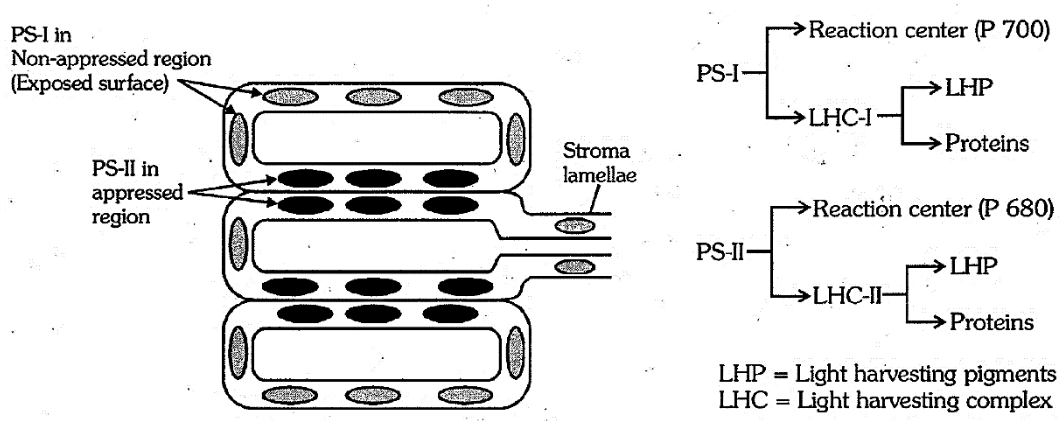
PHOTOSYNTHESIS IN HIGHER PLANTS
THE ELECTRON TRANSPORT

ELECTRON TRANSPORT CHAIN:

It is of two types.

(A) Non-cyclic (B) Cyclic



PHOTOPHOSPHORYLATION

ATP synthesis by cells On mitochondrial and chloroplasts) is named phosphorylation. Photophosphorylation is the synthesis of ATP from ADP and inorganic phosphate in the presence of light. It is of two types (according to Arnon et al)

(a) Cyclic photophosphorylation :

When only PS-I is functional, the electron is circulated within the photosystem-1 and the phosphorylation CATP synthesis) occurs due to cyclic flow of electrons.

A oossible location where this could be happening is in the stroma lamellae because the stroma lamellae membranes lack PS-D as well as NADP reductase enzyme. Cyclic photophosphorylation also occurs when only light of wavelengths beyond 680 nm are available for excitation.

During cyclic photophomhorylation the excited electrons does not pass on to NADP+ bufis cycled back to the PS-I complex through the electron transport chain/system (ETS). The cyclic flow, hence, nisults only in the synthesis of ATP but not of NADPH.

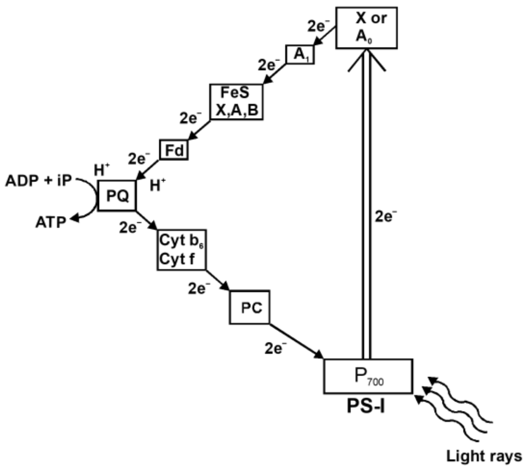


Fig: Light reaction : Cyclic photophosphorylation with electron transport chain

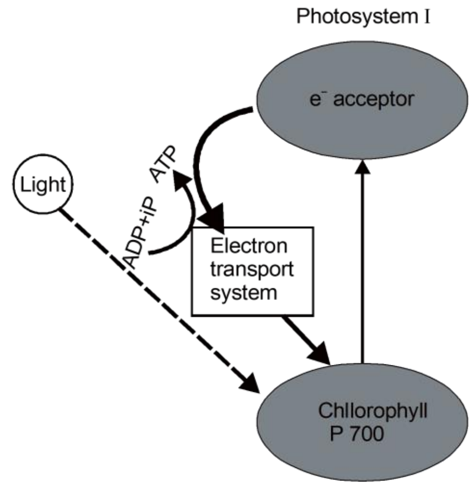


Fig : Cyclic photophosphorylation

(b) Non-cyclic photophosphorylation :

When the two photosystems CPS I and PS IT) work together the process called non-cyclic photophosphorylation. The two photosystems are connected through an electron transport chain.

This whole scheme of transfer of electrons, starting from the PS II, uphill to the acceptor, down the electron transport chain to PS-II, excitation of electrons, transfer to another acceptor, and finally down hill to NADP±. reducing it to NADPH + H±. It is called the Z scheme, due to its characteristic shape. This shape is formed when all the carriers are placed in a sequence on a redox potential scale.

Z scheme was proposed by Hill and Bendall.

Redox potential :

If is the measure of the tendency of a chemical molecule to acquire electrons and thereby be reduced. It is also called oxidation - reduction potential. It is measured in volts (v) or mili volts (mv).

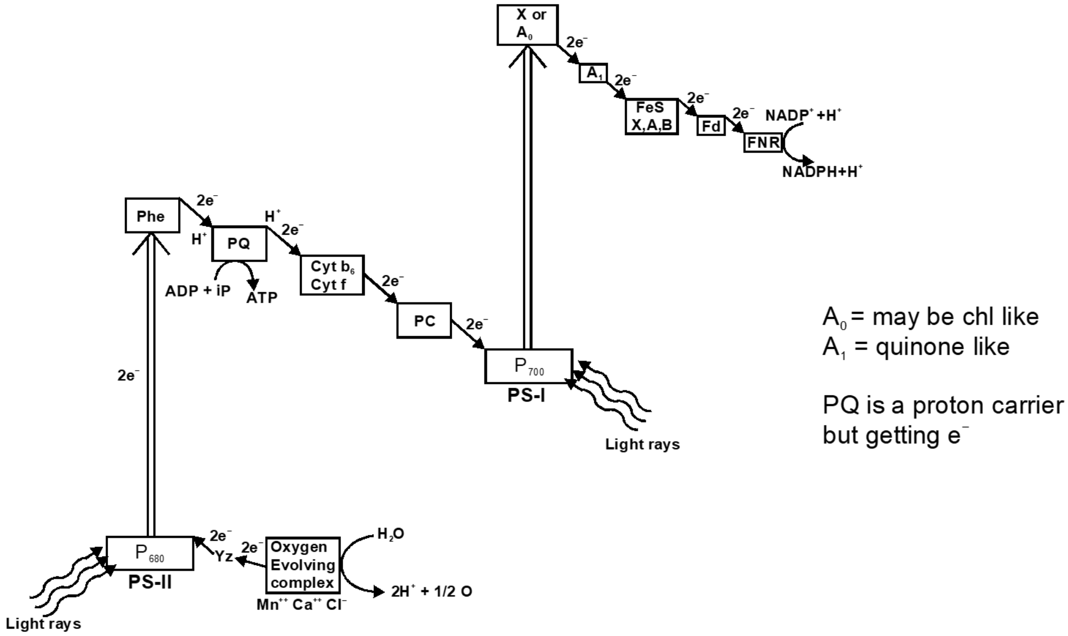


Fig: Light reaction : Non-cyclic photophosphorylation with electron transport chain

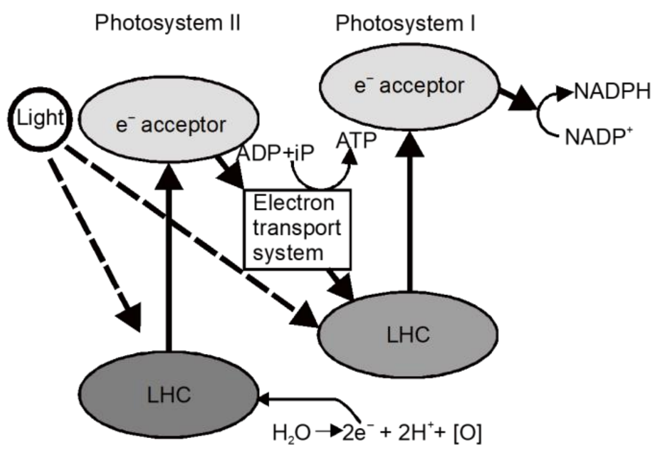


Fig. Z scheme (Non-cyclic photophosphorylation) of light reaction

- **Photolysis of water:** The phenomenon of breaking up of water into hydrogen and oxygen in the illuminated chloroplasts is called photolysis. In this process oxygen evolving complex, electron carrier Y_Z, Mn^{2+}, Cl^-,Ca^{++} ions are helpful. $2H_2O \rightarrow O_2 + 4H^+ + 4e^-$

$$4H_2O \rightleftharpoons 4H^+ + 4OH^-$$

$$4OH^- \xrightarrow[Mn^{++},\ Ca^{++},\ Cl^-]{\text{Oxygen evolving-complex}} 2H_2O + O_2\uparrow + 4e^-$$

- The electrons released during photolysis of water are picked up by P_{680} photocentre of photosystem-II with the help of electron carrier Y_Z.

- **This whole scheme of transfer of electrons, starting from the PS II, uphill to the acceptor, down the electron transport chain to PS-I, excitation of electrons, transfer to another acceptor, and finally downhill to $NADP^+$ reducing it to $NADPH + H^+$ is called the Z scheme, due to its characteristic shape. This shape is formed when all the carriers are placed in a sequence on a redox potential scale.**

Photophosphorylation: (Light driven ATP synthesis)

Cyclic and Non-cyclic Photo-phosphorylation

- **The process through which ATP is synthesised by cells (in mitochondria and chloroplasts) is named phosphorylation. Photophosphorylation is the synthesis of ATP from ADP and inorganic phosphate in the presence of light.**
- It was discovered by **Arnon et al (1954)**.

(A) Non-cyclic Photo-phosphorylation

1. **When the two photosystems work in a series, first PS II and then the PS I, a process called non-cyclic photo-phosphorylation occurs.**
2. **The two photosystems are connected through an electron transport chain, as seen earlier – in the Z scheme.**
3. **Both ATP and $NADPH + H^+$ are synthesised by this kind of electron flow.**

(B) Cyclic Photo-phosphorylation

1. **When only PS I is functional, the electron is circulated within the photosystem and the phosphorylation occurs due to cyclic flow of electrons.**
2. **A possible location where this could be happening is in the stroma lamellae. While the membrane or lamellae of the grana have both PS I and PS II the stroma lamellae membranes lack PS II as well as NADP reductase enzyme. The excited electron does not pass on to $NADP^+$ but is cycled back to the PS I complex through the electron transport chain.**

3. **The cyclic flow hence, results only in the synthesis of ATP, but not of NADPH + H^+. Cyclic photophosphorylation also occurs when only light of wavelengths beyond 680 nm are available for excitation.**

- It can be explained through chemiosmotic theory.

CHEMIOSMOTIC HYPOTHESIS

- This hypothesis has been put forward by Peter Mitchell to explain the mechanism of ATP synthesis in respiration (oxidative phosphorylation) and in photoswthesis (Photophosphorylation).
- This hypothesis (ATP synthesis) based I linked to development of a proton gradient across a membrane.

Photophosphorylation		Oxidative phosphorylation	
(1)	Membranes through which proton graident develop. are the membranes of thylakoid	(1)	Membrane through which proton gradient develop. is the inner membrane of mitochondria
(2)	Protons accumulate towards the inner side of the embrane. i.e., in the lumen.	(2)	Protons accumulate towards the outerside of the membrane i.e. in the iiltermembrane space.
(3)	Light energy is utilised for the production of proton gradient required for phosphorylation	(3)	Energy of oxidation reduction utilised for the same process.

Mechanism for development of proton gradient :

Steps that cause a proton gradient to develop :

(a) Since splitting of the water molecule takes place on the inner side of the thylakoid membrane. The protons or hydrogen ions that are produced by the splitting of water accumulate within the lumen of the thylakoids.

(b) As electrons move through the photosystems, protons are transported across the meml:irane. This happens because the primary acceptor of electron (Phaeophytin) which is located towards the outer side of the membrane transfers its electron not to an electron carrier but to an H carrier (Plastoquinone), Hence. this molecule (plastoquinone) removes a proton &om the stroma where transporting an electron. When this molecule passes on its electron to the -electron carrier (Cytochrome f) on the inner side of the membrane,· the proton is released into the inner side or the lumen side of the membrane.

(c) The NADP reductase enzyme is located on the stroma side of the membrane. Alongwith electrons that come from the acceptor of electrons of PS-I, protons are necessary for the reduction of $NADP^+$ to NADPH+ H^+. These protons are also removed from the stroma. Hence, within the chloroplast proton in the stroma decrease in number, while in the lumen there is accumulation of protons. This create a proton gradient across the thylakoid membrane as well as a measurable decrease in pH in the lwnen.

Significance of proton gradient :

This gradient is important because it is the breakdown of this gradient that leads to synthesis of ATP. The gradient is broken down due to the movement of protons across the membrane to the stroma through the transmembrane channel of the CF_0 of the ATP synthase.

ATP synthase enzyme Macbinary :

The ATP SYnthase enzyme consists of two parts :

(a) CF_0 : It is embedded in the membrane and forms a transmembrane channel that carries out facilitated diffusion of protons across the membrane.

(b) CF_1 : It is protrude on the outer surface of the thylakoid membrane on the side that faces the stroma.

Requirements of chemiosmosis :

(i) A membrane (ii) A proton pump (iii) A proton gradient (iv) ATP synthase enzyme

Mechanism of ATP synthase action :

- The breakdown of the proton gradient provides enough energy to cause a confonnational change in the CF_1 particle of the ATP synthase, which makes the enzymes synthesize several molecules of energy packed ATP.
- Radiation or light energy is used to pump protons across a membrane, to create a gradient or high concentration of protons within the thylakoid lumen.

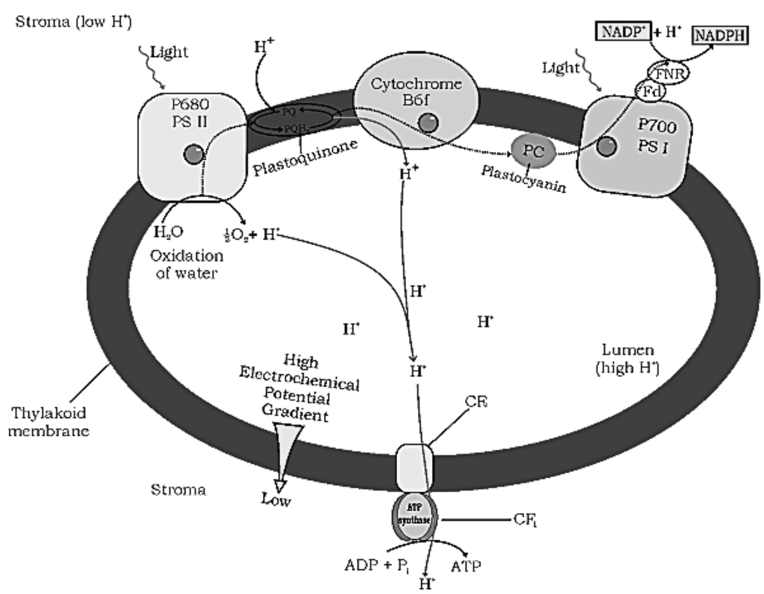


Fig. ATP synthesis through chemiosmosis (in noncyclic process)

Differences between Non cyclic and cyclic photophosphorylation

S. No.	Non cyclic	Cyclic
1	PS-I and PS-II both are active	Only PS-I active
2	Photolysis of water takes place	Photolysis of water does not take place
3	Water is consumed	Water is not consumed
4	O_2 liberates	O_2 does not liberate
5	Source of electron is water	Source of electron is P-700
6	It is affected by DCMU (Dichlorophenyl Dimethyl Urea)	It is not affected by DCMU. Affected by paraquat (methyl viologen)
7	It is found in green plants	It is found in bacteria & green plants
8	$NADPH+H^+$ is also formed with ATP	Only ATP is formed.