.wheat, rice, cotton	Eg.sugarcane,sorghum,amaranthus
Less efficient	High efficient