CLASS – 11
BIOLOGY

Chapter – 13

Photosynthesis

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PGT- Biology

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Mechanism of photosynthesis

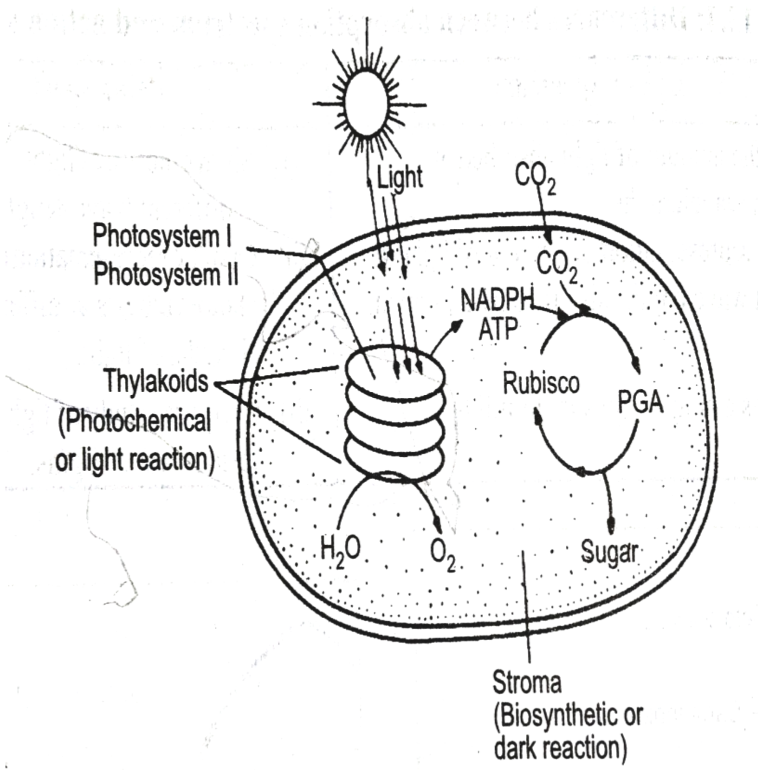
- Photosynthesis consist of two main parts:

1. **Photochemical or light reaction:**

- In this light is essential which absorb by chlorophyll molecules to split water into *hydrogen (H^+)* and *hydroxyl (OH) ions*.
- The hydrogen ions are carried to $NADPH_2$ which are used to reduce CO_2 in dark reaction.

2. **Biosynthetic phase or dark reaction:**

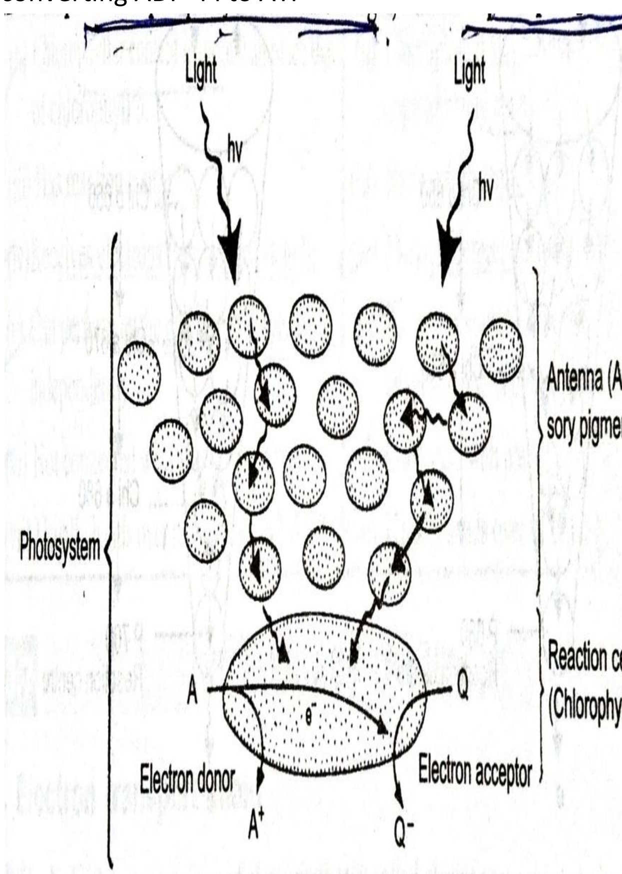
- Calvin Cycle or Light or Independent Reaction
- Also called Carbon Fixation or C_3 Fixation
- In this phase hydrogen of *$NADPH_2$ from light reaction and CO_2 are used to form carbon compound like carbohydrate* .
- Energy from ATP molecules is utilized for these reactions.



Light reaction

- In this when chlorophyll molecules absorbs a photon of light then it move from the ground state to excited state.
- The added energy lifts the electrons from the chlorophyll molecules.
- The added energy lifts the electron from chlorophyll molecules which used to reduce $NADPH_2$.
- The excited state is unstable and the chlorophyll molecules regain its lost electron from the water molecules and gets back to the ground state.

- During this electron transfer energy is utilized in converting ADP+Pi to ATP



and this process of phosphorylation occurs in light so it term as photophosphorylation.
- The light reactions convert solar energy to chemical energy
- Produce ATP & NADPH

Photosystem and reaction centers

- There are two type of light harvesting complexes are present with in photosystem, called phtosystem I and II (i.e. PS-I or P_{700} and PS-II or P_{680}).
- Each photosystem have light harvesting system called antennae (i.e. made up of hundreds f pigment molecules except chlorophyll a) while Chlorophyll a form the reaction center (i.e. collects all the energy collected by others accessory pigment molecules) and use this energy to convert light energy into chemical energy.

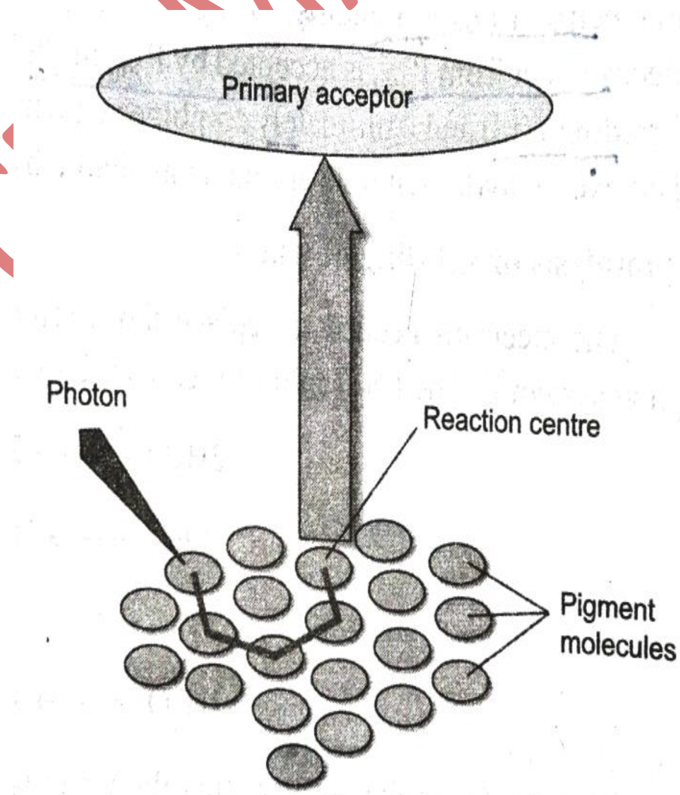
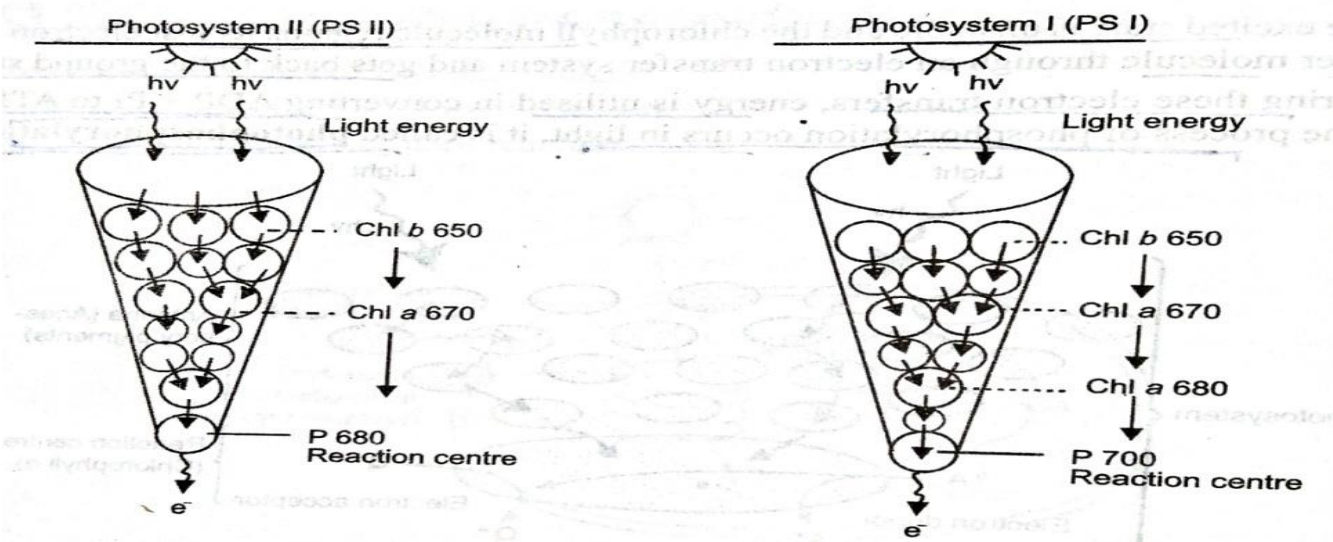


Fig. 13.10 The light harvesting complex

- PS-II is located in the appressed region of grana thylakoids and PS-I in the stroma thylakoids and non -appressd regions of grana.
- The reaction center emits the electron which moves from one electron carriers to another by oxidation reduction reactions and form electron transport chain.



Photolysis or splitting of water

- In this water get split into hydrogen (i.e. combined with CO_2 to produce sugars) and oxygen (i.e. releaed as by products).

$$2H_2O \longrightarrow 2H^+ + 2OH^-$$
$$2OH \longrightarrow H_2O + O + 2e^- \rightarrow \text{To PS II}$$
$$2H_2O \longrightarrow 4H^+ + O_2 + 4e^-$$

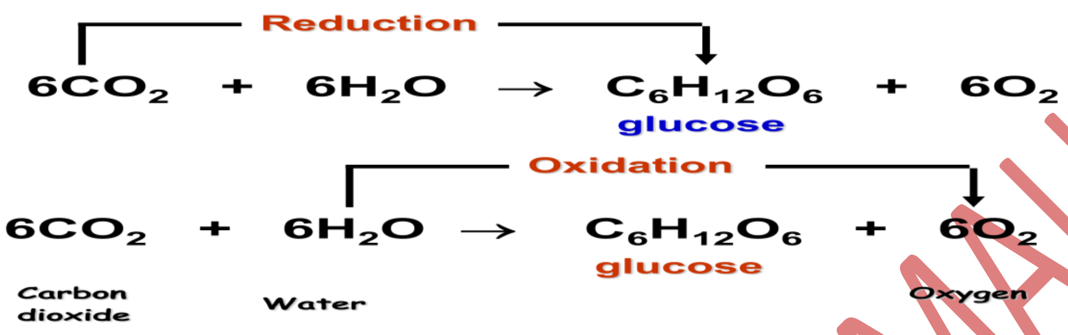
- The electron need to replace which remove from PS-I are provided by PS-II which in turn regains the lost electrons by the photolysis of water.

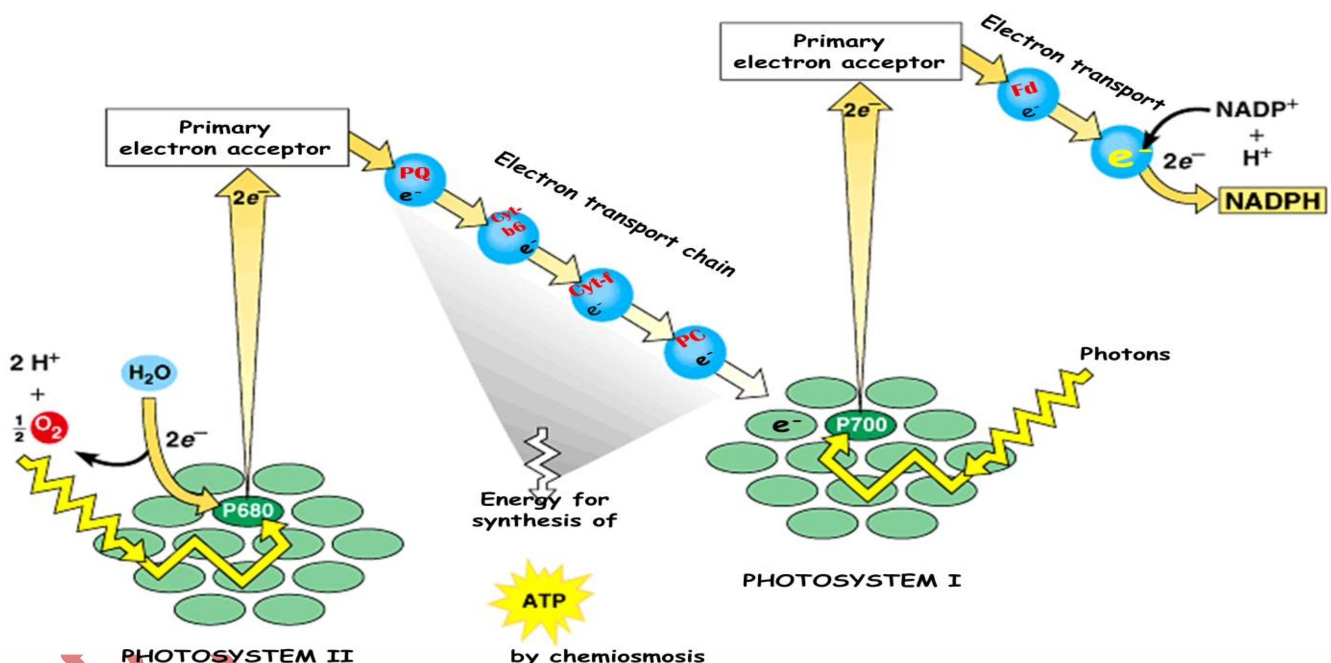
Difference between PS-I and PS-II

Photosystem- I (PS-I)	Photosystem –II (PS-II)
Located in the non appressed part of grana thalakoids as well as stroma thalakoids.	**Present in the appressed part of grana thalakoids.**
Chlorophyll content is more than chlorophyll b.	**Chlorophyll a and chlorophyll b are approximately equal.**
Has reaction center P_{700}	**Has reaction center P_{680}**
Receives electron from photosystem II	**Received electron from photolysis of water.**
Can perform cyclic photo-phosphorylation independently	**Perform non-cyclic photo-phosphorylation in conjunction with photolysis of water.**

Not connected with photolysis of water	**Connected with photolysis of water**
It handover its electron to $NADP^+$.	**Usually handover its electron to PS.**

Electron transport chain



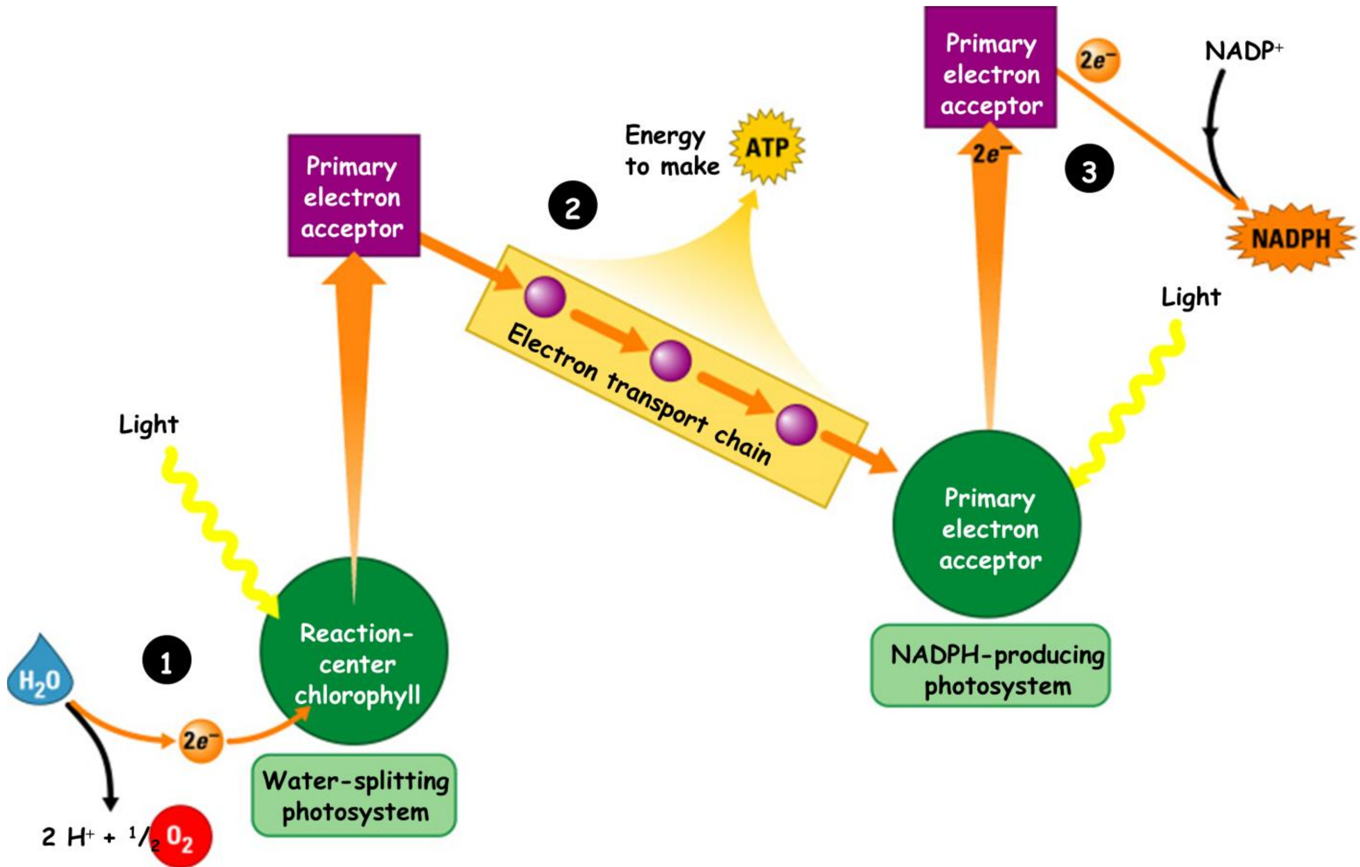


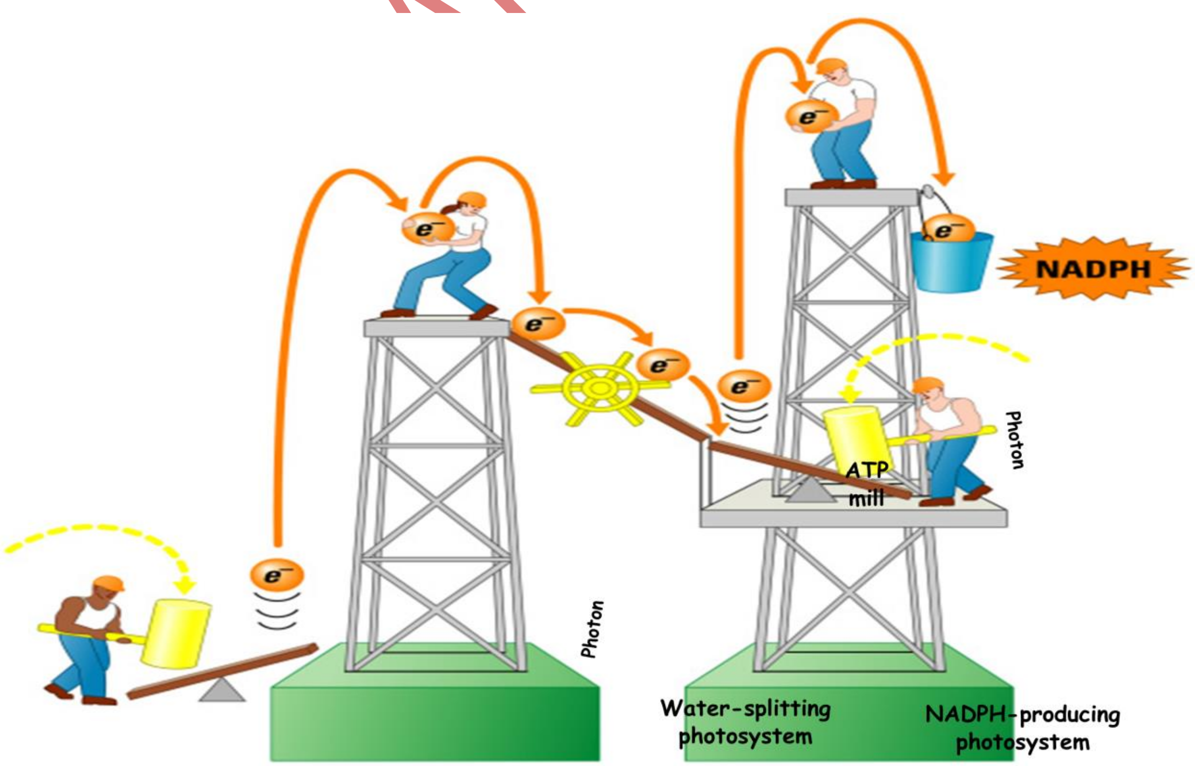
Non cyclic and cyclic Photophosphoylation

- Photophosphorylation is process of formation of ATP molecules from ADP in the presence of light by cells (i.e. in chloroplast).
- It occurs in chloroplast in two way:

1. Non – cyclic photophoosphorylation
2. cyclic photophoosphorylation

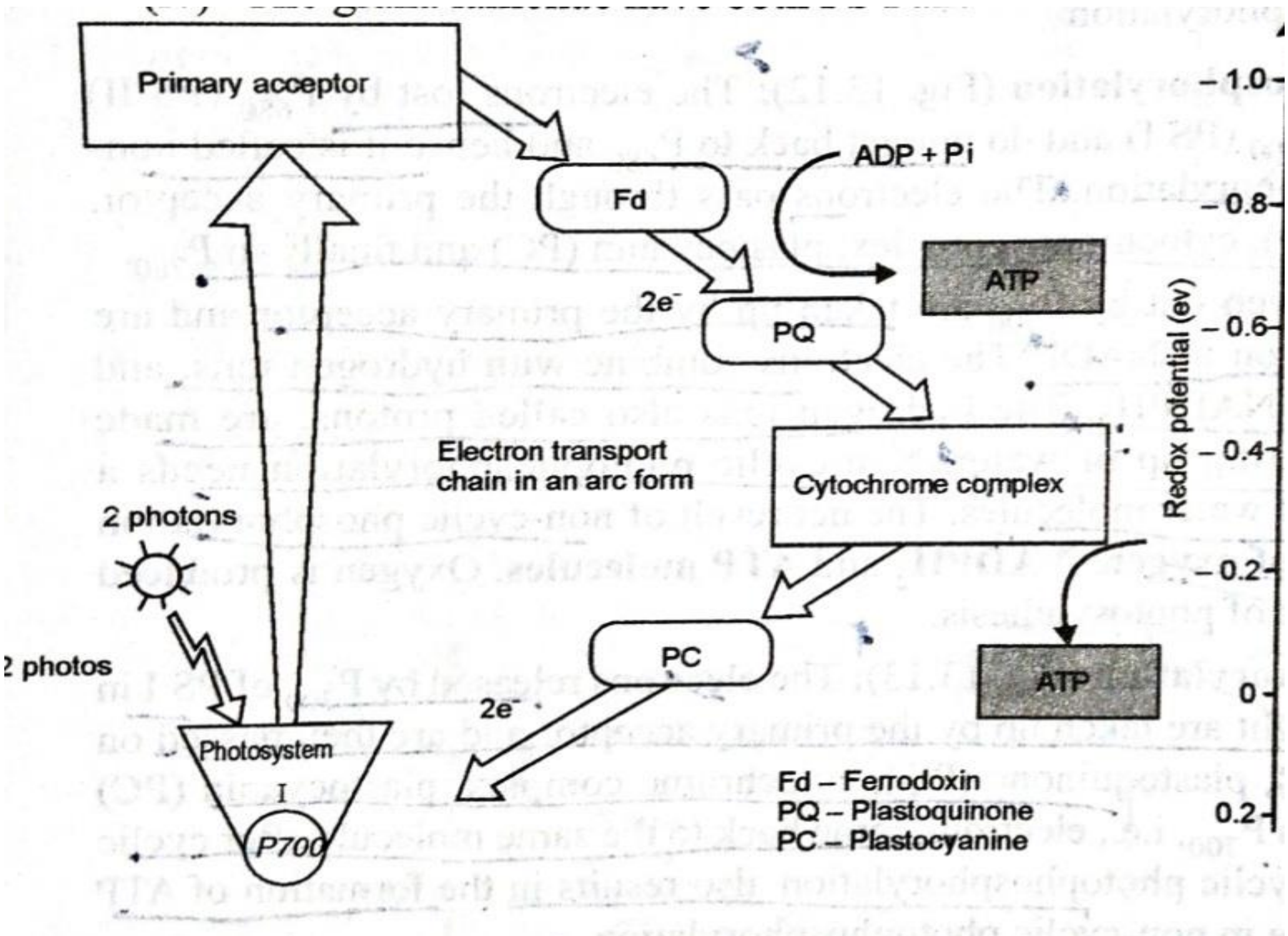
Non –cyclic photophosphorylation





Cyclic photophosphorylation

- When the wavelength is greater than 680nm then only PS-I can be activated because it has maximum absorption at 700nm and while PS_II absorb 680nm so it remain inactive.



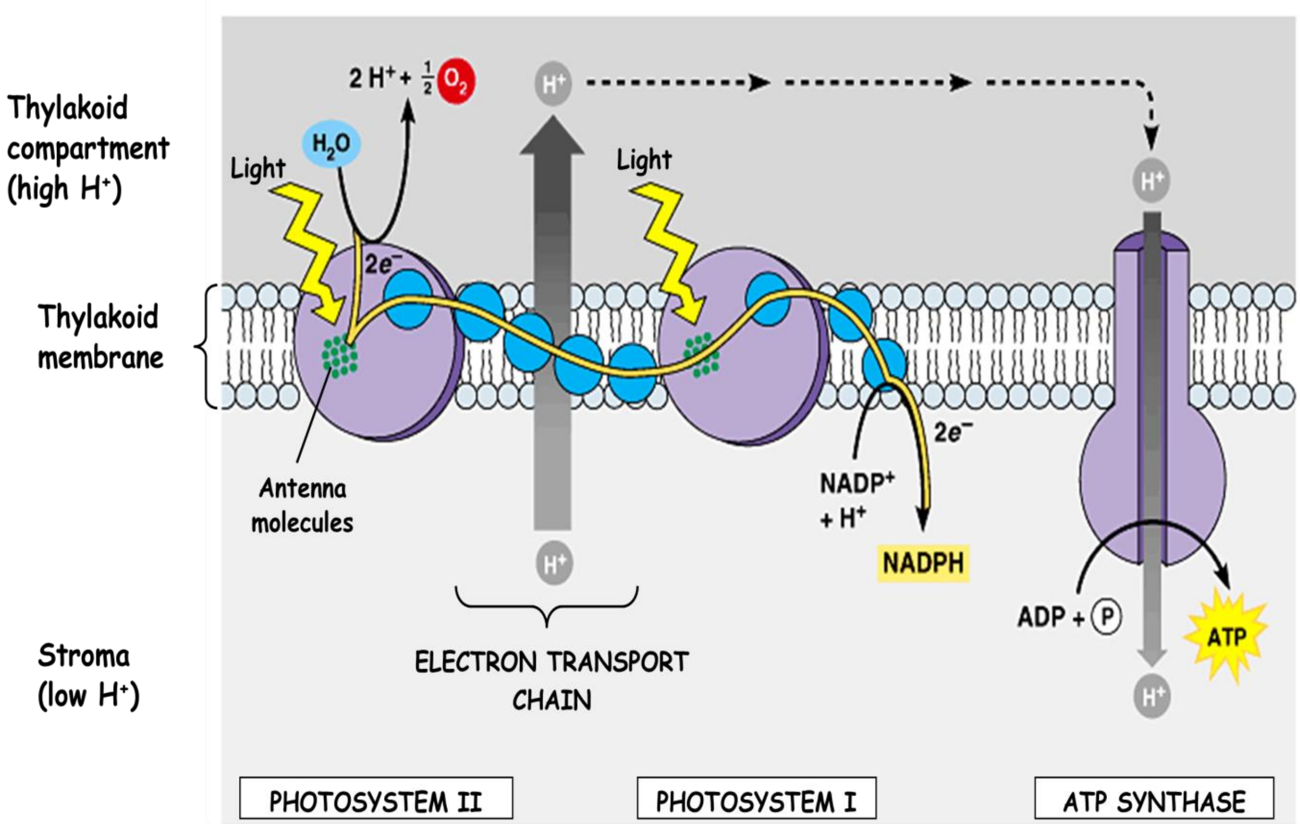
- if PS_II is inactive so their will be no any flow of electron from water to NADP which also stop carbon-dioxied fixation and utilization of NADPH in dark reaction.
- Under these circumstances only cyclic photophosphorylation can be seen in the chloroplast.

Chemioosmotic hypothesis

- Powers ATP synthesis
- Takes place across the thylakoid membrane
- Uses ETC and ATP synthase (enzyme)
- H+ move down their concentration gradient through channels of ATP synthase forming ATP from ADP
- The electron transport chains are arranged with the photosystems in the thylakoid membranes and pump H^+ through that membrane

– The flow of H^+ back through the membrane is harnessed by ATP synthase to make ATP

– In the stroma, the H^+ ions combine with $NADP^+$ to form NADPH



Where does the ATP and NADPH used?

- ATP and NADPH are used in the next phase for the synthesis of sugars (i.e. biosynthetic phase of photosynthesis).
- Melvil Calvin first discovered the first CO_2 was a 3-carbon acid (i.e. 3-phosphoglyceric acid or PGA).
- Most of the plant have first product of CO_2 fixation but in some plant it had 4-carbon compound (i.e. oxaloacetic acid or OAA).
- Studies show that acceptor molecules were a 5-carbon ketone sugar (i.e ribulose bisphossphate (RuBP).

Calvin cycle

- It is also called biosynthetic or dark reaction which does not require light but depend on the product of light reaction (i.e. ATP and NADPH molecules)and utilized it for carbon fixation.
- It takes place in stroma region.
- Calvin trace the path of carbon by using the radioactive carbon (i.e. C^{14}) in carbon dioxide and cultured unicellular algae (i.e. chlorella) which carrying out photosynthesis with normal carbon dioxide were exposed to $^{14}Co_2$.
- The algae are rapidly killed at different interval by dropping them into hot methanol and then soluble product of photosynthesis were separated by 2D-paper chromatography and identified by autoradiography.

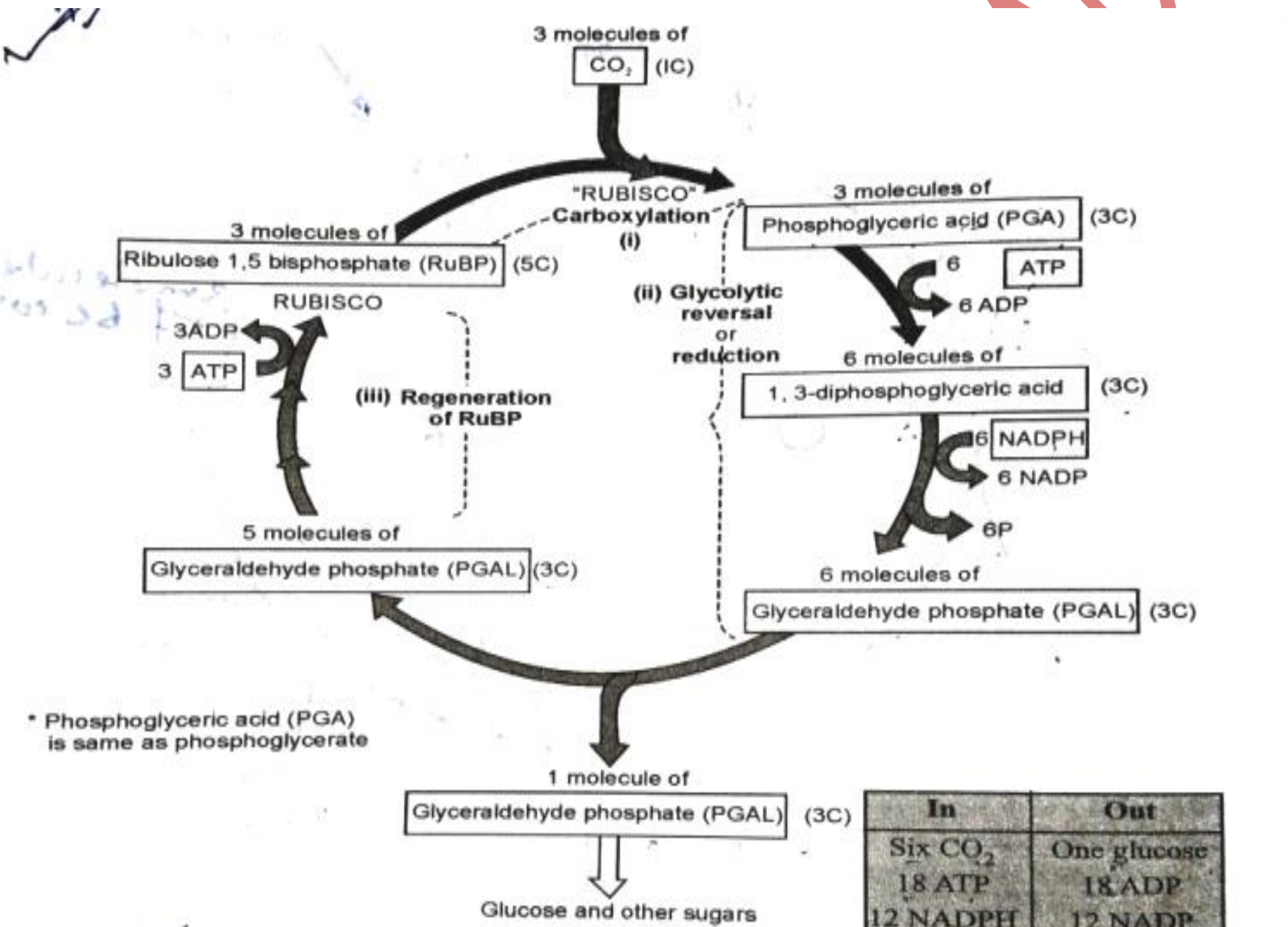
- Fixation of Co_2 studied in three major steps:

1. Carboxylation
2. Glycolytic reversal or reduction
3. Regeneration of RuBP

carboxylation

3 Co_2 + 3RUBP + 3H_2O → 6C intermediate compound → 6PGA

Glycolytic reversal or reduction



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

Fig. 13.16 The Calvin cycle or C_3 cycle; to make 1 molecule of glucose, 2 molecules of PGAL are required

Overall Equation

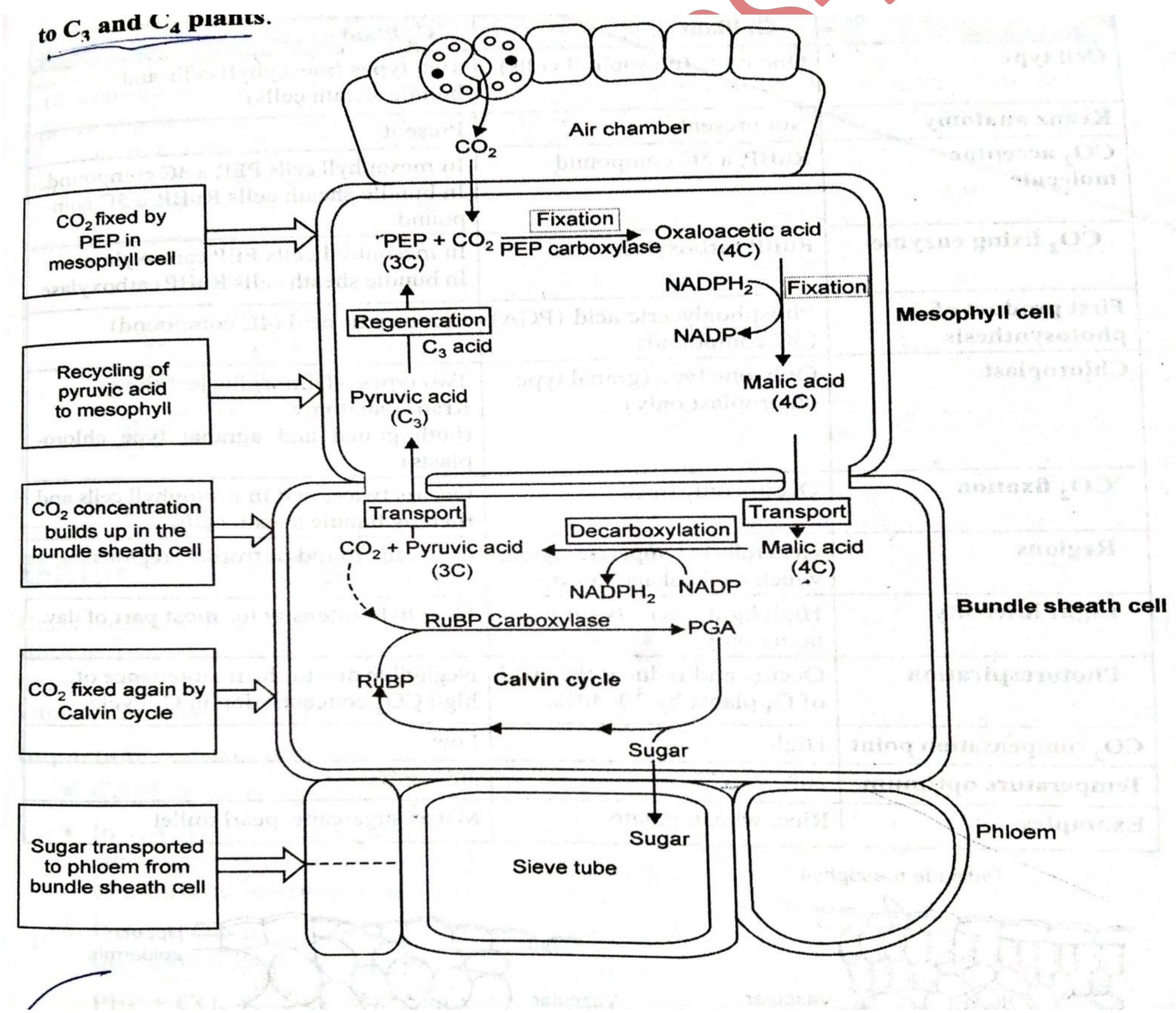
$$6RuBP + 6CO_2 + 12H_2O \xrightarrow[12\ NADPH_2 \ \to\ 12\ NADP]{18\ ATP\ \to\ 18\ ADP} 6RuBP + C_6H_{12}O_6$$

Regeneration of Ribulose bisphosphate

- The glyceraldehyde phosphate undergoes series of reaction and utilizing its 5 molecules and 3 molecules of ATP then 3 molecules of 5C sugar RuBP re regenerated.
- Rest one molecule of glyceraldehydes phosphate is used to make other molecules like glucose sucrose and starch.
- To make two molecules of 3C sugar (i.e. glyceraldehydes phosphate or PGA) – 6 molecules of Co_2 are required which mean 1 molecules of glucose takes 6 turns of Calvin cycle are required.

C_4 pathway

- It is adaptation in plants that grow in high light intensity regions to reduce photorespiration.
- In this tropical plant (i.e. sugarcane grasses and maize) have first photosynthetic product of 4c compounds (i.e. oxaloaetic acid malic and aspartic acids).
- C_4 pathway help o reduce the photorespiration by having a special Kranz leaf anatomy (i.e. mesophyll cell and bundle sheath cells from two rings outside the vascular bundles).
- C_4 plant are adaptive to reduce the



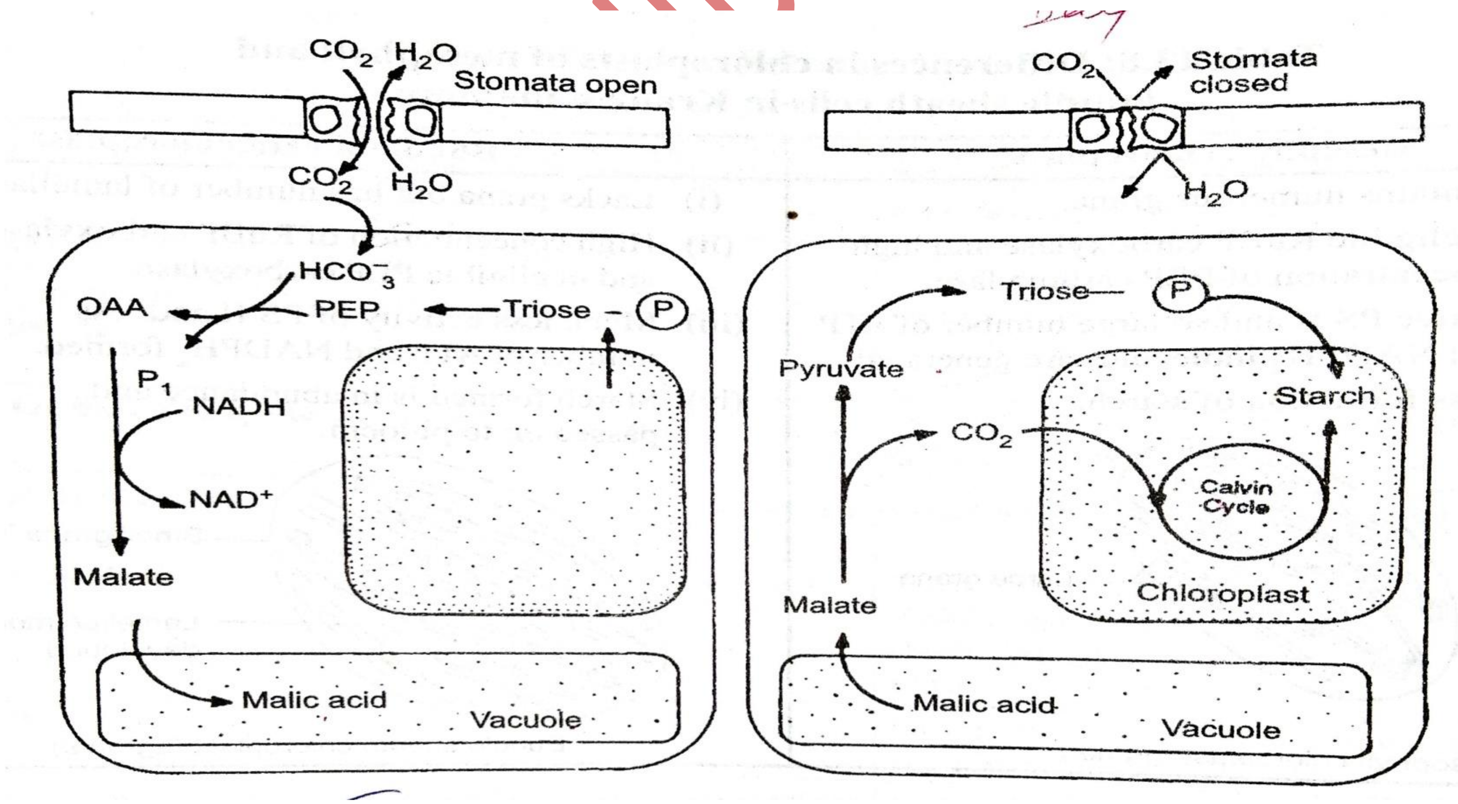
- photorespiration because they have following characteristics:

1. Special leaf anatomy
2. Show responds to highlight intensities.
3. Tolerate high temperatures
4. Lack photorespiration
5. Have grate productivity of biomass
6. Also use Calvin pathway (i.e. occurs in bundle sheath cells) the main biosynthetic pathway.

Crassulacean acid metabolism

- It is an adaptation by many succulent (i.e. water storing) and other plant like cacti, pine apple etc that grow in dry condition and hot regions to decrease photorespiration.
- The important feature that occurs in CAM pathway are :

1. It occurs in plant that normally grows in dry conditions.
2. In CAM plant stomata open during night (i.e. plant take CO_2 through the open stomata and fix it in malic acid) and close during the day (i.e the accumulated malic acid use as source of CO_2 and proceed via C_3 pathway) .



Photorespiration

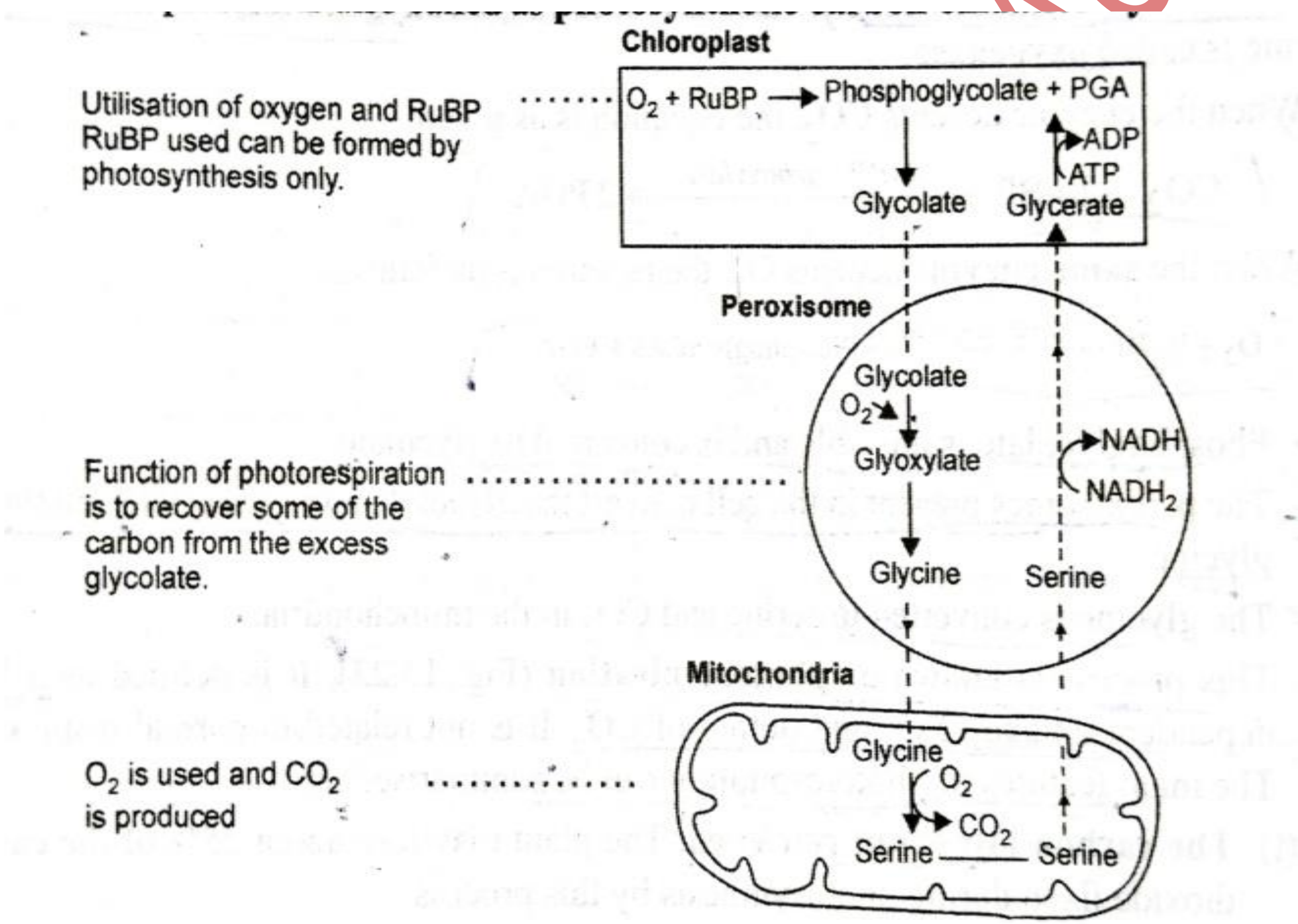
- The high concentration of oxygen inhibits the photosynthesis because the CO_2 fixing enzyme have affinity with CO_2 as well as O_2.
- As this reaction is oxygenation reaction so the enzyme I called oxygenase.

1. When enzyme accept CO_2 the it give:

CO_2 + RuBP → 2PGA

2. When the same enzyme accept O_2 :

O_2 + RuBP → Phosphoglycolate + PGA



Important feature of photorespiration

1. Carbon lost is not retrieved.
2. Wasteful loss of ATP and NADPH
3. As increase of O_2 concentration, the affinity of RuBP carboxylase increase with oxygen and decrease with CO_2.
4. It involves three organelles – chloroplast, mitochondria, peroxisomes.
5. Increase the tempraturre leads more photorespiration.
6. Increase in light.
7. Decrease the yield.

Factors influencing photosynthesis

- The rate of photosynthesis is influenced by a number of environmental factors like light availability of CO2 and water, temperature and number of genetic factors (i.e. leaf age, leaf angle, leaf orientation etc.).
- According to law of limiting factors a chemical process is affected by more than one factor ad rate of process is limited by the slowest step in the pathway or the most limiting factors (i.e. which is nearest its minimal value).

Light

- Photosynthesis varies with the light intensity and light quality.

Light intensity:

- In absence of light no photosynthesis will occurs and as the light intensity increases the photosynthesis increases proportionally until a saturated point (i.e. point beyond which an increase in light intensity does not cause any further increase in the rate of photosynthesis).
- After the saturation point the CO2 may become limiting.
- Very high light intensity photosynthesis reduce be accuse it lead to bleaching or destruction of chlorophyll.
- Process of distraction of chlorophyll in the presence of light I called photo-oxidation which presented by carotenoids (i.e. help to detoxify the bad affect of activated O2 on chlorophyll molecules and act as antioxidants).
- Light quality: depend on the wavelength of light plant receives and the rate of photosynthesis vary as it how in the absorption spectrum that photosynthesis is maximum in blue and red regions of visible light.

Temperature

- In photosynthesis the temperature has less effect in light reaction but the dark reaction being enzyme controlled is greatly influenced.
- The temperate plant - C_3 plant work best at optimum temperature of $25^{O}C$ and above $35^{O}C$ it lead to decrease the rate of photosynthesis.
- At the high temperature enzyme become inactive and affinity of RuBisCo also reduce for CO_2.
- At low temperature the inactivate enzyme and reduce the rate of photosynthesis.

Concentration of CO_2

- CO_2 require for the dark reaction so it become a limiting factor under field condition when water is in plenty.
- The land plant absorbs CO_2 through stomata and when stomata close then the rate of photosynthesis decreases due to non-availability of CO_2.
- The submerge water plant absorb CO_2 in the form of carbonates or bicarbonates dissolved inn water through epidermis or mesophyll cells.

Availability of water:

- Water is reactant molecules for photosynthesis and become limiting factors in several conditions.
- Suring sunny afternoon brings about temporary wilting and in prolonged hot period lead to severe yield losses.

Nutrient supply:

- All the essential elements affect the rate of photosynthesis like nitrogen has direct impact because being the basic component of chlorophyll and all the enzyme involved in dark reaction.

Internal factor:

- Age of leaf affect the rate of photosynthesis like rate of photosynthesis is increases as leaf mature and become maximum when leaf fully grown and expanded and rate may decreases in ageing leaf.

- Chlorophyll content – during the mineral deficiency of mineral or lack of light lead chlorosis which reduced rate of photosynthesis.
- Number of stomata affect the intact of CO_2, transpiration and ascent of sap which affect the rate of photosynthesis.

Chemosynthesis

- Is a process of obtains energy by certain bacteria.
- Bacteria which obtain energy from chemosynthesis are called chemosynthetic autotophs or chemoautotrophs.
- It is process of carbohydrate synthesis in which bacteria use energy from inorganic chemicals by chemical reactions.
- Chemosynthetic autotroph use CO_2 as a source of carbon and they may be aerobic or anaerobic.