Part - 1 . System Physiology

Photosynthesis :-

(1) LHC (2) Mechanism of Electron transport.
(3) Photoprotective mechanism (iv) CO_2 fixation.

$$6CO_2 + 6H_2O \underset{\text{chlorophyll}}{\overset{\text{solar energy}}{\rightleftharpoons}} C_6H_{12}O_6 + 6O_2.$$

Where the PS takes place?

Chloroplast has its own protein making machinery along with its genetic material.

CP has 2 main components:-

(i) Thylakoid (ii) Stroma

PS rxn divided into 2 major part:-

(i) Light rxn ↳ granum (ii) Dark rxn ↳ Stroma

Photosynthesis is a photochemical rxn that occurs by transfer of high energy electron to mean by molecule and returning to its original state by taking up a low energy e⁻ from some other ~~source~~ molecule.

This process is carried out by a photosynthetic unit of about 250-400 chlorophyll molecules in which one molecule (specifically Chlorophyll a complexed with a protein called the reaction center and core pigment) acts as the reaction center and other molecules (chlorophyll a (6) / chlorophyll b (5) / accessory pigment carotenoid or lutein (2) complexed with protein) acts as antenna complex.

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Light Harvesting Complex:-

LHC = Primary photosynthetic pigment + Accessory Pigments acts as antenna complex structure

→ Chlorophylls & Bacteriochlorophylls

Carotenoids, Xanthophylls,

Phycoerythrobillin, Phycocyanobillin

→ Red algae → Blue green algae

Photosystem:- Photochemical reaction center + Antenna complex

Photosystem II.

Reaction center has a ligand to core protein.

PS I (P700)	PS II (P680)
Chl-a associated with protein PsaA and Psa B.	Chla associated with proteins D1 and D2.
Absorb wavelength of 700 nm.	Absorb wavelength of 680 nm.
Chl a and Chl b are equal in no in antenna complex.	Chl a is higher than Chl-b.

These proteins are reqd for the proper functioning of the chlorophyll molecule

NB:- Chl a and Chl b are structurally similar but the only difference is Chl-a has a methyl group and Chl-b has a aldehyde grp

Imp.

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Stacked
Inner

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Distribution of Photosystem in Thylakoid membrane.

PSII is located predominantly in the stacked regions (appressed or grana lamellae) of the thylakoid membrane whereas PSI and ATP synthase are found in the unstacked (Non-apressed or stroma lamellae) regions protruding into the stroma. Cytochrome b6f complexes are evenly distributed.

Why there is a non-uniform distribution of Photosystems?

PSII : PSI = 1.5 : 1

The nonuniform distribution of photosystems helps in balancing the energy equilibrium between them.

↓

The energy needed for excitation of PSII is more than PSI (short wavelength requires more energy).

↓

So the physical contact between them would have lead to overexcitation of PSI and underexcitation of PSII interfering with the process. (34:45) (GA).

NCPP.

PSII → e^- → Pheophytin → Plastoquinone (Q_A) (It is a tightly bound compound to the photosystem I whereas Plastoquinone (Q_B) is a bit lose bonded compound to PSII.

↓

Plastoquinone undergoes oxdn redn cycle and transfers e^- to cytochrome b_6/f complex

↓

All of these are multiunit enzymes.

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Cytochrome b_6/f complex transfers the e^- to ~~the~~ Plastocyanin which transfers the e^- to PSI.

↓

PSII and PSI are linked together by Cyt b_6/f complex.

↓

Another major role of cyt b_6/f complex is that it pumps protons to the lumen of the thylakoid - for ATP synthesis.

↓

PSI gets activated and transfers e^- to phylloquinone which is a modified chlorophyll a

↓

Iron sulfur protein

↓

Ferredoxin → Flavoprotein $\xrightarrow{NADP^+ + H^+}$ NADPH → Calvin cycle

Z-scheme.

Mechanism of

Pheophytin : Chlorophyll molecule with Mg replaced H atoms.

Plastoquinone :- Q_A tightly bound to PSII Q_B loosely bound.
↳ grp of biomolecule
It is photosynthetically active quinone.

Cyt b_6f complex :- Protein complex enzyme linked complex.

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Chlorophyll molecule in between has Mg ions.

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Plastocyanin:- Small water soluble and copper containing protein.

Ferrodoxin:- Small water soluble iron Sulfur compound.

FNR:- Flavoprotein Ferrodoxin NADP+ reductase. It converts NADP+ to NADPH i.e. reduced NADP.

Mechanism of e^- transport:-

Photochemical reaction or light driven e^- flow carried out by multienzyme system in thylakoid membrane.

↓

The process involves PSII & PSI both.

↓

The e^- takes a zigzag path (Z-scheme) from H_2O to the $NADP^+$.

Imp qstn.

↓

4 integral membrane proteins carry out the most important function:-

. PSII oxidizes H_2O to O_2 in the thylakoid lumen resulting a proton release into the lumen.

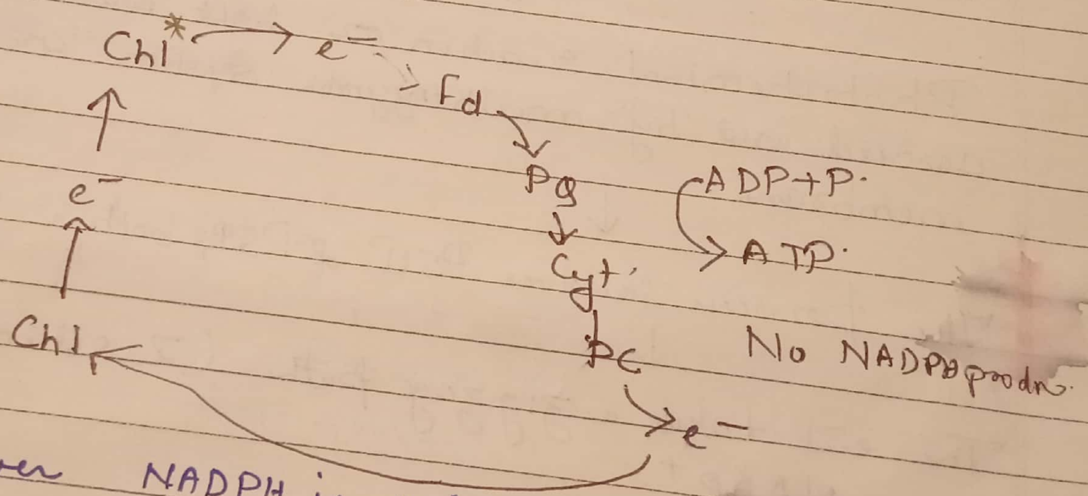
Cytochrome b6f accepts e^- from PSII and delivers them to PSI. It also transports additional protons into the lumen of thylakoid from the stroma.

3) PSI reduces $NADP^+$ to NADPH in the stroma by the action of ferredoxin (Fd) and the flavoprotein ferredoxin - NADP reductase (FNR).

4) ATP synthase produces ATP as protons diffuse back through it from the lumen into the stroma.

Cyclic PP.

occurs in thylakoid membrane



Whenever NADPH is not req. ie. NADPH is accumulated then but ATP requirement is there then plants switch their NCPP to CPP.

CPP is more efficient in terms ATP prodn. Whenever chloroplast is having low ATP, then it can switch from NCPP to CPP.

Some Noteworthy points

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If ATP concn is low then NADPH gets accumulated and the plant switch from ncpp to cyclic mode of phosphorylation as it is more efficient in terms of producing ATP.

DCMU (3-(3,4 dichlorophenyl)-1,1 dimethylurea) or diuron acts as a herbicide by interfering with the photosynthetic pathway by blocking the flow of e^- from PS II to cyt b_6.

Photo protective ~~Emissio~~ ~~of~~ mechanism.

In addition to act as accessory photosynthetic pigment carotenoids also act as photoprotector.

The excess energy absorbed by chlorophyll gets transferred to carotene molecule that prevents formation of singlet oxygen (reactive superoxide) by chlorophyll molecules.

The carotenoid is unable to create this harmful reactive oxygen species and releases the excess energy as heat.

The chlorophyll molecule is said to be quenched.

Non Photochemical Quenching.

Nitrogen fixation

(1) Biological Nitrogen Fixation.
(2) Nitrate Assimilation.
(3) Ammonium assimilation.

Biological Nitrogen Fixation.

Conversion of atmospheric N_2 to ammonia or ammonium ions.

Atm. $N_2 \longrightarrow NH_3 / NH_4^+$.

↓

Energy consuming process.

↓

Atmospheric N_2 can be fixed through:-

(i) Atmospheric N_2 fixation (lighting) (5-8%).

(ii) Industrial N_2 fixation.

(iii) Bacterial N_2 fixation.

Atmospheric fixation as a result of lightning which breaks the N_2 triple bond and allows N_2 to combine with O_2 to form nitrogen oxides that are dissolved in rain and fall to earth.

↓

Industrial fixation by the Haber process in which N_2 and H_2 gases are heated ~ 500°C under a pressure of ~ 250 atm to produce liquid ammonia which is used commercially to make fertilizer.

Bacterial N_2 Fixation:-

It is done by bacteria that reduce N_2 to NH_3 through an ATP-dependent process requiring the multisubunit enzyme complex nitrogenase.

Nitrogen Fixing Bacteria:-

(I) ~~Free living~~ (II) ~~Symbiotic bacteria.~~

Symbiotic N_2 Fixation.

Host Plant	N-fixing symbionts.
Leguminous: legumes, Parasponia.	Azorhizobium, Bradyrhizobium, Photorhizobium, Rhizobium, Sinorhizobium.
Actinorhizal: alder (tree), Ceanothus (shrub), Casuarina (tree), Datisca (shrub).	Frankia.
Gunnera.	Nostoc.
Azolla (water fern)	Anabaena.
Sugarcane	Acetobacter.

Free living N_2-Fixation.

Type	N-fixing genera.
Cyanobacteria (blue-green algae)	Anabaena, Calothrix, Nostoc.
Other bacteria	
Aerobic.	Azospirillum, Azotobacter,
Facultative	Beijerinckia, Derxia, Bacillus, Klebsiella.
Anaerobic.	
- Non photosynthetic -	Clostridium, Methanococcus
- Photosynthetic -	Chromatium, Rhodospirillum

Biological N_2-fixation req anaerobic conditions:-

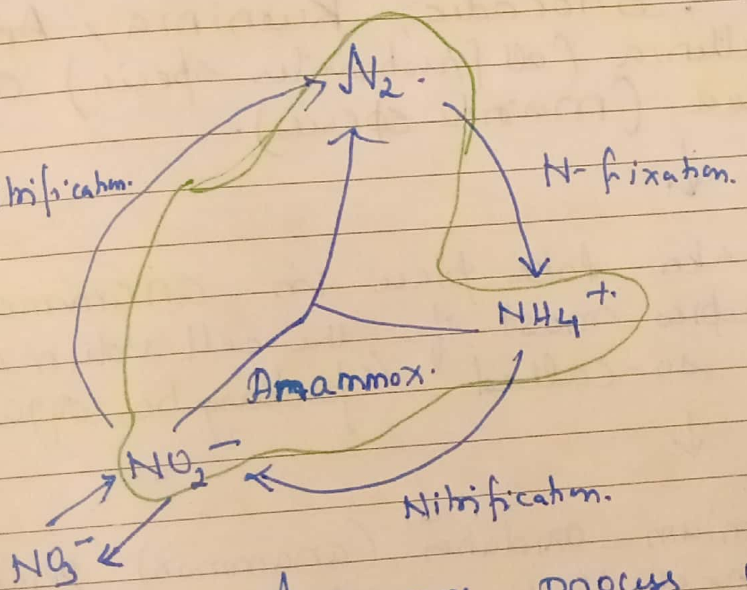
- Nitrogenase is irreversibly inactivated by O_2.
- N_2-fixing bacteria use different mechanisms to maintain anaerobic intracellular conditions.

Heterocyst :- are structures only in cyanobacteria for N_2 - fixation.
↓
Thick walled cells that differentiate when filamentous cyanobacteria are deprived of NH_4^+.
↓
• Lack PSII, so they do not generate O_2 by photosynthesis.

Anammox.

It is anaerobic ammonium oxidation.

The N- Cycle :-



The Anammox process is a biological, auto-trophic process, which is strictly anaerobic.
↓
Ammonia and nitrite are biologically converted into N_2 gas.

It has even been estimated that about 50% of the annual fixed nitrogen loss on the earth could be attributed to Anammox activity.

↓

Anamox bacteria are distributed in various natural habitats, including anoxic marine sediments, freshwater sediments, terrestrial ecosystems and some special ecosystems such as petroleum reservoirs.

↓

Currently 5 anammox genera have been discovered: Brocadia, Kuenenia, Anammoxoglobus, Jettenia (all fresh water species) and Scalindua (marine species).

↓

Anammox rxn takes place in anammoxosome which occupies most of the cell volume and is a so-called "prokaryotic organelle".

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[An]aerobic ammonium oxidation (anammox) process [is] a very cost effective and sustainable way [of] removing ammonium from effluents.

↓

Anammox with bacteria is thought to a cost effective alternative that could be performed "on-site" but its effectiveness and ~~its~~ interaction with other microbes was unclear.

↓

The anammox process can be used for the removal of ammonium from nitrogen rich effluents.

→ These effluents are found in :-

- Municipal waste water treatment.
- Organic solid waste treatment.
- Food industries.
- Manure processing industry.
- Fertiliser industry.
- Petrochemical industry.
- Metallurgical industry.

Advantages :-

• Anammox to the treatment of wastewaters lead to substantial saving of energy and resources.

• Anammox would req less than 50% of oxygens compared to denitrification.

Appliacation of the Anammox process would make unnecessary the addition of extra organic e^- donors.

Disadvantages :-

Long start-up time is reqd to grow enough biomass

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The growth rate of the enrichment culture is extremely low.

• The doubling time of Anammox culture has been reported to be 30 days.

↓

The optimum pH level is 8.

↓

Therefore, it can be necessary to adjust the pH of the wastewater.

Symbiotic N_2 fixation.

The symbiosis bet^n legumes and rhizobia is not obligatory.

↓

Symbionts seek out one another through an elaborate exchange of signals only under nitrogen limited conditions.

↓

Symbiotic association involves root nodule formation that requires specific genes in both the host and the symbionts.

↓

(i) Nodulin genes (Nod):- Plant genes specific to nodule formation.

(ii) Nodulation genes (nod):- Rhizobial genes that participate in nodule formation.

Nodulation genes (nod genes).

- Common nod genes. (nod A, nod B and nod C)
- Host specific nod genes. nod P, nod Q, nod H or nod F, nod E, nod L.

↓

common nod genes are found in all rhizobial strains.

↓

	M	T	W	T	F	S	S
J	30	31					1
U	2	3	4	5	6	7	8
L	9	10	11	12	13	14	15
18	16	17	18	19	20	21	22
	23	24	25	26	27	28	29

8.00 The host specific nod genes differ among rhizobial species and determine the host range.

9.00 ↓

10.00 nodD is constitutively expressed and it regulates the transcription of other nod genes

11.00

12.00 Root Nodule Formation Process.

1.00

Plant root releases isoflavanoids and betaines that attract rhizobia.

↓

Interaction with these signals induce nodD gene expression.

↓

Nod D activates transcription of other nod genes.

↳ factor from nod D

↓

particular legume host responds to a specific Nod factor. The legume receptors for Nod factors appear to be special lectins (sugar binding proteins) produced in root hairs.

Binding induces root hair curling with cutins.

↓

Cell wall degrades at site of infection allowing bacteria to enter root hair inducing infection thread growth

↓

Bacteria move through the infection thread, infecting more plant cells.

↓

Bacteria stop dividing and form large differentiated N_2-fixing endosymbiont organelles called bacteroids.

↓

While moving through the cells, it makes use of golgi vesicles.

Leghemoglobin

Nodules contain an oxygen binding heme protein called leghemoglobin.

↓

Leghemoglobin is present in infected nodule cells at high concentration and gives the nodules a pink color.

↓

The host produces the globin portion of leghemoglobin in response to infection by the bacteria.

Notes

The bacterial symbiont produces the heme portion.

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Leghemoglobin has a high affinity for oxygen thus protecting nitrogenase from inactivation by oxygen.

Nif Genes (present in free living bacteria)

Genes encoding enzymes involved in atmospheric N_2-fixation.

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Primary enzyme encoded – Nitrogenase complex.

↓

Also encodes a no of regulatory proteins involved in N_2 fixation.

↓

Found in both free living nitrogen fixing bacteria and in symbiotic bacteria.

↓

Nif gene expression induced by low concn of fixed N_2 and O_2 concn.

nod genes (Rhizobial genes)

Fall into 4 classes:–

nod D.

nod A, B and C (common nod genes).

hsn (host specific nod genes).

Other nod genes.