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NEET- 2020- 45 Days Crash Course

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Chapter Name : Photosynthesis in PLANTS

Lecture Outline :

Historical background
Raw materials
Absorption and action Spectrum
Photophorylation , C3 cycle
c4

History of Photosynthesis – (1648-1779)

Van Helmont (1648)

food come from water

- ❑ By weighing the Willow plant, concluded that plant take food mostly from soil water.

Stephen Hales (1727)

- ❑ Recognised the importance of air (CO2) photosynthesis (nourishment) in plants. He is considered and "Father of plant physiology". *

J. Priestley (1772)

Plant restore whatever the animal or burning candle removes

- ❑ He carried out very interesting experiment on Bell jar& Candle. He came to conclude that plants purify air (burning of candles) exchange occurs during photosynthesis. (Phlogiston r Bad air from candles)

Jan Ingenhousz (1779)

- ❑ He explained the importance of light and green colour and also suggested the O_2 releases in the presence of light by green parts.

O_2 is released c̄ photosyn

History of Photosynthesis – (1818-1932)

Pallatier & Caventou (1818)

- They named green pigment as 'Chlorophyll' and isolated the chlorphyll with the help of alcohol.

Englemann (1888)

algae

- Described action spectrum of photosynthesis Spirogyra/Cladophora and aerobic bacteria experiment.

V I B G Y O R

F. F. Blackman (1905)

PS is a biphasic rxn

- Dark reaction associated with light reaction in photosynthesis and law of limiting factors.

Emerson and Arnold (1932)

- Concept of two pigment system (photosystem) in light reaction. Red drop & Emerson enhancement effect.

History of Photosynthesis – (1932-1941)

Van Niel

$H_2O \rightarrow O_2$
$CO_2 \rightarrow C_6H_{12}O_6$

- O_2 releases from water and O_2 of glucose comes from CO_2.

$$6CO_2 + 12H_2S \xrightarrow{\text{Bacteria}} C_6H_{12}O_6 + 12S + 6H_2O$$

Oxygen comes from water in photosynthesis.

→ Green & Purple S bact
→ PS is light dependent

Robert Hill & Bendal (1937)

- Detailed study of light reaction in isolated chloroplast of stellaria.

→ Plant use light energy to generate reducing power

Ruben, Hassid & Kamen (1941)

- Used O_{18} to experimentally show that O_2 in photosynthesis released from water.

$$6CO_2^{16} + 12H_2O^{18} \xrightarrow[\text{Chlorophyll}]{\text{Light}} C_6H_{12}O_6^{16} + 6H_2O + 6O_2^{18}$$

Used O^{18}

History of Photosynthesis – (After 1942)

Arnon

- ATP formation in presence of light (photophosphorylation) and cyclic and non–cyclic electron transport system.

M. Calvin and Benson (1954)

→ C_3 cycle

- Biochemical cyclic pathway of dark reaction and recognised PGA is Ist stable product in dark reaction. (It is formed from unstable 6C Keto Acid)

Hatch & Slack (1967)

- C_4 pathway dicarboxylic acid cycle (DCA cycle) in sugarcane and maize. Ist stable product is oxaloacetic acid (OAA 4C).

Park & Biggins

- Photosynthetic units as Quantasome in chloroplast.

Introduction

energy required

living

- "Photosynthesis is a photo–biochemical process **(anabolic & endergonic)** in which organic compounds (carbohydrates) are synthesised from the inorganic **raw material (H_2O & CO_2)** in presence of light & pigments. O_2 is evolved as a by product".

- Light energy is conserved into chemical energy by photosynthesis.

$$6CO_2 + 12H_2O \xrightarrow[\text{light}]{\text{Pigment}} C_6H_{12}O_6 + 6O_2\uparrow + 6H_2O$$

- 90% of total photosynthesis is carried out by aquatic plants (85% algae) & 10% by land plants

- First true & oxygenic photosynthesis started in cyanobacteria. (BGA)

- Action spectrum of photosynthesis is red & blue light. (most effective in reaction)

- Rate of photosynthesis is higher in red wavelength of light, but highest in white light (Full spectrum), than monochromatic light.

Important Contributions And Terms

- ❖ Blackman discovered dark reaction (By study of Q_{10} value or temperature coefficient).

- ❖ Calvin and Benson gave cyclic pathway for this, thus dark reaction is called as Calvin cycle OR C_3–cycle.

- ❖ Q_{10} (Temperature coefficient) for light reaction is one, while Q10 for dark reaction is between 2-3. (By Vont Hoff).

- ❖ Q_{10} means the doubling of rate of reaction, which involves chemicals, on 10°C rise in temperature in it's optimum range.

- ❖ The product of photosynthesis has been found greater in intermittent light than in continuous light because light reactions are faster than the dark reaction.

Summary of Photosynthesis

Photosynthesis

Light reaction/Hill reaction.

ATP
$NADPH_2$

Experiment on isolated chloroplast (Stelaria plant) study of light reaction,

O_2 gas liberated from photolysis of H_2O, only in the presence of suitable e– acceptor

Activⁿ of chl
Photolysis of
$H_2O \rightarrow H^+ + OH^-$
Pro. of $NADPH_2$
$NADP \rightarrow NADPH_2$
Evolution of O_2
Photophosphorylation
(ATP formⁿ)

Dark reaction/Blackman reaction.

Dark reaction is rate limiting step of photosynthesis

$\boxed{CO_2 \rightarrow C_6H_{12}O_6}$

(DCPIP (Dichlorophenol Indophenol- a dye), ferricyanide, NADP⁺ → Hill reagents

** NCERT

$$\frac{1}{2}O_2 \leftarrow \boxed{H_2O} \xrightarrow{\text{Light}} 2H^+ + 2e^- \quad + \text{NADP} \longrightarrow \text{NADPH}_2$$

Existence of Photosystems

Emerson & Arnold → worked on Chlorella and gave the concept of two photosystem or two pigment systems.

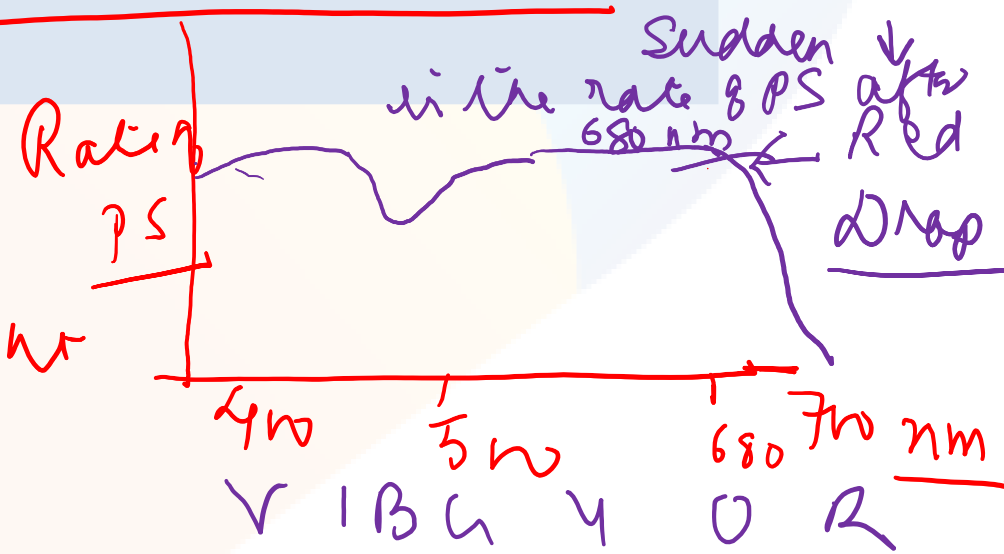
- When they gave only monochromatic light, longer than 680 nm wavelength, then quantum yield is suddenly dropped down, this event is called as red drop.

PS at 700 nm → 10 -
PS at 653 nm → 53 ,

700 + 653 — 72 *
Combination

- When Emerson gave light, shorter and greater than 680 nm (combined light) then photosynthetic, activity increases, this is called as Emerson effect or enhancement effect. *

Quantum Yield
amount of O_2 released per quantum of light absorbed



Quantum And Quantum Yield

Quantum requirement

❖ The number of light Quanta or photons required for the evolution of 1 mol. of O_2 in photosynthesis = 8

Quantum Yield

❖ The number of oxygen molecule evolved by one quantum of light in photosynthesis is called as Quantum yield

Arnon's experiment (Chlorella)

❖ Discovered cyclic and non–cyclic photophosphorylation

$$(ADP + iP \xrightarrow[\text{Chl.}]{\text{light}} ATP.$$

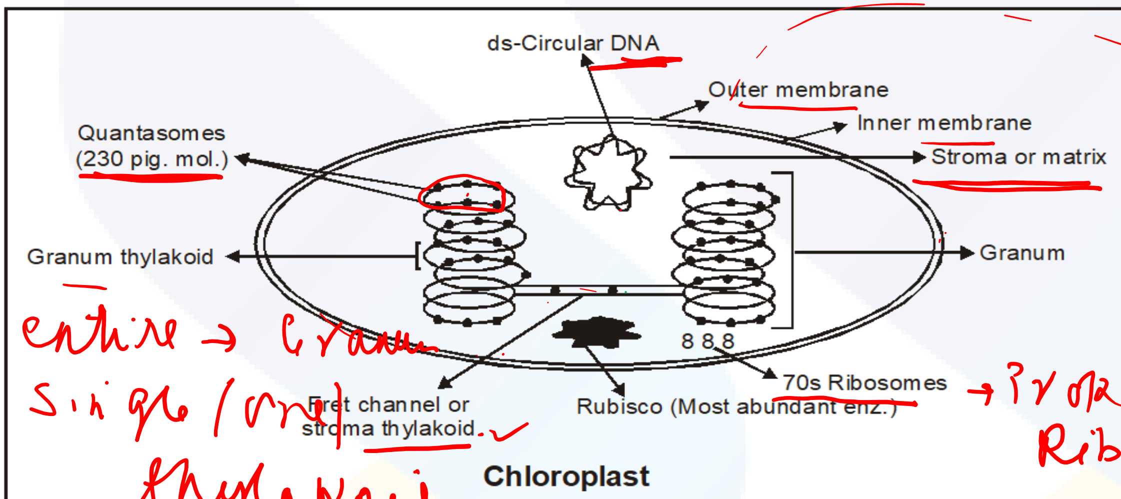
❖ E.T.S. in photosynthesis was proposed by Arnon.

Chloroplast And Pigments

Chloroplast and Pigments

Site of PS

mesophyll of leaves
↓
Chloroplast



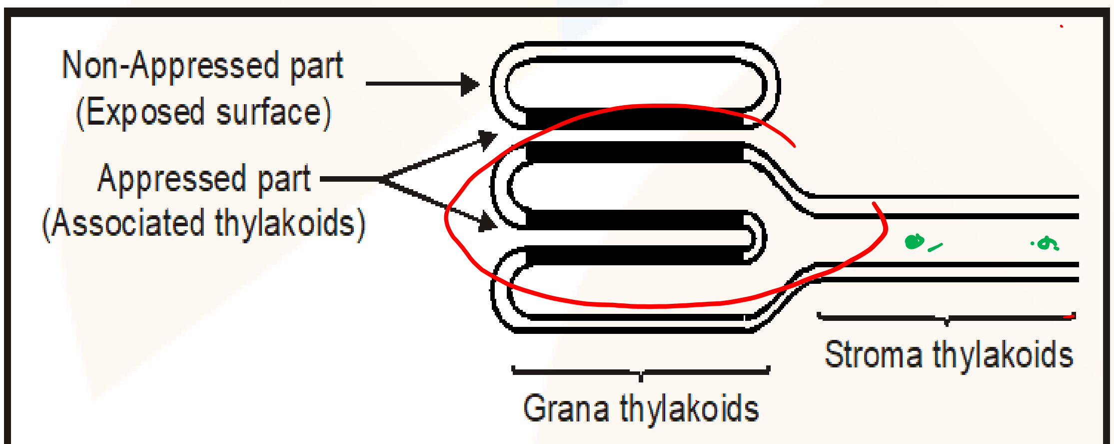
Chloroplast

entire → Granum

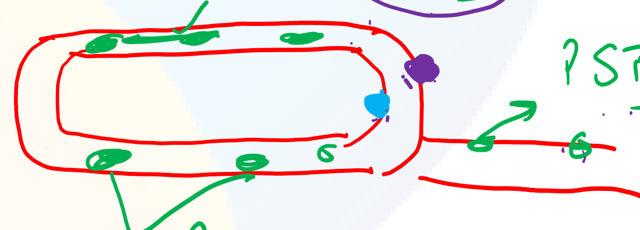
single (one) thylakoid

→ prokaryotic Ribosome

Photosynthetic pigments



PS I, PS II



PS I
Both PP
Not associated with stroma

PS II
Only Non cyclic complex

Composition of Chlorophyll

❖ Many pigment present in photosynthetic cells. **PSU** (Photosynthetic units) presents on thylakoid membranes, are made up of 230-400 molecules of various pigments, called **Quantasomes** by **Park** & **Biggins**.

** NEET

PS I — In non appressed region of grana and stroma thylakoids. on both granum & intergranum. (P-700, 680 nm¯, Cyclic ETS).

PS II — located in the appressed region of granal thylakoids. on only granum. (P-680, 680 nm¯, non cyclic ETS).

P.P

(1) Chl - a, b, c, d, e, bacterio chl & bacterio viridi

Chlorophyll – a — $C_{55}H_{72}O_5N_4Mg$ → CH_3 grp. at III^{rd} C of II^{nd} pyrrole ring

Appears bright or blue-green. In paper chromatography

CHO

(2) Carotenoid

Chlorophyll – b — $C_{55}H_{70}O_6N_4Mg$ → CHO group at III^{rd} C of II^{nd} pyrrole.

(3) Phycobilins

Appears yellow green/grass green. In paper chromatography

Chlorophyll a and b comparison

Chl a	Chl b
→ at position R CH_3 group	at position R CHO group
→ Bluish green	Olive green
→ Red - in reflected light	Brownish red in reflected light
→ Green - Transmitted light	Yellowish green
$C_{55}H_{72}O_5N_4Mg$	$C_{55}H_{70}O_6N_4Mg$

Structure of Chlorophyll

- Chlorophylls are magnesium porphyrin compounds. Porphyrin ring consists of four–pyrrole rings (Tetrapyrrole).

- Chlorophyll molecule has a Mg–porphyrin head and alcoholic phytol tail. Head is hydrophilic and phytol tail is lipophilic (hydrophobic). → ** NEET

- Phytol tail is alcoholic with one double bond. Phytol part embeded in lipid layer

- Chl–a and carotenes are universal pigment, which are found in all O_2 liberating cells

- Chlorophylls are soluble only in organic solvents like ketons, ethers etc.

$C_{55}H_{72}O_5N_4Mg$ → chl a [CH_3]

$C_{55}H_{70}O_6N_4Mg$ → chl b [CHO]

Chlorophyll Synthesis

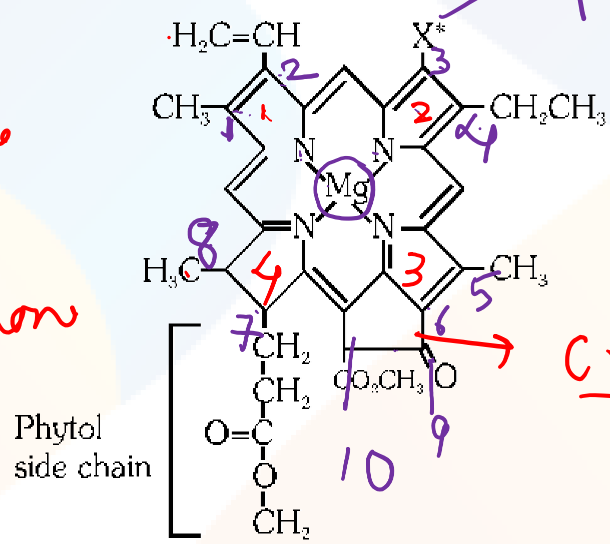
Succinyl CoA + Glycine → Protochlorophyll (Protochlorophyllide) $\xrightarrow[2H]{\text{Light}}$ Chlorophyll.

- Light for chlorophyll synthesis is required only in angiosperms, (exception Nelumbium and Citrus)

CH3 / CHO
ch a   ch b

Head

→ I - IV → Pyrrole ring
+
→ Cyclopentanone ring



→ Head – Porphyrin Head
→ Tail – Phytol Side Chain

C.R

CHLOROPHYLL STRUCTURE x* –CH$_3$ in Chlorophyll A, –CHO in Chlorophyll 'b'

4 ring – 7th carbon
↓
Phytol Tail

KINDS OF PIGMENTS - I

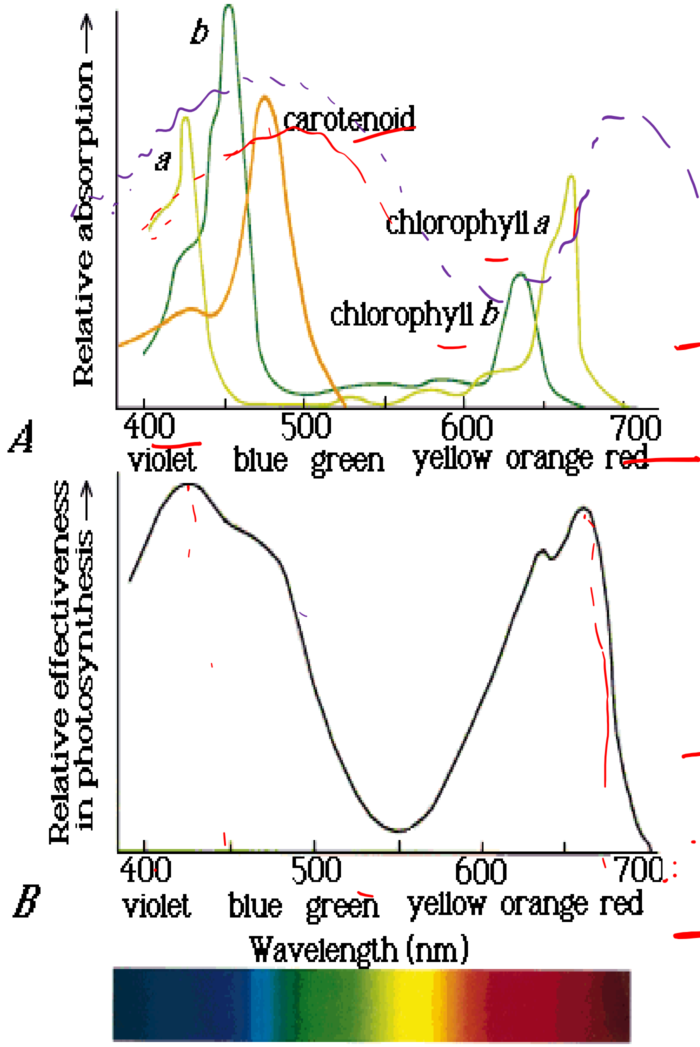
Pigments	Formula	Distribution	Absorption (mm)
Chlorophylls →			
Chl. – a	$C_{55}H_{72}O_5N_4Mg$	All green plants.	435, 670, 680 (Several forms)
Chl. – b	$C_{55}H_{70}O_6N_4Mg$	All green plants (except BGA Red, brown and diatoms algae)	453, 480, 650
Chl. – c	$C_{35}H_{32}O_5N_4Mg$	Brown algae and diatoms	645
Chl. – d	$C_{54}H_{70}O_6N_4Mg$	Red Algae (Rhodophyceae)	740
Chl. – e		Xanthophyta (Tribonema & Vaucheria Zoospores)	
Bacterio Chl. – a	$C_{55}H_{74}O_6N_4Mg$	Purple & green bacteria	800, 850, 890
Bacterio Chl. – b	$C_{55}H_{74}O_6N_4Mg$	Purple bacteria (Rhodopseudomonas)	1017

Kinds Of Pigments - II

Pigments	Formula	Distribution	Absorption (mm)
Bacterioviridin		Green bacteria (Chlorobium)	750, 760
(Chlorobium chlorophyll)			
Carotenoids →			
Carotenes →			
α–carotene	$C_{40}H_{56}$	Red, green algae & All green plants	450, 470
β–carotene	$C_{40}H_{56}$	In all green plants	450, 480
γ –carotene		Green bacteria	
Xanthophylls/ Carotenols→			
Luteole	$C_{40}H_{56}O_2$	Red, green algae, all plants	425, 475
Violaxanthin	$C_{40}H_{56}O_2$	Green leaves	425, 450, 475
Fucoxanthin	$C_{40}H_{56}O_3$	In Brown algae	
Phycobilins			
Phycocyanin		BGA (mainly), red algae	618
Phycoerythrin		Red algae (mainly), BGA	490, 576
Allophycocyanin			

* 3 NET

Absorption and Action Spectrum



Chl a → blue, Red

Chl b → blue green, Red

Carotenoids → Green yellow

phycobilins Red

↳ blue green

→ By Engleman

V I B G Y O R

more O_2 → rate of PSn

By Spectrophotometer

Light Reaction

(A) Light reaction/Hill reaction/Photochemical reaction/Generation of assimilatory powers ($NADPH_2$ + ATPs)/Photophase.

Blackman

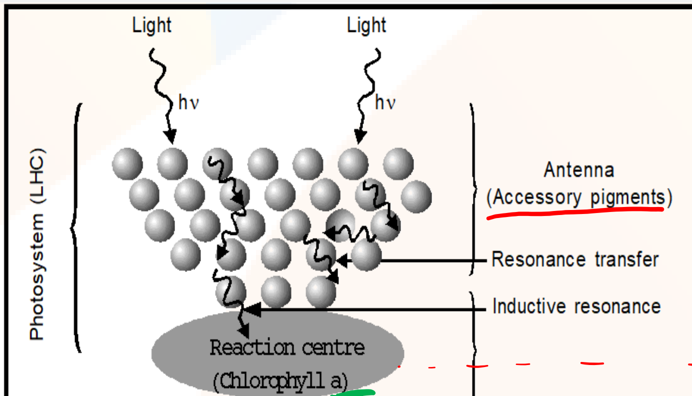
L.R

ATP

NADPH2

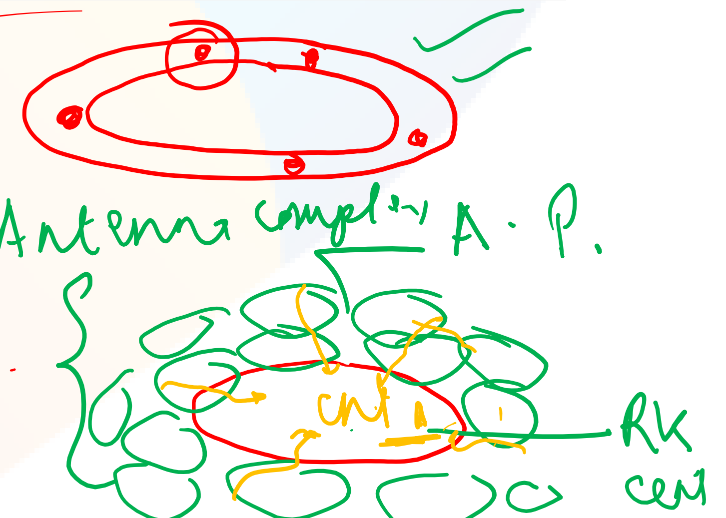
D.R

- Antenna or accessory pigments receive radient energy and transfer it among themselves.
- This transfer of energy is known as resonance transfer. Then antenna molecules excited and transfer their energy to the chlorophyll 'a' molecules of reaction centre.
- It is known as inductive resonance. finally chl. 'a' of leaf center molecules converts the light energy into electrical energy by bringing about electric charge separation.



Conversion of light into electrical energy. Accessory pigment molecules absorb light and **funnel** it to the reaction centre for conversion to electrical energy and charge separation.

Antenna complex A.P.



CYCLIC ETS And PHOTOPHOSPHORYLATION

In cyclic ETS, only PS–I (LHC–I) works, which consists of Chl–'a' 670, Chl–a–683, Chl–'a'–695, carotenoids, some molecules of chl–'b' & reaction centre–Chl–'a'–700/P–700.

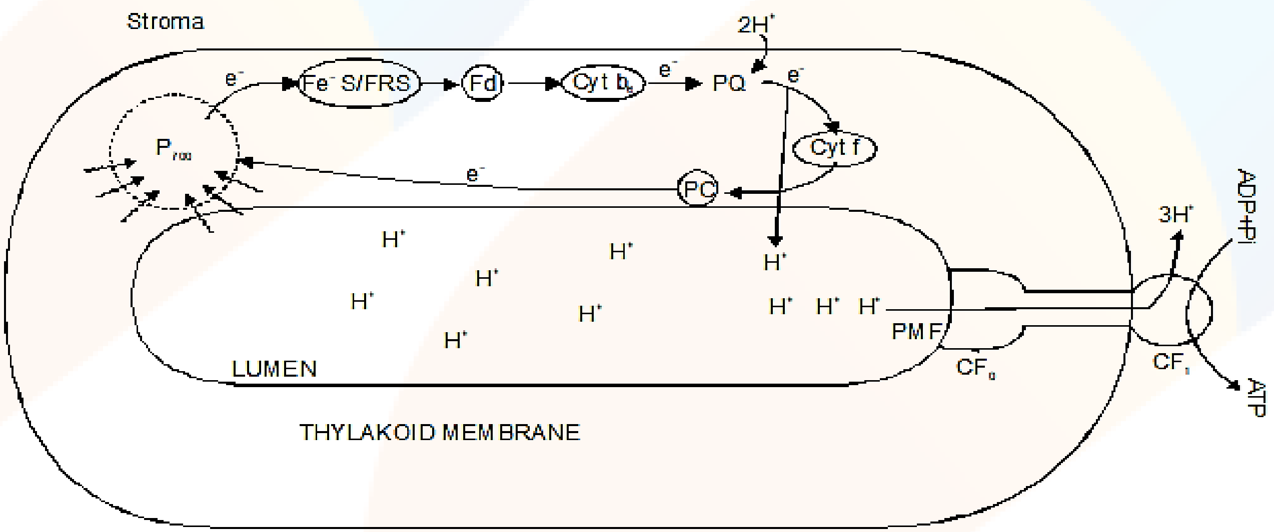
Cyclic ETS OR PS–I is activated by wavelength of light greater than 680 nm.

During Cyclic ETS the electron ejected from reaction centre of PS-I, returns back to its reaction centre.

no oxygen evolution occurs, because photolysis of water is absent

$NADPH_2$ (reducing power) is not formed in cyclic process.

Plastocyanin (PC) is Cu–containing blue coloured protein in cyclic ETS



CYCLIC - PHOTOPHOSPHORYLATION

Z-Scheme/Non-cyclic ETS and Photophosphorylation

Both PS–I and PS–II involved in non cyclic ETS. PS–II (P–680) consists of Chl–a–660, Chl–a–673, Chl–a–680, Chl–a–690, Chl–b, or Chl–c or Chl–d, carotenoids & phycobilins. Phycobilins present only in PS II

The e– ejected from PS–II never back to chl–a–680 (reaction centre) & finally gained by NADP. thus gap of e– in PS–II is filled by photolysis of water as a result, oxygen evolution occurs in Z–scheme.

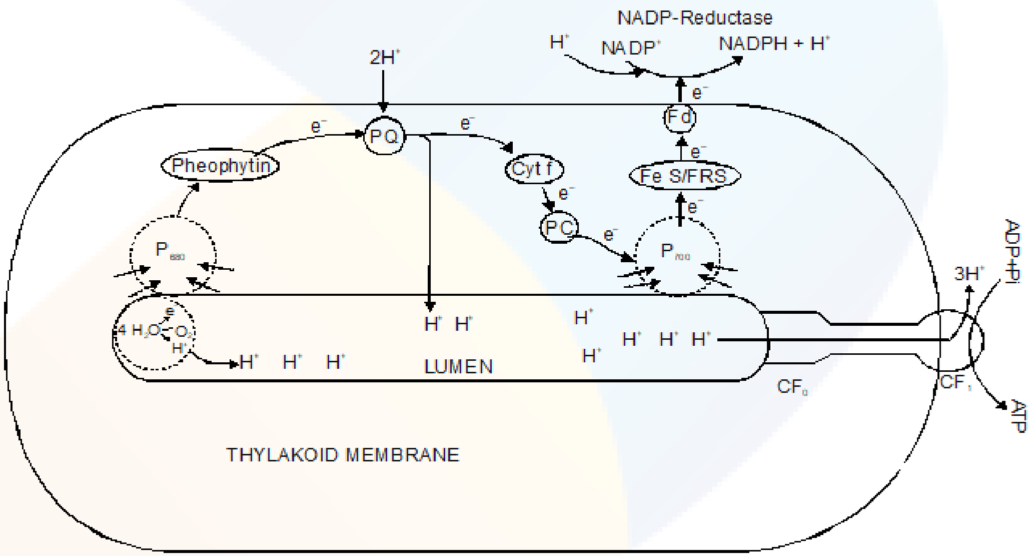
noncyclic ETS produces approx 3 ATP and 2$NADPH_2$

12 $NADPH_2$ + 18 ATP are required as assimilatory power to produce one molecule of Glucose in dark reaction

Plastocyanin (PC) is link between PS–I and PS–II in non cyclic ETS. (Some scientists–cyto-f)

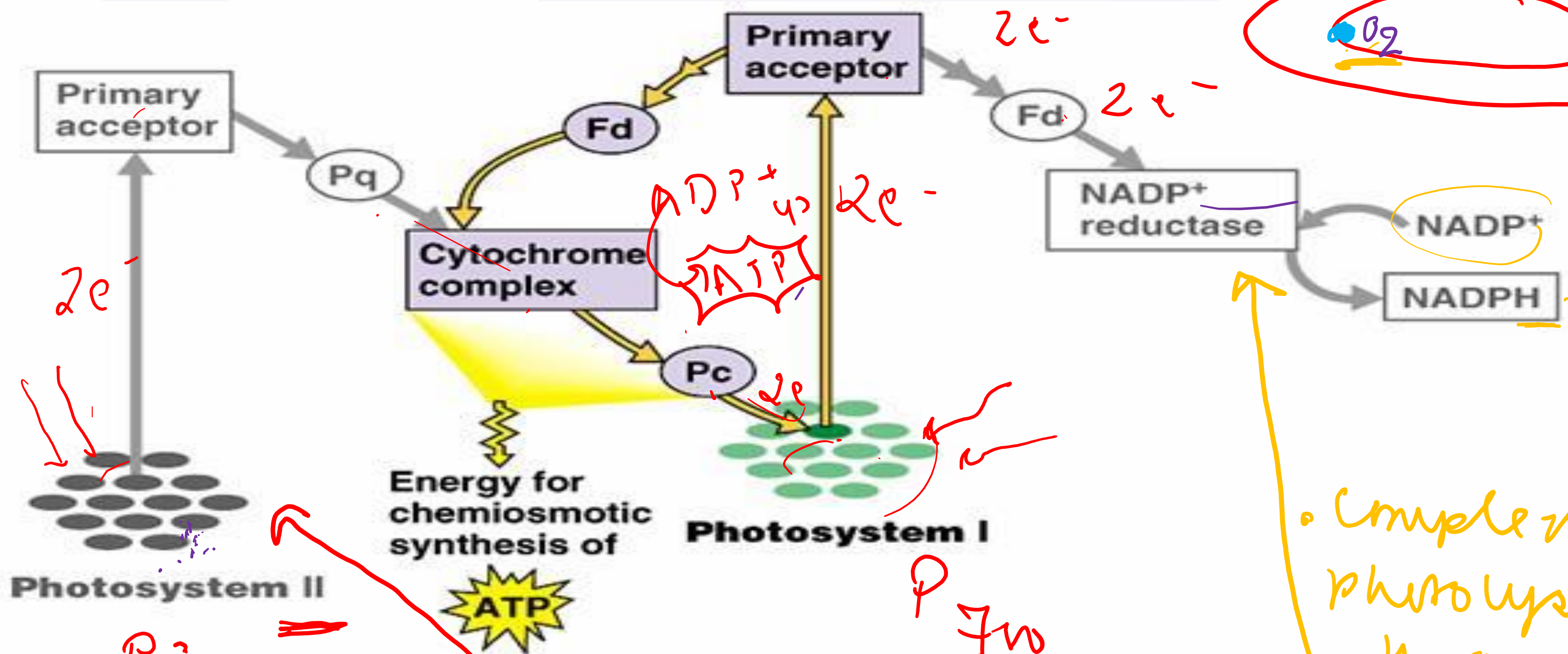
Final e- acceptor in Z–scheme is NADP+ (Hill reagent)

During Non-Cyclic ETS energy flow takes place from PS II to PS I



NON-CYCLIC - PHOTOPHOSPHORYLATION

Non cyclic Photophosphorylation



NADP red

O_2

$2e^-$

ADP + Pi → ATP

Stroma

P 680

P 700

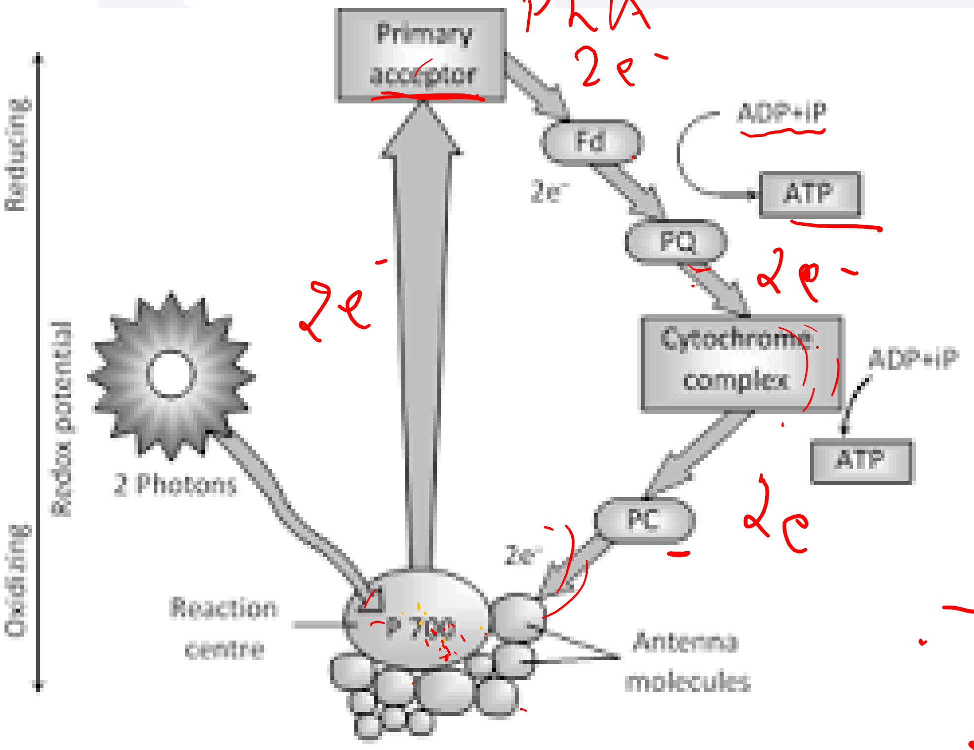
$H_2O \rightarrow 2e^- + \boxed{2H^+} + [O]$

photolysis

O_2 evolved

- Complete for photolysis of H_2O → Inner thylak mem
- NADP red Outer mem of thylakoid

Cyclic Photophosphorylation



Cyclic photophosphorylation

Prod^n of ATP in the presence of light

CPP

Non cy PP

Chl a

700 nm → PS I

680 nm → PS II

→ Only PS I

→ No O_2 splitting of H_2O

→ No O_2 released

→ No NADPH$_2$ Anaerobic

→ Only ATP

→ Low light, low conc CO_2

Cyclic photophosphorylation	Non –cyclic photophosphorylation
Only PS I is involved	PS I and PS II are involved
No photolysis of water takes place	Photolysis of water takes place
Oxygen not evolved	Oxygen evolved
NADPH+H$^+$ is not synthesized	NADPH+H$^+$ is synthesized
Electron is cycled back to reaction centre	Electron does not return to reaction centre

PS I – 700nm

PS II 680nm ** imp

Location

On the membrane of thylakoid + stromal lamellae

On the membrane of thylakoid

CHEMIOSMOTIC THEORY- I

Chemiosmotic theory

- ❖ Proposed by Peter Mitchell
- ❖ During ETC of photosynthesis concentration of H^+ gradually increases in thylakoid lumen.
- ❖ During cyclic photphosphrylation PQ leads to shifting of H^+ from stroma to thylakoid lumen.
- ❖ On the other hand during non cyclic photophoshorylation there are three causes of difference in H^+ ion concentration.
- ❖ This differential H^+ ion concentration leads to development of proton gradient and electrical potential across thylakoid memberane.
- ❖ PMF do not allow stay of H^+ ions in lumen so H^+ start to move towards stroma through CF_0 particle selectively.
- ❖ The passage of $3H^+$ ions leads to activation of ATP synthase and it forms ATP from ADP and Pi.
- ❖ Some physiologist believe that synthesis of one ATP is required passage of $2H^+$ ions.

DARK REACTION and Warburg effect

(B) Dark Reaction/Blackman Reaction/Calvin cycle/C_3–Cycle/Biochemical phase/ Carbon assimilation/photosynthetic carbon reduction cycle (PCR-Cycle)/Reductive pentose phosphates pathway

- ❖ Blackman reaction is called as dark reaction, because no direct light is required for this.
- ❖ I[st] stable compound of Calvin cycle is 3C-PGA (Phosphoglyceric acid) thus Calvin cycle is called as C_3–cycle. (First compound is unstable, 6C keto acid)
- ❖ Rubisco (Ribulose bis-phosphate carboxylase-oxygenase)
- ❖ Is main enzyme in C_3–cycle, which is present in stroma & it makes 16% protein of chloroplast. Rubisco is most abundant enzyme.
- ❖ CO_2–acceptor in Calvin cycle is RuBp. This carboxylation reaction is catalysed by rubisco.
- ❖ C_3, C_4, C_5, C_6 and C_7 monosaccharides are intermediates of calvin Cycle

Warburg effect

- ❖ Inhibitory effect of high conc. of O_2 on photosynthesis is called as Warburg effect (It is due to Photorespiration).
- ❖ 6 turns of Calvin cycle are required for the formation of one glucose.

STEPS OF CALVIN CYCLE – I

Carboxylation →

$$6,\ RuBp\ (RuDp) + 6,CO_2\ (HCO_3^{'}) \xrightarrow[\text{(Carboxydismutase)}]{\text{Rubisco}} 6C\ \text{unstable comp.} \longrightarrow 12,3.PGA\ (3C)$$

Glycolytic reversal →

$$12\ \text{Mol.}\ \underbrace{\boxed{3-PGA}}_{(3\ C)} + 12ATP \xrightarrow{\text{Triokinase}} 12,\ 1,3.BiPGA$$

$$12,\ 1,3.BiPGA \xrightarrow[12NADPH_2 \rightarrow 12NADP^+]{\text{Dehydrogenase}} 12,\ 3.PGAL\ (\text{Triose phosphate}) + 12H_3PO_4$$

5 Molecules of PGAL isomerise in to DHAP (Dihydroxy acetone phosphate).

$$\underset{9C\ (3C \times 3)}{3,\ PGAL} + \underset{(9C)\ (3C \times 3)}{3\ \text{mol.}\ DHAP} \xrightarrow{\text{Aldolase}} \underset{(18C)\ (6C \times 3)}{3,\ \text{Fructose-1,6-Biphosphate}}$$

$$[1\ \text{mol. fructose} \xrightarrow{\text{Isomerase}} \boxed{C_6H_{12}O_6}\ \text{Glucose} \longrightarrow \text{Sucrose/Starch}]$$

STEPS OF CALVIN CYCLE – II

Regeneration of ribulose 1,5 biphosphate

2, fructose.P + 2, PGAL $\xrightarrow{\text{Transketolase}}$ 2 Mol, Erythrose.P + 2 Mol. Xylulose.P

(12C) (6C) (8C) (10C)

2, Erythrose.P + 2, DHAP $\xrightarrow{\text{Aldolase}}$ 2, Sedoheptulose–1,7–BiP

(8C) (6C) (14C)

2, Sedoheptulose–P + 2 PGAL $\xrightarrow{\text{Trans Ketolase}}$ 2, Xylulose–P + 2, Ribose–P

(14C) (6C) (10C) (10C)

2 + 2, Xylulose–P $\xrightarrow{\text{Epimerase}}$ 4, Ribulose–5P

(20C)

2 , Ribose–5P $\xrightarrow{\text{Isomers}}$ 2 Ribulose–5P

(10C)

6, Ribulose–5P + 6ATP $\xrightarrow{\text{Kinase}}$ 6, Ribulose-1, 5-BiP (CO2 acceptor) + 6 ADP

STEPS OF CALVIN CYCLE – III