6. Photosynthesis

6.0 : Introduction

Q.1. Define photosynthesis. Why is it a redox reaction ?

Ans: Photosynthesis (photon-light; synthesis-putting together).is an intracellular anabolic process in which glucose is synthesized from simple inorganic materials like CO_2 and water in the presence of light and chlorophyll with the evolution of oxygen as a by-product.

The overall equation of photosynthesis is

$$6CO_2 + 12H_2O \xrightarrow[\text{Chlorophyll}-a]{\text{Sunlight}} \underset{\text{Glucose}}{C_6H_{12}O_6} + 6H_2O + 6O_2 \uparrow$$

Photosynthesis as a redox reaction :

i) Photosynthesis is considered as a redox reaction as it involves both reduction and oxidation reactions.

ii) Water is oxidized by the removal of H^+ while CO_2 is reduced by the addition of H^+.

iii) The redox reactions of photosynthesis are necessary for the conversion of light energy into chemical energy.

Q.2. Why is photosynthesis called an anabolic process ?

Ans. i) Photosynthesis is the process by which solar energy is trapped by autotrophic organisms and converted into food for rest of the organisms.

ii) Plants use simple inorganic materials and build these up into complex organic molecules. This is called **autotrophic nutrition or autotrophism** (auto = self, trophism = feeding).

iii) In photosynthesis, carbohydrates are synthesized by utilizing the light energy. Thus, it is called **anabolic process** or energy building process and a mode of autotrophic nutrition.

Q.3.What are Chemoautotrophs? Give example.

Ans: Organisms which prepare their food by chemosynthesis, i.e. they use energy released during chemical reactions for synthesis of food an; called as **Chemoautotrophs.** e.g. Bacteria such as nitrifying bacteria (*Nitrosomonas*), sulphur bacteria (*Thiobacillus*) and iron bacteria (*Ferrobacillus*) are chemosynthetic autotrophs.

Q.4. Why is photosynthesis called an endergonic process ?

Ans: A chemical reaction that requires the absorption of energy is called endergonic reaction. Sunlight provides necessary energy to plants for production of sugars during photosynthesis. Hence, it is an endergonic process.

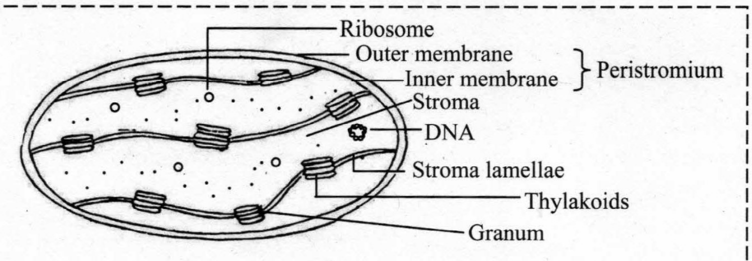
Q.5. What are Photosynthetic autotrophs (Photoautotrophs)? Give examples.

Ans: The organisms which prepare their own food by using light energy (solar energy) are called photosynthetic autotrophs or photoautotrophs. e.g. All green plants, protists like *Diatoms* and *Dinoflagellates*, prokaryotes like Cyanobacteria and green sulphur bacteria (*Chlorobiumy*)

6.1 : Site of Photosynthesis

Q.6. Describe the ultrastructure of chloroplast.

Ans:



Chloroplast

Ultrastructure of chloroplast :

i) Chloroplast are oval or elliptical in shape having a length of 4 to 10 microns and breadth of 2 to 3 microns.
ii) It shows a double layered lipoprotein membrane (outer membrane and inner membrane together called Peristromium). It is about 40 - 60 $\overset{0}{A}$ in thickness.
iii) The space in between these membranes is called **periplastidial space** or intraenvelop space.
iv) The internal space is filled with a colourless, dense matrix called **Stroma**. It consists of lipids, proteins, DNA, RNA, enzymes and 70S ribosome.
v) In the stroma, there are disc-like plates called grana connected by tubules called **stroma lamellae or intergrana or fret membranes.**
vi) Each granum consists of 12 – 20 disc-like structures called **thylakoids.** These are arranged one above the other like a stack of coins.
vii) Internal space of each thylakoid has Ultra-microscopic particles called as **Quantasomes.**
viii) In each quantasome, there are 230 – 300 molecules of photosynthetic pigments forming the pigment system.
ix) DNA of chloroplast is circular, closed, naked ring and is called as **plastidome.**

Additional Information

Q.7. What is quantasome ?

Ans: According to Park and Biggins, photosynthetic pigments are located in the membranes of thylakoids in specific areas called quantasome. Quantasome is a photosynthetic unit, believed to have about 160 molecules of chlorophyll-a, 70 molecules of chlorophyll-b and 50 carotenoid molecules.

Q.8. Write a note on Granum.

Ans: i) In stroma, small dark green, cylindrical granular sacs called grana are present. There may be 40-60 grana present in each chloroplast.
ii) A single granum is composed of stack of 12-20 sac-like thylakoids.
iii) Each thylakoid has large number of spherical bodies called quantasomes or photosynthetic units.
iv) Each quantasome has about 250 to 300 pigment molecules which are organized into two pigment systems, viz. PS-I and PS-II.
v) The granum, therefore, is well-equipped for the photochemical reaction of photosynthesis.

Q.9. Give the functions of grana and stroma.

Ans: Functions of grana :
i) In grana, ATP and NADPH2 are produced in presence of light.
ii) Photolysis of water takes place to release O2 in the atmosphere.
iii) Cyclic and non-cyclic photophosphorylation takes place in grana.
iv) It is the site for light reaction.

Functions of stroma :
i) In stroma, CO_2 is fixed in absence of light to form hexose sugar.
ii) ADP and NADP are produced which are necessary for the light reaction.
iii) C_3 and C_4 cycles take place in the stroma.
iv) It is the site of dark reaction.

Q.10. State the functions of chloroplast.

Ans: i) Chloroplast is called as the photosynthetic apparatus as both steps of photosynthesis are completed in it.
a) Light reaction takes place in the grana.
b) Dark reaction takes place in the stroma.
ii) All necessary enzymes needed for photosynthesis are found to be present in the chloroplast.

Q.11. Distinguish between Grana and Stroma.

Ans:

No.	Grana	Stroma
i)	The grana consists of quantasomes containing the pigment chlorophyll.	Proteinaceous matrix in the chloroplast is called matrix or stoma.
ii)	Light reaction occurs in grans	Dark reaction occurs in stroma
iii)	ATP, $NADPH_2$ and O_2 are produced in grana.	ATP and $NADPH_2$ are used in stroma.
iv)	Photolysis of water and release of O_2 occurs in grana.	Fixation of CO_2 and synthesis of glucose occurs in stroma.

6.2 : Photosynthetic pigments and their role

Q.12.Name the various photosynthetic pigments.

Ans: Chlorophyll – a, Chlorophyll – b, Carotenoids (Carotenes, Xanthophylls), Phycobilins are the various photosynthetic pigments.

Q.13.What is the main function of chlorophyll pigment ?

Ans: The main function of chlorophyll pigment is to absorb light of specific wavelength in the visible region.

Q.14.State the location of pigments in the chloroplast.

Ans: In the chloroplast, photosynthetic pigments are located in the thylakoid membrane.

Q.15. What are photosynthetic pigments ?

Ans: i) A photosynthetic pigment is a pigment present in chloroplasts or photosynthetic bacteria and captures the light energy necessary for photosynthesis.

ii) Photosynthesis is a photo-biochemical reaction which is mediated through the absorption of light energy.

iii) The light energy is absorbed by photosynthetic pigments in plants.

iv) These pigments have the capacity to absorb light of certain wavelength and reflect light of other wavelengths, imparting different colours to pigments.

v) The colour of specific pigment indicates the wavelength reflected by the pigment.

vi) Different types of photosynthetic pigments are chlorophylls, carotenoids and phycobilins, etc.

Q.16. Describe different types of photosynthetic pigments and explain their role.

Ans: The three main types of photosynthetic pigments are Chlorophyll, Carotenoids (Carotenes,Xanthophylls) and Phycobilins.

Chlorophylls :

i) Chlorophylls are the most important and abundant photosynthetic pigments.

ii) They are green pigments soluble in organic solvent and insoluble in water.

iii) They are of seven different types, viz. chlorophyll a, b, c, d, e, bacteriochlorophyll and bacterioviridin.

iv) Chlorophyll-a and chlorophyll- b are present in higher plants and green algae.

Chlorophyll – a :

a) It is a blue green pigment with molecular formula $C_{55}H_{72}O_5N_4Mg$.

b) It is present in all photosynthetic organisms (except photosynthetic bacteria).

c) As chlorophyll-a converts light energy into chemical energy, it is the essential pigment or primary photosynthetic pigment.

Chlorophyll – b :

a) It is a yellowish green pigment with molecular formula $C_{55}H_{70}O_6NMg$.

b) It is found in higher plants, green algae, bryophytes and all vascular plants.

c) Chlorophyll-b transfers the absorbed light to chlorophyll-a and functions as the accessory pigment.

v) Both chlorophyll-a and chlorophyll-b show maximum absorption in blue, violet and red region of the visible spectrum.

vi) Chlorophyll c, d and e are found in algae along with chlorophyll-a.

Carotenoids :

a) Carotenoids are fat soluble lipid compounds, widely distributed in chloroplasts and chromoplasts.

b) They primarily absorb blue-violet region of visible light and transfer it to chlorophyll-a, thus function as accessory pigments.

c) There are two types of carotenoids, viz. carotenes and xanthophylls.

Carotenes :

a) Carotenes are orange/yellow in colour.

b) They are unsaturated hydrocarbons with molecular formula $C_{40}H_{56}O_2$.

c) They are insoluble in water and soluble in organic solvents like alcohol and benzene.

d. β - carotene is the most common.

Xanthophylls :

a) They are oxidized form of carotene with molecular formula $C_{40}H_{56}O_2$.

b) They are yellow in colour.

c) They are also insoluble in water and soluble in organic solvent.

d. Lutein is the most widely distributed xanthophyll in plants, give yello~ colour to autumn leaves.

Phycobilins :

a) These are accessory pigments present in cyanobacteria and algae.
b) They are water soluble pigments.
c) Two examples ofphycobilins are phycocyan ins (blue) and phycoerythrins (red).

Q.17.Why is chlorophyll-a called essential pigment ?

Ans: Chlorophyll-a is called as an essential pigment because of the following reasons :

i) Chlorophyll-a is the reaction center in the granum and is capable of converting solar energy into chemical energy.
ii) Chlorophyll-a absorbs solar energy as well as accepts energy from other accessory pigments.
iii) It plays an important role in both cyclic and non-cyclic photophosphorylation.
iv) It helps in photolysis of water and release of oxygen which is necessary for life.

Q.18. Which is the major Xanthophyll present in plants?

Ans: Lutein is the major Xanthophyll present in plants.

Q.19. Distinguish between Chlorophyll – a and Chlorophyll – b.

Ans:

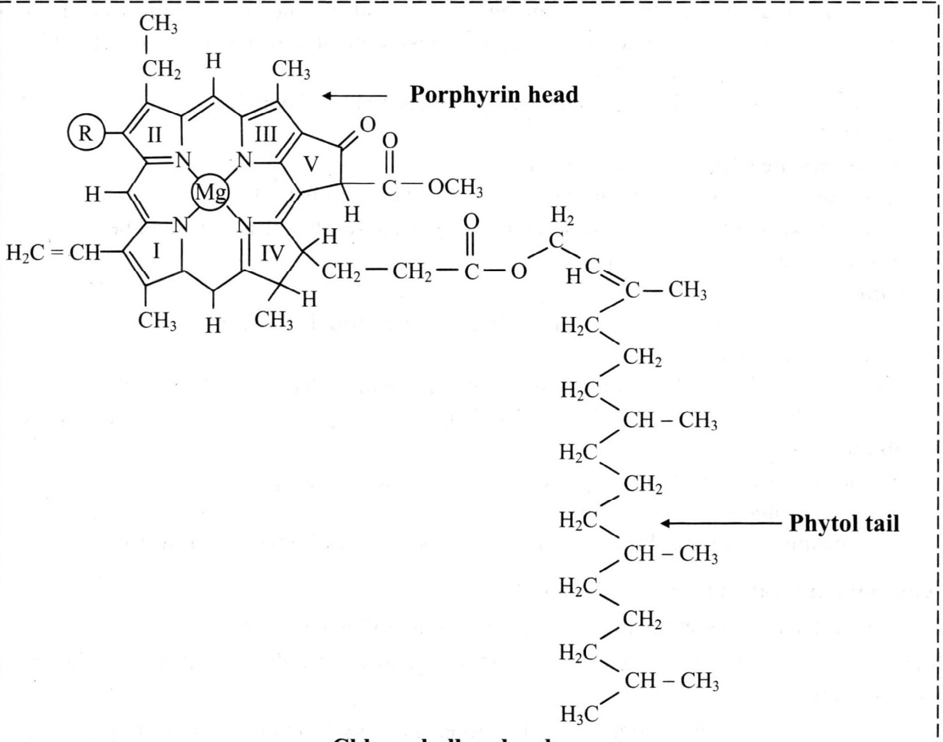
No.	Chlorophyll-a	Chlorophyll-b
i)	Empirical formula is $C_{55}H_{72}O_5 N_4Mg$.	Empirical formula is $C_{55}H_{70}O_6N_4Mg$.
ii)	It is blue - green in colour	It is yellow - green in colour
iii)	It is primary photosynthetic pigment.	It is an accessory photosynthetic pigment.
iv)	It is soluble in petroleum	It is soluble in 90% methyl alcohol
v)	Carbon -3 contains methyl group	Carbon - 3 contains aldehyde group

Q.20.Suppose there were plants that had high concentration of chlorophyll-b, but lacked chlorophyll-a. Would it carry out photosynthesis? Then, why do plants have chlorophyll-b and other accessory pigments?

Ans: Photosynthesis cannot be carried out without the presence of pigment chlorophyll a. P_{700}acts as a reaction centre of PS – I and P_{680} acts as a reaction centre of PS – II. Chlorophyll-b and other accessory pigments are able to absorb shorter wavelengths and then transfer their energy to chlorophyll–a for photophosphorylation. Such accessory pigments not only enable a wider range of wavelength of incoming light to be used for photosynthesis but also protect chlorophyll-a from photo-oxidation.

Q.21. Describe the structure of a typical chlorophyll molecule.

Ans:



Chlorophyll molecule

i) Both chlorophyll-a and chlorophyll-b are similar in their molecular structure, except that the methyl group (-CH3) in chlorophyll-a is replaced with aldehyde group (-CHO) in chlorophyll-b.
ii) A typical chlorophyll molecule has porphyrin head and phytol tail.
iii) It looks like a kite.
iv) Head is polar, rhomboid with four pyrrole rings, attached to each other by methine group.
v) In the centre of these rings, there is non-ionic Mg atom.
vi) The head is hydrophilic and is found in the protein part ofthylakoid membrane.
vii) A long non-polar phytol tail is attached to the 4th pyrrole ring.
viii) It is lipophilic and extends in lipid layer ofthylakoid membrane.

Q.22. Write a note on nature of light and its role in photosynthesis.

Ans: Nature of light :

i) Light energy shows dual nature. It behaves as wave form during propagation, while on interaction with matter, it behaves as a stream of discrete packets of energy known as photons or light quanta.
ii) A quantum is the amount of energy present in a photon. This energy is absorbed by the photosynthetic pigments.
iii) Visible light useful in photosynthesis is only a small part of the spectrum ranging from 390 nm (violet light) to 760 nm (red light). This portion is often referred to as **photosynthetically active radiation (PAR).**
iv) The energy content of a photon is inversely proportional to the wavelength of light. Shorter the wavelength greater is the energy and vice-versa.

Role of light :

i) Absorption of visible light by photosynthetic pigments is maximum in red and blue part, while it is little in yellow and orange part. Green part shows negligible absorption.
ii) Accordingly, maximum photosynthesis occurs in red light followed by blue light, while green light shows little or no photosynthesis.

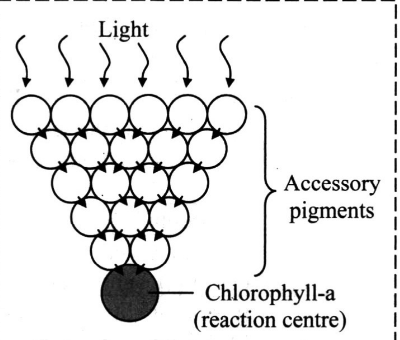
Q.23.Which wavelength of visible spectrum are absorbed maximum by chlorophyll and which wavelength of light are least absorbed ?

Ans: Blue and red wavelength of light are absorbed maximum by chlorophyll pigment and green wavelength is least absorbed.

Q.24. Explain the role of accessory pigments in photosynthesis.

Ans: Role of accessory pigments :

i) Photosynthetic pigments such as chlorophyll-b, carotenes and xanthophylls are called accessory pigments.
ii) These pigments absorb light energy of different wavelengths and transfer it to chlorophyll-a.
iii) The light (radiation energy) captured by these pigments is funneled into the reaction centre for conversion into the chemical energy.
iv) Carotenoids (carotenes and xanthophylls) protect chlorophyll-a from photo-oxidation.



Transfer of light energy by accessory pigments

Q.25.Explain the photoexcitation of chlorophyll-a.

Ans:Photoexcitation of chlorophyll-a :

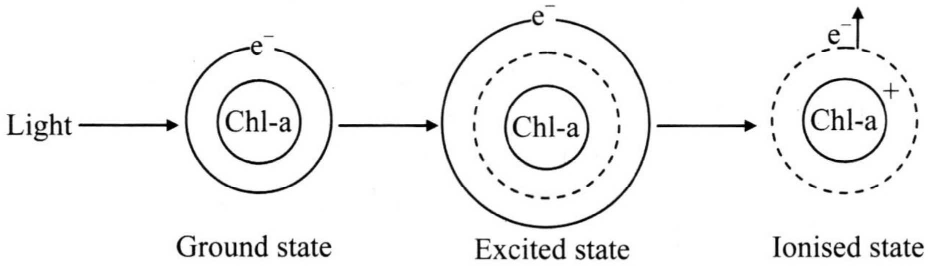
i) Chlorophyll-a is the essential photosynthetic pigment as it converts light energy into chemical energy and acts as a reaction centre.
ii) Initially, it lies at ground state or singlet state but when it absorbs or receives photons (solar energy), it gets activated and goes in excited state or excited second singlet state.
iii) In the excited state, chlorophyll-a emits an electron. The emitted electron is energy rich, i.e. has extra amount of energy.
iv) Due to the loss of electron (e^-), chlorophyll-a becomes positively charged. This is the ionized state.

Chlorophyll-a molecule cannot remain in the ionized state for more than 10^{-9} seconds.

v) The energy rich electron is then transferred through various electron acceptors and donors (carriers).

vi) During the transfer, the electron emits energy which is utilized for the synthesis of ATP. This shows that light energy is converted into chemical energy in the form of ATP.

vii) There are the two forms of chlorophyll-a, P_{700} and P_{680} which form reaction centres of PS-I and PS-II respectively for the photochemical reaction.



Photoexcitation of chlorophyll-a

Q.26. What do you mean by two pigment system ?

Ans: i) The accessory pigments and the reaction centre together form pigment system or photosystem.

ii) In higher plants, photosynthetic photochemical reactions are promoted by two pigment systems.

iii) These pigment systems are called pigment system I and pigment system II (or photosystem I (PS- I) and photosystem II (PS-II).

iv) In PS-I, chlorophyll-a shows maximum absorption at 700 nm, thus P_{700} is the reaction centre.

v) In PS-II, chlorophyll-a shows maximum absorption at 680 nm, thus P_{680} is the reaction centre.

vi. During photosynthetic photochemical reactions, these two pigment systems work independently inside the photosynthetic apparatus, i.e. chloroplast.

vii) In PS-II, manganese, calcium and chloride ions are present in addition to the electron carrier. These ions play an important role in photolysis of water.

viii) Each photo system is with Core Complex (CC) and Light harvesting complex (LHC).

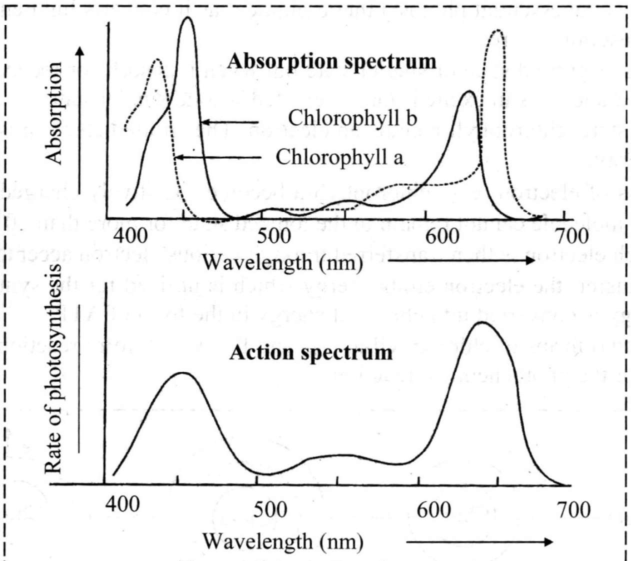
Q.27. Distinguish between PS-I and PS-II.

Ans:

No.	PS - I	PS - II
i)	It has P_{700} as the reaction centre.	It has P_{680} as the reaction centre.
ii)	PS–I is located on the outer surface of thylakoid	PS –II is located on the inner surface of thylakoid, i.e. in the stroma.
iii)	Chlorophyll–b is absent.	Chlorophyll – b is present.
iv)	It is involved in cyclic as well as non-cyclic	It is involed in only non-cyclic photophosphorlation
v)	It is not invloved in photosysis of water	It is involved in the photolysis of water
vi)	Molecular oxygen is not evolved in this system	It involves the evolution of molecular oxygen.
vii)	It donates the electrons to Ferredoxin Reducing	It donates the electrons to Quinone

Q.28. Explain absorption and action spectrum.

Ans:



Absorption and action spectra

i) Absorption spectrum :

a) The graph showing the absorption of light by pigments at different wavelengths IS called absorption spectrum.

b) It is studied with the help of an instrument called spectrophotometer.

c) Absorption spectrum of chlorophyll-a and chlorophyll-b shows that, they absorb in both blue and red region of the spectrum.

ii) Action spectrum :

a) The graph showing the rate of photosynthesis at various wavelengths is called action spectrum.

b) The rate of photosynthesis is measured in terms of O_2 evolved and CO_2 utilized.

c) Action spectrum graph shows that rate of photosynthesis is more in red than in blue.

6.3 : Light Dependent Reactions

Q.29. What are light dependent reactions ?

Ans: The 'light-dependent reactions' is also called as photochemical phase or primary phase. The 'light-dependent reactions' or light reactions are the first stage of photosynthesis that occurs in grana of chloroplast, the process by which plants capture and store energy from sunlight. In this process, light energy is converted into chemical energy in the form of the energy-carrying molecule ATP.

Q.30."Hill's experiment does not prove that the source of oxygen evolved during photosynthesis is water".This statement is true or false? Explain.

Ans: Robert Hill proved that source of oxygen evolved during photosynthesis is water and not carbon dioxide. Hence, it is called Hill's Reaction.

i) In this experiment, Hill suspended isolated chloroplasts in a medium free of CO_2.

ii) Ferric salts and haemoglobin were added in the medium as hydrogen and oxygen acceptors respectively.

iii) When the suspension was exposed to light, he found that ferrous salts and oxyhaemoglobin were formed.

iv) This indicates that water molecule splits into Wand OH^- ions, which are accepted by ferric salts and haemoglobin.

v) This process of splitting up of water molecules under the influence of light in the presence of chlorophyll is called **Photolysis of water.**

vi) Hill's reaction can be represented as follows :

$2H_2O + 2A \rightarrow 2AH2 + O_2$

(Where A is a hydrogen acceptor)

Q.31. What was used to prove that source of oxygen evolved during photosynthesis is water?

Ans: Ferric salts (as hydrogen acceptor) and haemoglobin (as oxygen acceptor) were used to prove that source of oxygen evolved during photosynthesis is water.

Cyclic and non-cyclic photophosphorylation

Q.32.Define photophosphorylation.

Ans: Formation of ATP molecules from ADP and inorganic phosphate (Pi) in presence of light and chlorophyll during the photochemical phase of photosynthesis is called photophosphorylation or photosynthetic phosphorylations.It can be represented as follows:

$$ADP + Pi \xrightarrow[Chl.a]{light} ATP$$

Q.33.Describe non-cyclic photophosphorylation/ Z-Scheme.

Ans: Non-cyclic photophosphorylation involves the following steps:

i) Photoexcitation of PS-II :
PS-II absorbs light and gets excited, which results in ionisation of chlorophyll-a and a high energy electron is expelled from PS-II.

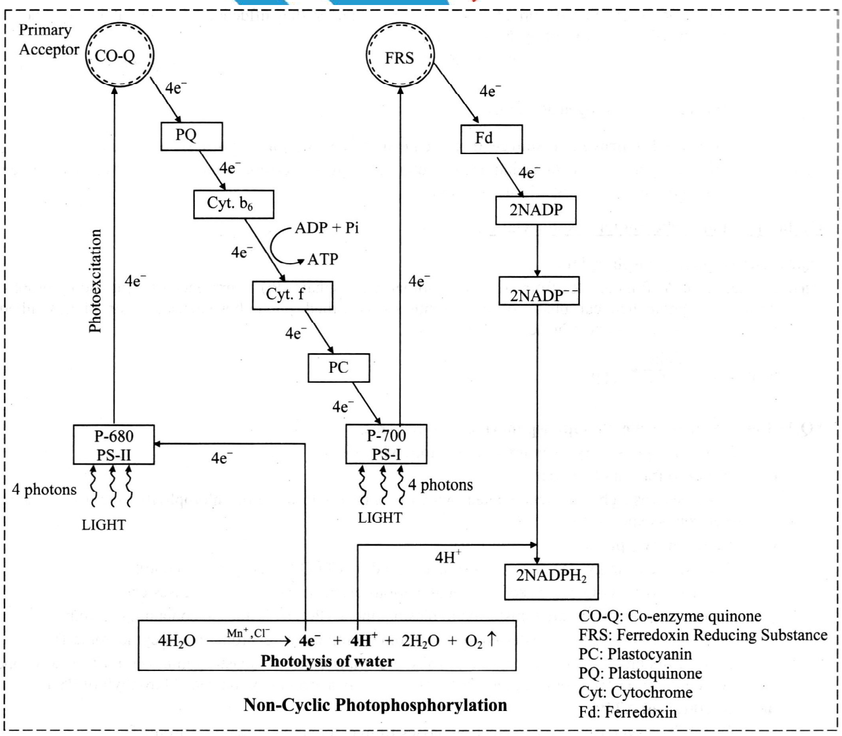
ii) Electron Acceptors :
The expelled energy rich electron is first accepted by CO-Q (co-enzyme quinone). Electron from CO-Q moves down through various electron carriers and releases energy. From CO-Q, electrons are transferred to plastoquinone (PQ) (it is an iron containing protein). From PQ, electrons are transferred to cytochrome complex (cytochrome-b and cytochrome-f). From cytochrome complex, the electrons are transferred to plastocyanin (PC) (it is a copper containing protein). From PC, the electrons are finally accepted by ionized chlorophyll of PS-I.

iii. Synthesis of ATP :
One ATP is synthesized when electron passes from cytochrome b6 to cytochrome f.

iv) Photoexcitation of PS-I :
The light energy absorbed by PS-I is transferred to reaction centre P_{700}.It gets excited and expels energy rich electrons. The electrons are first accepted by unknown electron acceptor called FRS (Ferredoxin Reducing Substance). Electron from FRS moves down through various electron carriers and release energy. From FRS, electrons are transferred to ferredoxin (it is an iron containing protein). The reduced ferredoxin transfers electron to NADP to form $NADP^{--}$ in the presence of enzyme Fd-NADP-reductase.

v) Photolysis of water :
Splitting of water into Wand OH- in presence of light and chlorophyll is called photolysis of water. Manganese, calcium and chloride ions present in PS-II play an important role in photolysis of water Photolysis of water occurs in order to satisfy the electron need of PS-II and proton need of $NADP^{--}$

vi) Assimilatory power :
ATP and $NADPH_2$ are together called as assimilating power by Calvin, as it is required for assimilation of CO_2



Q.34.Which substance acts as hydrogen acceptor in plants when photolysis of water takes place?

Ans: In plants, NADP acts as hydrogen acceptor in plants when photolysis of water takes place.

Q.35. What is photolysis of water? Give the significance of photolysis of water.

Ans: Photolysis of water: It is the process of splitting up of a water molecule into H^+ OH^- ions under the influence of light.

Significance of Photolysis :

i) It results in the release of O_2 which is indispensable for life.

ii) it supplies H_2 for reduction of CO_2.

iii) It supplies electron for neutralization of chl-a' of PS II in non-cyclic photophosphorylation.

Q.36. Describe briefly cyclic photophosphorylation.

Ans: i) It involves the pigment system I, i.e. the reaction centre is made by P700 chlorophyll.

ii) When light falls on the PS-I, it gets excited, the accessory pigments pass on the energy to the reaction centre P_{700} which emits a pair of energy rich electrons.

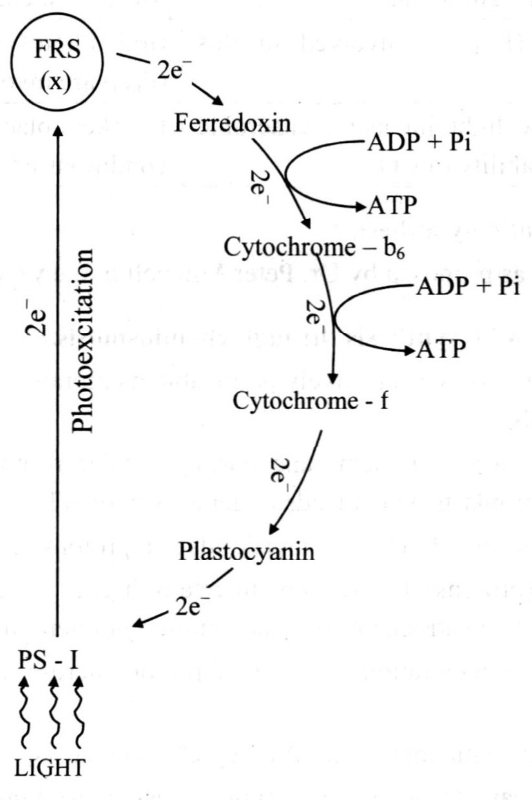
iii) These electrons are accepted by the electron acceptor called Ferredoxin Reducing Substance (FRS).

iv) From FRS, the pair of electrons are transferred through a series of electron carriers, i.e. Ferredoxin (Fd), Cytochrome b6, Cytochrome f and Plastocyanin (PC).

v) From Plastocyanin, the electrons return back to the P_{700}^+ chlorophyll molecule.

vi) During the transfer of electrons between Cytochrome b_6 and Cytochrome f, the energy released is used to form ATP. However, ATP formation may also take place when electrons are transferred from ferredoxin to cytochrome -b_6.

vii) The electrons released by the chlorophyll ultimately return back and hence it is called as Cyclic photophosphorylation.



Cyclic Photophosphorylation

Q.37.Under which condition cyclic photophosphorylation will take place ?

Ans: When photo system-I is illuminated by light, P_{700}(reaction centre) is excited and emits out energy rich electron which is first accepted by FRS and then transferred through a series of electron carriers. The electron released ultimately returns back to PSI. Thus, cyclic photophosphorylation takes place.

Q.38.What are cytochromes ?

Ans: Cytochromes are electron carrier proteins that catalyze intracellular oxidations.

Q.39. Give significance of cyclic and non cyclic photophosphorylation.

Ans: Significance of cyclic photophosphorylation :

i) ATP molecules are produced which are required for synthesis of glucose.

ii) ATP molecules are essential for the dark reaction.

Significance of non-cyclic photophosphorylation:

i) ATP molecules as well as NADPH2 are produced.

ii) Photolysis of water takes place to release O_2

Q.40.Differentiate between Cyclic and Non-cyclic photophosphorylation.

Ans:

No.	Cyclic Photophosphorylation	Non - cyclic Photophosphorylation
i)	Electrons emitted by chlorophyll return back to the same chlorophyll.	The electrons emitted by chlorophyll do not return back to the same chlorophyll.
ii)	$NADPH_2$ is not formed.	$NADPH_2$ is formed.
iii)	Does not involve photolysis of H_2O	Involves photolysis of H_2O
iv)	No evolution of O_2	There is evolution of O_2
v)	Less efficient and less significant	More efficient and significant process.
vi)	Only Photosystem-I (P_{700})is involved in this cycle	Both Photosystem PS–I (P_{700}) as well as PS–II (P_{680})are involved.
vii)	It operates under low light intensity, anaerobic conditions, poor availability of CO_2	It takes place under optimum light, aerobic conditions and in the presence of sufficient CO_2

Q.42. Explain the mechanism of ATP synthesis through chemiosmosis.

Ans:i) The movement of ions across a selectively permeable membrane, down their electrochemical gradient is called **chemiosmosis.**

ii) Hydrogen ions move across a membrane during cellular respiration in mitochondria and during photosynthesis in chloroplasts,which leads to generation of ATP.

iii) In photosynthesis, these membranes are thylakoids and protons accumulate in the lumen.

iv) When hydrogen ions (protons) diffuse from an area of higher proton concentration to an area of lower
proton concentration, an electrochemical concentration gradient of protons is developed.

v) This electrochemical concentration gradient of protons across a membrane could be harnessed to make ATP.

vi) **ATP synthase** is the enzyme that makes ATP by chemiosmosis.

vii) It allows protons to pass through the membrane using the kinetic energy to phosphorylate ADP making ATP.

vii) It allows protons to pass through the membrane using the kinetic energy to phosphorylate ADP making ATP.

viii) Due to splitting of water molecule on the inner side of the membrane, hydrogen ions accumulate within the lumen ofthylakoids.

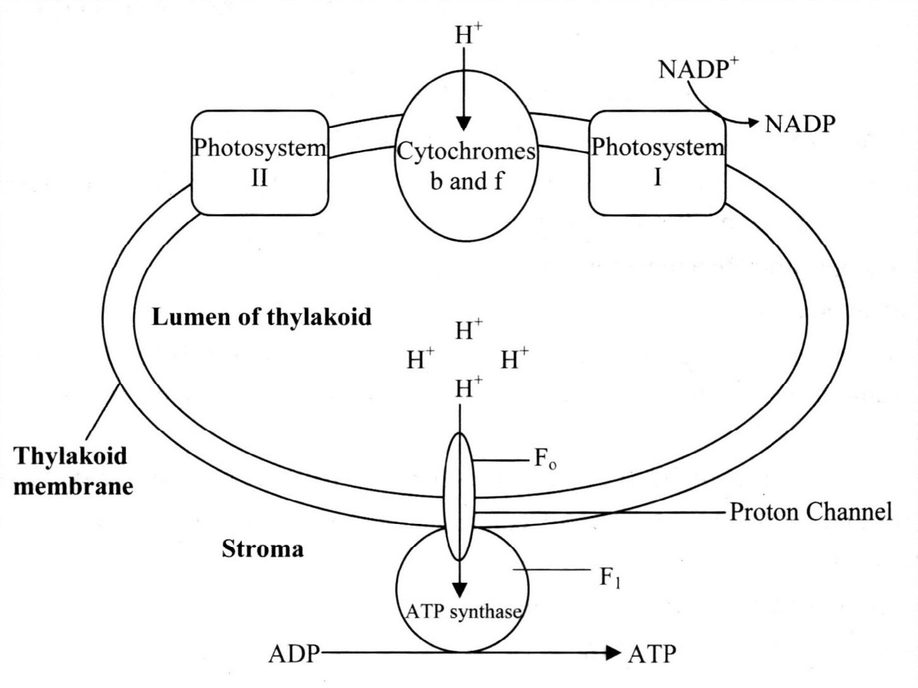
ix) The NADP reductase enzyme is located in the stroma side of the membrane.

x) For reduction of NADP to $NADPH_2$, protons are required along with electrons that come from ferredoxin.

xi) Hence, within the chloroplast, protons in the stroma decrease in number, while in the lumen, there is increase in the number of protons.

xii) This creates a proton gradient across the thylakoid membrane.

xiii) There is subsequent spontaneous movement of protons generating energy which is used for the synthesis of ATP.



ATP synthesis through Chemiosmosis

6.4 : Light Independent Reaction

Q.43.Give an account of Calvin cycle.

Ans:Calvin cycle: The entire process of dark reaction was traced by Melvin Calvin, an American scientist along with his associates. Hence, the process is called as Calvin cycle. Since the first stable product formed is a 3-carbon compound, it is also called as C_3 pathway and the plants are called C_3 plants. It is also called biochemical phase because in this phase, chemical form of energy, i.e. ATP is converted into biological form, i.e. Glucose. It is also called synthesis phase or secondary phase. Presence of dark reaction was first established by Blackman, so it is called Blackman's reaction.

The cycle is divided into the following phases :

a. Carboxylation phase :

RuBP (Ribulose-1 ,5-bisphosphate) accepts atmospheric CO_2 in the presence of enzyme RuBP carboxylase (RuBisCO) and forms a 6-carbon unstable compound. This unstable compound soon splits into two molecules of 3-carbon compound called PGA (Phosphoglyceric acid) in presence of the same enzyme :

$$\underset{(5C)}{RuBP} + \underset{(1C)}{CO_2} \xrightarrow[\text{RuBP Carboxylase}]{Mg^{++}} \underset{(6C)}{\text{Unstable compound}}$$

$$\underset{(6C)}{\text{Unstable compound}} + H_2O \xrightarrow[\text{RuBP Carboxylase}]{Mg^{++}} \underset{(3C)}{\text{2 molecules of 3-PGA}}$$

b. Reduction phase (utilization of assimilatory power) :

i) The phosphoglyceric acid molecules are first phosphorylated by using ATP to produce 1,3 di-phosphoglyceric acid.

ii) It is then reduced by using $NADPH_2$ to produce phosphoglyceraldehyde (PGAL) and inorganic phosphate is released.

3PGA + ATP ⟶ 1,3-diphosphoglyceric acid + ADP

1,3-diphosphoglyceric acid + $NADPH_2$ → 3PGAL + NADP + Pi.

iii) Some molecules of 3 PGAL are converted into its isomer dihydroxyacetone phosphate (DHAP) in presence of enzyme triose phosphate isomerase.

c) **Synthesis of sugar and Regeneration phase :**

Synthesis of sugar :

i) For the synthesis of one molecule of glucose, six molecules of RuBP and six molecules of CO_2 are required, i.e. six turns of Calvin cycle are required. for the synthesis of one molecule of glucose.

ii) Out of 12 molecules of PGAL, 2 molecules (i.e. 1/6th part) are used for the synthesis of glucose.

iii) A molecule of PGAL and DHAP combine together to form a molecule of fructose 1, 6- diphosphate as shown below :

3 PGAL + DHAP $\rightarrow$ Fructose-1,6-diphosphate
(3C) (3C) (6C)

[Note: Fructose-1,6-diphosphate is the first carbohydrate formed during this process]

iv) Fructose-1,6-diphosphate undergoes dephosphorylation to form fructose-6-phosphate which on isomerization forms glucose-6-phosphate.

v) Glucose-6-phosphate undergoes dephosphorylation to form glucose. Glucose, thus formed is either utilized or stored as starch.

Regeneration phase :

i) RuBP gets regenerated through many biochemical reactions called sugar phosphate interconversions.

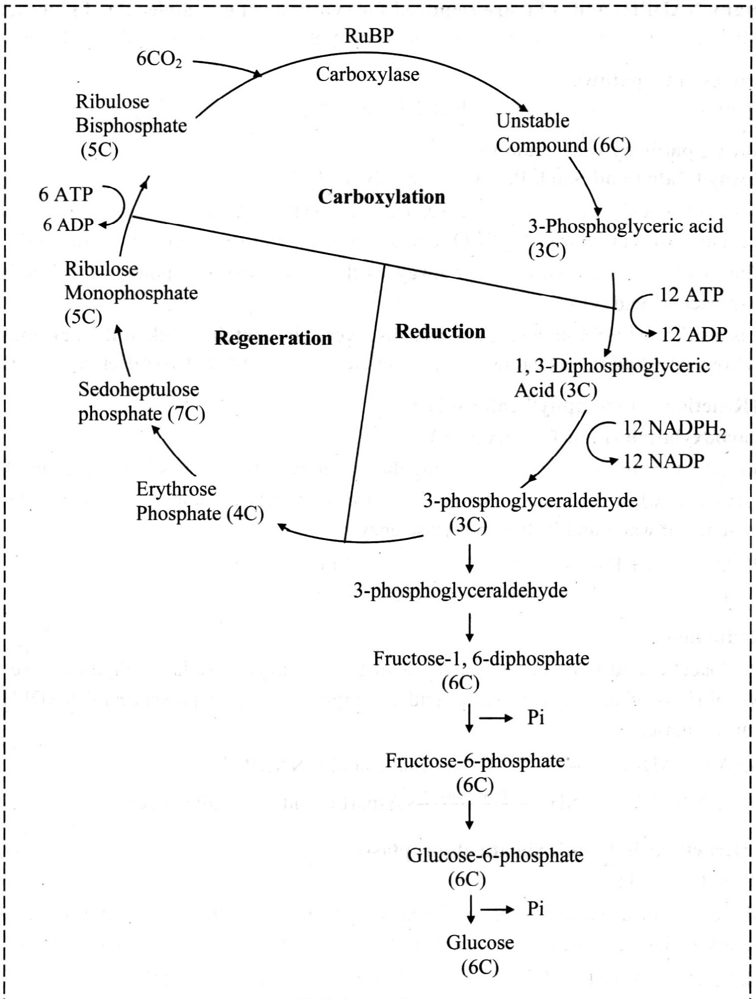
ii) All the intermediate compounds formed like erythrose-4-phosphate, xylulose-5-phosphate, ribose-5-phosphate, sedoheptulose-7-phosphate, etc. are sugar phosphates.

iii) Out of 12 molecules of PGAL, 10 molecules are utilized for the regeneration of 6 molecules of RuMP (ribulose monophosphate) which on phosphorylation form RuBP as shown below :

12 PGAL $\rightarrow$ 6 RuMP ...(i)

6 RuMP + 6 ATP $\rightarrow$ 6 RuBP ...(ii)

iv) Thus, RuBP which is necessary for the reduction of CO_2 is regenerated to keep the process going.



Calvin cycle

Significance of C_3 pathway :

i) CO_2 is reduced to form organic food in the form of 3-phosphoglyceraldehyde (3C) or glucose (6C) by using ATP and NADPH2. It can be utilized directly in plant metabolism or can be stored in the form of starch.

ii) ATP and $NADPH_2$ are utilized as energy and hydrogen donor to form ADP and NADP respectively for reuse in the photochemical (light) reaction.

Q.44. Which is the ultimate pathway for fIxing carbon dioxide (CO_2) into glucose? [Mar 2014]

Ans: C_3 pathway (Calvin cycle) is the ultimate pathway for fixing carbon dioxide (CO_2) into glucose.

Q.45. Which is the first CO_2 acceptor in C3 pathway ? [Oct 2014]

Ans: The first CO_2 acceptor in C_3 pathway is Ribulose -1, 5 - diphosphate (RUDP).

Q.46.How many ADPH2 and ATP are required for synthesis of one molecule of glucose?

Ans: 12 NADPH2 and 18 ATP molecules are required for synthesis of one molecule of glucose.

Q.47.Who proposed C4 pathway ?

Ans: The C_4 pathway was proposed by Hatch and Slack (1966).

Q.48.Describe C_4 pathway with examples.

Ans: C_4 pathway (Hatch and Slack Pathway) or H.S.K. Pathway :

i) Certain tropical' plants like maize, sugarcane, jowar, *Amaranthus, Portulaca, Chenopodium, Atriplex,* etc. have low concentration of CO_2 due to which they follow alternative pathway.

ii) This pathway is known as C_4 pathway as the first stable compound is a 4-carbon compound, i.e. Oxaloacetic acid (OAA).

iii) It is also called HSK pathway as it was discovered by **Hatch, Slack and Kortschak.** The reactions occuring in this pathway are completed in two parts at two different sites as given below :

Part I (Reactions in mesophyll chloroplasts):

i) Carboxylation (First CO_2 fixation) :

Initially, the atmospheric CO_2 entering the mesophyll chloroplasts is accepted by PEP A (Phosphoenol pyruvic acid), a 3-carbon compound to form a 4-carbon compound called Oxaloacetic acid in the presence of water and PEP carboxylase enzyme.

$$\underset{(3C)}{PEPA} + CO_2 + H_2O \xrightarrow{\text{PEP carboxylase}} \underset{(4C)}{OAA} + H_3PO_4$$

ii) Reduction :

Oxaloacetic acid is reduced to malic acid by the enzyme Malate dehydrogenase in the presence of NADPH2 or changed to aspartic acid by amination in the presence of NADPH2 and the enzyme transaminase.

$$OAA + NADPH_2 \xrightarrow{\text{Malate dehydrogenase}} \text{Malic acid} + NADP$$

$$OAA + NADPH_2 + NH_3 \xrightarrow{\text{Transa min ase}} \text{Aspartic acid} + NADP + H_2O$$

Part II (Reactions in bundle sheath chloroplasts)

i) Decarboxylation :

Malic acid or aspartic acid is then transported to the bundle sheath chloroplasts where it undergoes decarboxylation in the presence ofNADP to form pyruvic acid with the release of CO2.

$$\underset{(4C)}{\text{Malic acid}} + NADP \xrightarrow{\text{Malate dehydrogenase}} \underset{(3C)}{\text{Pyruvic acid}} + CO_2 + NADPH_2$$

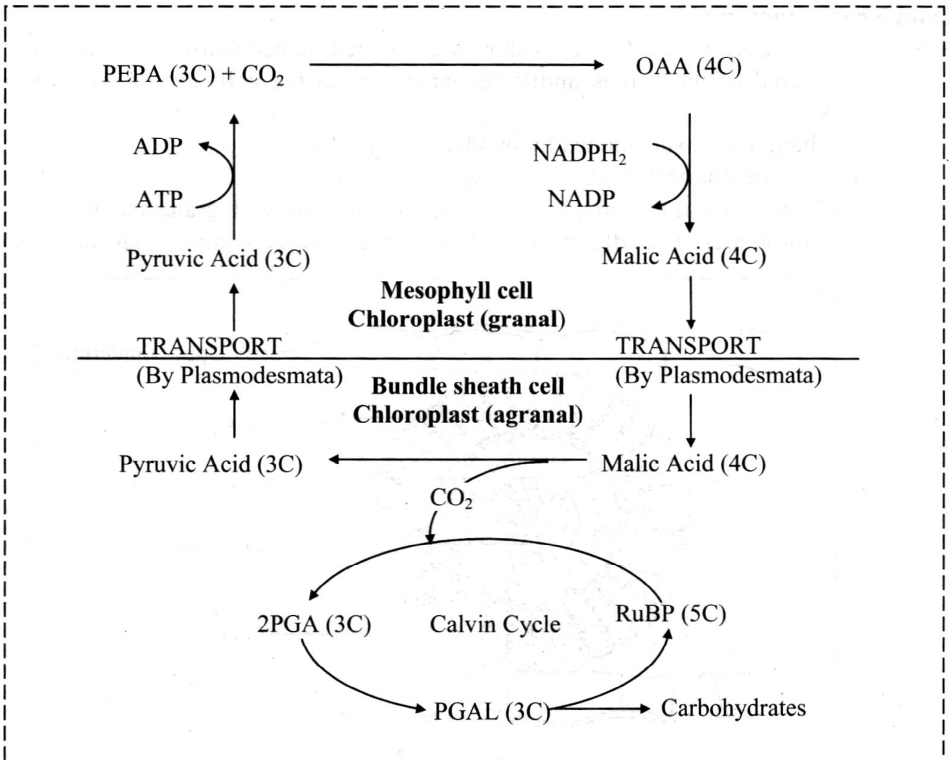
Note : In case if aspartic acid is formed, it undergoes deamination to form pyruvic acid.

ii) **Second CO_2 fixation :**

The released CO2 is accepted by RuBP (second carbon acceptor). It enters the Calvin cycle and eventually forms glucose which is stored as starch in bundle sheath chloroplasts. Pyruvic acid produced due to decarboxylation of malic acid is transported to mesophyll cells where it undergoes phosphorylation to regenerate PEPA as shown below :

$$\underset{(3C)}{\text{Pyruvic acid}} + ATP \xrightarrow{\text{Photophosphorylation}} \underset{(3C)}{PEPA} + ADP + Pi$$

iii) Thus, it is obvious that in C_4 plants, CO_2 is fixed twice in two different cells during the day time. CO_2 fixation in C_4 plants can occur at very low concentrations of CO_2, i.e. as low as photosynthesis even if the light intensity is high, temperature is high and the amount of available water is less.



C_4 Pathway

Q.49.Why light independent reactions cannot take place during day?

Ans:i) Light independent reactions do not require direct light.

ii) ATP and NADPH2 produced during the day time are used in light independent reactions. Hence, light independent reactions cannot take place during the day.

Q.50.RuBisCO is an enzyme that acts both as a carboxylase and oxygenase. Why do you think RuBis CO carries out more carboxylation in C_4 plants ?

Ans:i) RuBisCO which is the most abundant enzyme in the world can bind to both CO_2 and O_2 on its active sites.

ii) RuBisCO has much greater affinity for CO_2 than O_2. This binding is competitive.

iii) It is the relative concentration of O_2 and CO_2 which determines which of the two will bind the enzyme.

iv) The enzyme RuBisCO is absent in the mesophyll cells of C4 plants. It is present in the bundle-sheath cells surrounding the vascular bundles.

v) In C_4 plants, the Calvin cycle occurs in the bundle-sheath cells, and light reaction occurs in mesophyll cells. Such arrangement does not allow O_2 released in mesophyll cells to enter in bundle sheath cells.

vi) The primary CO_2 acceptor in the mesophyll cells is phosphoenol· pyruvate - a three-carbon compound. It is converted into the four-carbon compound oxaloacetic acid (OAA).

vii) In C_4 plants, a CO_2 concentrating mechanism is present which helps in reducing the occurrence of photorespiration.

viii) OAA is further converted into malic acid. Malic acid is transported to the bundle-sheath cells, where it undergoes decarboxylation and CO_2 fixation occurs by the Calvin cycle. This prevents the enzyme RuBisCO from acting as an oxygenase.

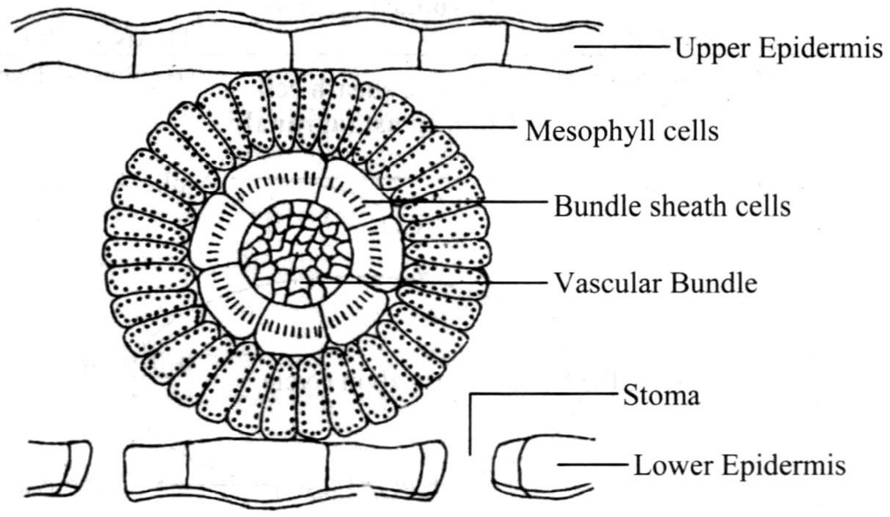
Q.51.Explain Kranz anatomy.

Ans: Kranz anatomy : Leaves of the C4 plants show some structural peculiarities called Kranz anatomy.

i) The mesophyll of the leaf is undifferentiated, i.e. all the cells are of one type and are compactly arranged.

ii) Vascular bundles are surrounded by bundle sheath cells.

iii) Chloroplasts are dimorphic, i.e. of two types :
   a) Chloroplasts of mesophyll cells are smaller and are with grana and arranged centrifugally.
   b) Chloroplasts of bundle sheath cells are larger and are without grana and arranged centripetally.



Kranz anatomy

Q.52. What is 'photorespiration'? Explain it with diagrammatic representation. [Mar 2014]

Ans: Photo respiration :

The process of respiration (oxidation) that is initiated in the chloroplast and takes place in the presence of light is called photorespiration.

Mechanism:

i) Ribulose bisphosphate carboxylase (main enzyme of Calvin cycle) has an ability to combine both CO_2 (carboxylation) and O_2 (oxygenation) with ribulose biphosphate (RuBP). Hence, the enzyme is called ribulose biphosphate carboxylase oxygenase (RuBisCO). In intense light, at low concentration of CO_2 (less than 1%) and increased concentration of O_2, the enzyme brings about oxygenation of RuBP to phosphoglycolate (2C) and PGA (3C)

ii) Phosphoglycolate loses phosphate group to form glycolate and PGA is used in Calvin cycle.

iii) Glycolate synthesized in chloroplast is an early product which moves to peroxisomes. Glycolate is oxidized to glyoxylate and hydrogen peroxide with the help of enzyme oxidase.

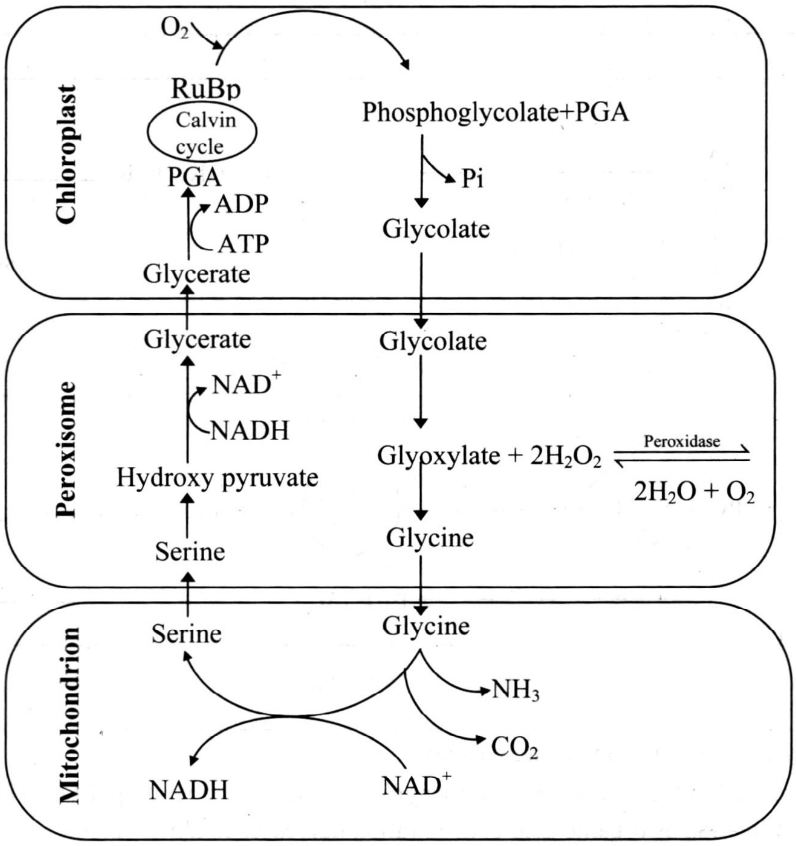
iv) Glyoxylate is converted into amino acid glycine by transamination reaction in presence of enzyme transaminase.

v) Glycine is then transported to mitochondria where two molecules of glycine interact to form one molecule of NH_3, one molecule of CO_2 and one molecule of serine.

vi) Serine is taken up by peroxisome and through a series of reactions, it gets converted into glycerate which enters the chloroplast and gets phosphorylated to form PGA.PGA enters Calvin cycle to make carbohydrates. In this process, one ATP molecule gets converted into ADP. Thus, 75% of the carbon lost by oxygenation of RuBP is recovered, but 25% is lost as release of one molecule of CO_2.

vii) Photorespiration is also called photosynthetic carbon oxidation cycle. It protects the plants from photo-oxidative damage.

viii) Photorespiration works to undo the act of photosynthesis as no energy rich compound (neither ATP nor $NADPH_2$) is produced in this process. Thus, it is a wasteful process. In high temperature and oxygen concentration, affinity of RuBP carboxylase for CO_2 decreases and for O_2 increases. Thus, photo respiration interferes with the process of photosynthesis. (In C_4 plants, photorespiration does not occur because they have the mechanism that increases the concentration of CO_2 at enzyme site).



Photorespiration

Q.53.Explain how photo respiration is avoided in C_4 plants ?

Ans: Photorespiration occurs in intense light and low concentration of CO_2 (less than 1%). However, in C_4 plants, light reaction and evolution of O2 takes place in mesophyll cells and absorption of CO_2 by RuBP takes place in bundle sheath cells.In the bundle sheath cells, CO2 concentration is more. Thus, possibility of oxygenation ofRuBP is avoided and photorespiration does not take place.

Q.54.Explain Crassulacean Acid Metabolism (CAM).

Ans: Crassulacean Acid Metabolism (CAM) is a specialized photosynthetic process which is characterized by the following criteria :

i) CO_2 uptake takes place mainly at night.

ii) Stomata are open during the night and are closed during the day, when CO_2 uptake is almost negligible.

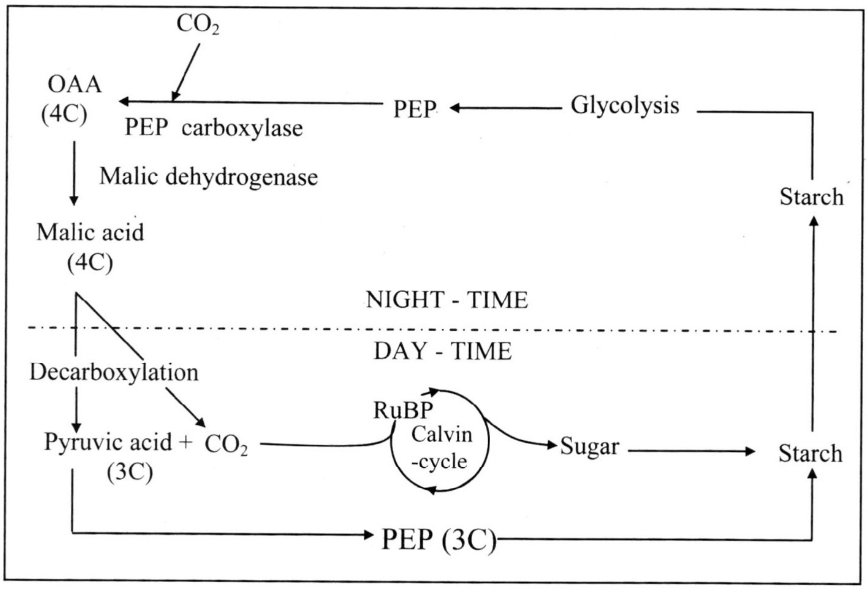
iii) Malate accumulates at night by carboxylation of PEP.

iv) Decarboxylation of malate during day yields CO_2 which is fixed by RuBP carboxylase. CAM has been named after the Family Crassulaceae in which the phenomenon was first observed. The examples exhibiting CAM are cacti, *Opuntia, Bryophyllum, Kalanchoe*, Pineapple, etc. In such plants, which grow in dry condition, stomata remains closed during day to check the loss of water due to transpiration. Thus, they show different mechanism for photosynthesis. The process of CAM is as follows :

During night time (when stomata are open):

i) CO_2 is absorbed and fixed by Phosphoenol.pyruvic acid (PEP,3C) in presence of enzyme PEP carboxylase. As a result of this, PEP gets converted into Oxaloacetic acid (OAA,4C).

ii) OAA (4C) further gets transformed into malic acid (4C) in presence of enzyme malic dehydrogenase. This process is called acidification as CO_2 is fixed in acids.



CAM Pathway

During day time (when stomata are closed) :

i) The malic acid gets converted into pyruvic acid (3C) liberating CO_2. This process is called deacidification as organic acid concentration decreases to almost zero.

ii) This CO2 then enters the Calvin cycle to prepare carbohydrates.

iii) Pyruvic acid gets converted into carbohydrates by reverse glycolysis. Thus, during night time, organic acid concentration of succulents increases and during day time, it decreases to almost zero. This day and night fluctuation in acid concentration is an essential feature of CAM plant.

Q.55.In CAM plants, why acid concentration increases during night ?

Ans: In CAM plants, malic acid accumulates during night, which is formed from Oxaloacetic acid in presence of the enzyme malate dehydrogenase.

Q.56.Even though a very few cells in C_4 plants carry out the biosynthetic - Calvin pathway, yet they are highly productive. Why ?

Ans: Although a very few cells in a C_4 plant carry out the biosynthetic-Calvin pathway, yet they are highly productive. This is due to the following reasons :

i) Caplants have a high value of net assimilation at high temperatures.

ii) Their rate of carbon assimilation is quite rapid.

iii) C_4 plants perform photosynthesis even when stomata are closed as PEP has high affinity for CO_2.

iv) Their rate of net photosynthesis at full sunlight is as high as 40 - 80 mg $CO_2/dm^2/hr$.

Q.57.Give the significance of C_3 pathway and C_4 pathway.

Ans: Significance of C_3 pathway:

i) Helps in the formation of carbohydrate by reduction of CO_2

ii) It utilizes ATP and $NADPH_2$ to form ADP and NADP, which are used in light reaction.

Significance of C_4 pathway :

i) C_4 plants can grow well in the regions having water scarcity.

ii) C_4 plants can photosynthesize at high temperature and high intensity of light.

iii) PEP carboxylase is more efficient and can absorb CO_2 (though the concentration of CO_2 is less).

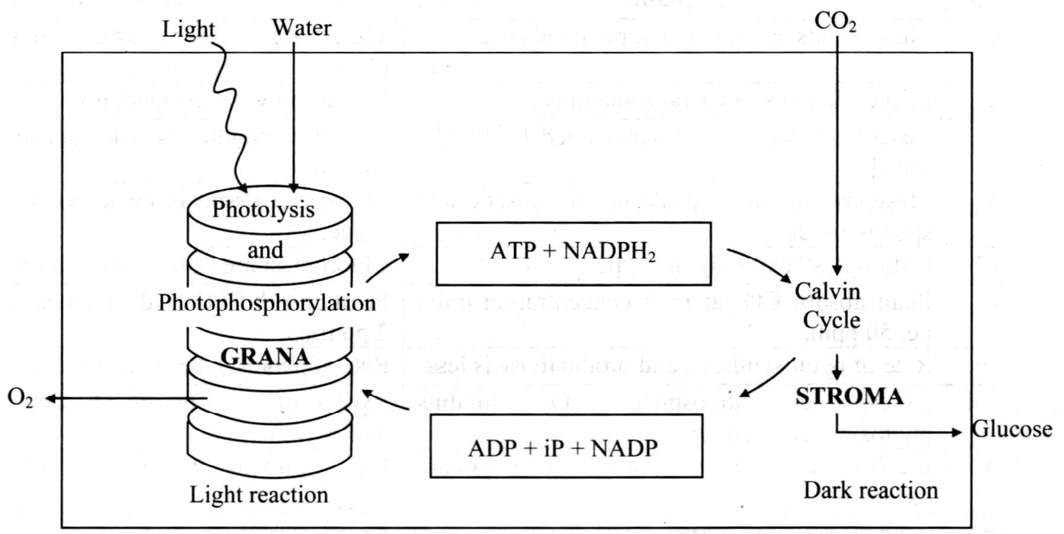
iv) Productivity of C_4 plants is more than C_3 plants.

Q.58. Write a note on interdependence of light and dark reactions of photosynthesis.

Ans:i) The two reactions of photosynthesis, i.e. light and dark reactions are dependent on each other, because neither of them can continue the process of photosynthesis alone.

ii) For example, light reaction of photosynthesis generates ATP and $NADPH_2$ which are necessary for the fixation of carbon dioxide and formation of carbohydrate from it.

iii) During dark reaction, ATP and $NADPH_2$ are transformed into ADP and NADP which are transferred to grana in which light reaction takes place.
iv) ADP and NADP get recharged to form ATP and $NADPH_2$ to continue the fixation of CO_2 and formation of carbohydrate from it in dark reaction.
v) Hence, light and dark reactions of photosynthesis are interdependent.



Interdependence of light and dark reaction

Q.59.Distinguish between Light and Dark Reaction.
Ans:

No.	Light Reaction	Dark Reaction
i)	It is a photochemical process.	It is a biochemical process.
ii)	It takes place in the presence of light	It is independent of light.
iii)	It takes place in the grana of chloroplast	It takes place in the stroma of chloroplast
iv)	Synthesis of ATP and $NAdPH_2$ takes place	Utilization of ATP and $NADPH_2$ takes place.
v)	It involves photolysis of H_2O.	It involves fixation of CO_2
vi)	Oxygen is released.	Carbohydrate is produced.

Q.60. Distinguish between C_3 and C_4 pathway. **[Sep 2008]**
Ans:

No.	C_3 Pathway	C_4 Pathway
i)	C_3 Pathway operates in algae, bryophytes and most of the vascular plants. e.g. wheat, oat, mango, China rose, etc.	C_4 Pathway operates in few higher vascular flowering plants. e.g. maize, sugarcane, *Sorghum, Amaranthus, Portulaca, etc.*
ii)	The primary acceptor of CO_2 is RuBP which is a 5-carbon compound.	The primary CO_2 acceptor is phosphoenol pyruvic acid (PEPA), which is a 3-carbon compound.
iii)	The first stable compound is three carbon compound called Phosphoglyceric acid (PGA)	The first stable compound is Oxaloacetic acid (OAA), a four carbon compound.
iv)	Plants show normal leaf anatomy	Plants show Kranz anatomy of leaf
v)	CO_2 is accepted when CO_2 concentration is more than 50 ppm	CO_2 is accepted even if CO_2 concentration is as low as 1-2 ppm.
vi)	The rate of photosynthesis is affected, when photorespiration occurs.	Photorespiration is avoided.
vii)	Opitmum temperature for the process is 10^o to 30^o C.	Optimum temperature for the process is 30^o to 45^o C.

Q.61. Distinguish between C_3 and C_4 plants.

Ans:

No.	C_3 Pathway	C_4 Pathway
i)	These plants re mostly temperate plants.	These are mostly tropical and subtropical plants
ii)	Leaves do not show Kranz anatomy	Leaves show Kranz anatomy.
iii)	Vascular bundle is not surrounded by bundle sheath.	Vascular bundle is surround by bundle sheath
iv)	Mesophyll tissue is made up of palisade and spongy tissue.	Mesophyll tissue is made up of only spongy tissue.
v)	Chloroplast is of only one type.	Chloroplast are of two types (dimorphic).
vi)	Plant absorb CO_2 at high concentration only, i.e. 50 ppm.	Plant absorb CO_2 at low concentration, i.e. 1–2 ppm.
vii)	Rate of photosynthesis and productivity is less.	Rate of photosynthesis and productivity is high.
viii)	Excess of atmospheric O_2 inhibits	Excess of atmospheric O_2 has no effect on photosynthesis.
ix)	E.g. Hibiscus, sunflower, wheat, rice potato, etc.	E.g. Sugarcane, maize, jowar, Amaranthus, etc.

6.5 : Significance of photosynthesis

Q.62. Write briefly about significance of photosynthesis.

Ans:Significance of photosynthesis :

i) Photosynthesis is the most important natural process during which light energy is trapped and converted into chemical form of energy.

ii) Photosynthesis involves synthesis of food. Plants use this food as a source of energy and this food is made available for all heterotrophic organisms. All living organisms, directly or indirectly depend on this process for energy. (except chemoautotrophs.)

iii) Photosynthesis releases O2, which is indispensable for life, maintains balance of O_2 and CO_2 in the atmosphere and helps to purify air. (Oxygen in the atmosphere may be used for ozone formation.)

iv) Various fossil fuels like coal, petroleum and natural gas are products of photosynthesis occurred in the geological past.

v) The plant products, such as cotton, alkaloids, resins, gums, tannins, steroids, rubber, timber, etc. are the products of photosynthesis, and are economically important.

Q.63. "Photosynthesis protects us from the harmful effects of ultraviolet radiations of the sun". Comment on the statement.

Ans:i) Oxygen released during photosynthesis gives rise to the layer of ozone which forms the uppermost layer of atmosphere, i.e. troposphere.

ii) Ozone prevents the ultraviolet rays of sun from entering the atmosphere of the earth to protect the living beings from its ill-effects like skin cancer.

6.6 : Factors affecting rate of photosynthesis

Q.64. Explain the factors affecting rate of photosynthesis.

Ans: The rate of photosynthesis is controlled by a number of factors such as:

External factors :

i) Light : Light is essential for photosynthesis as it provides energy for photosynthesis. The quality, intensity and duration of light influence the rate of photosynthesis significantly.

a) Quality : Light between the wavelength 400 nm and 700 nm is most effective for photosynthesis. Maximum photosynthesis takes place in red light and minimum in green light.

b) Intensity : The rate of photosynthesis steadily increases with the light intensity. However, if light intensity increases beyond a certain point, the chlorophyll undergoes photo-oxidation and is destroyed.

c) Duration : Longer duration of light favours photosynthesis. Generally if the plants get 10 to 12 hours of light per day, it favours good photosynthesis.

ii) **CO_2:** The low concentration of CO_2 (0.03%) in the atmosphere acts as a limiting factor in natural photosynthesis,when other environmental factors (light temperature, water, etc) are optimum. If the CO_2 supply is increased up to a certain limit, the rate of photosynthesis increases. However, very high concentration of CO_2 becomes toxic to the plants.

iii) **Water :** Water deficiency may decrease the rate as it is one of the raw materials for the process. Less availability of water may further check the rate by closing the stomata, thereby affecting the entry of CO_2

iv) **Temperature :** The optimum range of temperature for photosynthesis is from 10°C to 35°C.The rate of photosynthesis increases by increase in temperature upto 40°C. If temperature is increased too high, the rate of photosynthesis is also reduced due to denaturation of enzymes involved in the process.

v) **Oxygen :** Excess of oxygen may have inhibitory effect on photosynthesis. Enhanced supply of O_2 increases the rate of respiration and simultaneously decreasing the rate of photosynthesis by utilizing the common intermediate substances. Besides, O_2 destroys the excited state of chlorophyll and thus inhibits photosynthesis.

Q.65. Explain Blackmann's law of limiting factors.

Ans: i) In 1905, Blackmann proposed the law of limiting factors according to which, "when a process is conditioned to its rapidity by a number of factors, the rate of process is limited by the pace of the slowest factor.",

ii) He studied the effect of CO_2 concentration, light intensity and temperature on the rate of photosynthesis.

iii) According to him, for every factor, there is a minimum value when no photosynthesis occurs, an optimum value showing highest rate and maximum value above which photosynthesis fails to take place.

iv) For example, if optimum light and CO_2 is available and temperature is very low, then rate of photosynthesis will be controlled by temperature, i.e. it will increase with increase in temperature arid then, there will be a steady state.

v. Further increase in rate is possible only if there is increase in CO_2 concentration. Again, there will be steady state and further increase is possible if intensity of light increases.

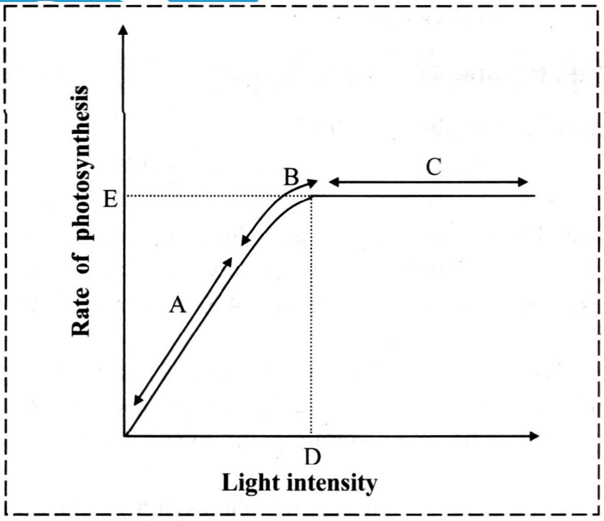
vi) Thus, at a time only one factor controls the rate of photosynthesis and is called as limiting factor.

Q.66.Figure given below shows the effect of light on the rate of photosynthesis. Based on the graph , answer the following questions :

i. At which point/s (A, B or C) in the curve light is a limiting factor ?

ii. What could be the limiting factor/s in region A ?

iii. What do C and D represent on the curve ?



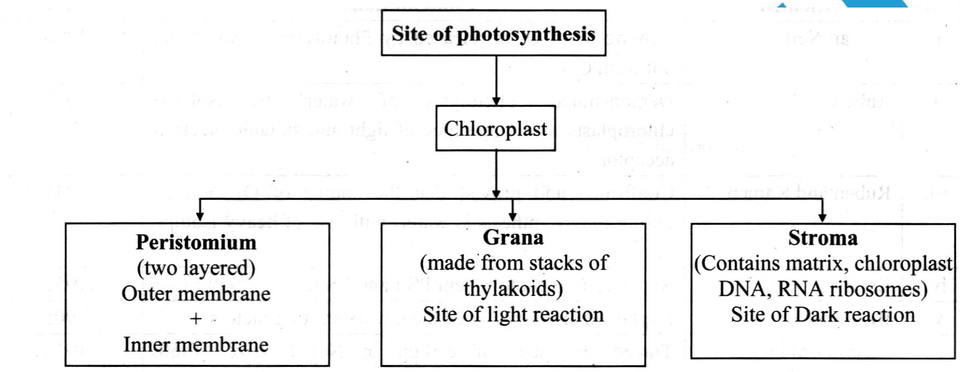
Ans:i) At point B

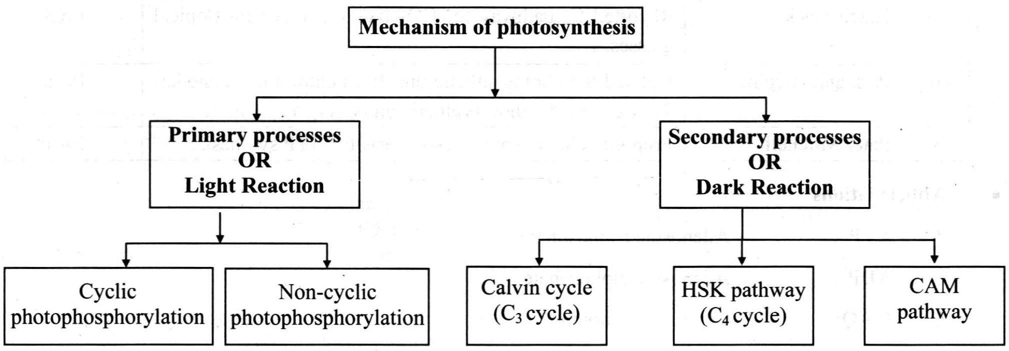
ii) Carbon dioxide concentration and quantity of water may be the limiting factor in region A.

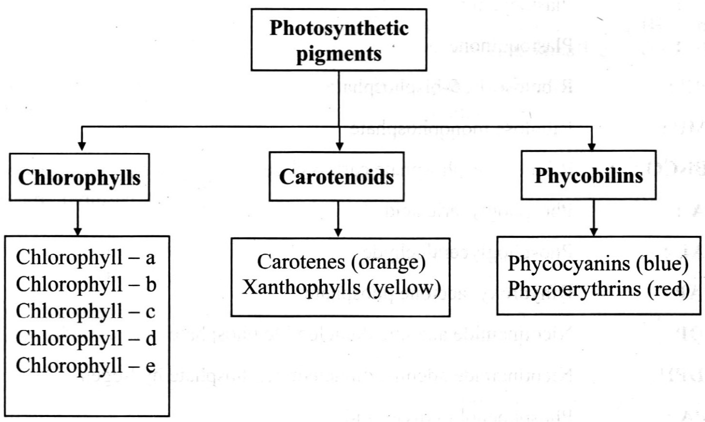
iii) C represents that rate of photosynthesis fails to increase, even by increasing light intensity because some other factor like CO_2 has become limiting. D is the light saturation point where the maximum amount of photosynthesis is achieved.

Additional Theory Questions

Q.1. Explain how photosynthesis is a mode of autotrophic nutrition? *Refer Q.2.*
Q.2. Draw a well labelled diagram of ultrastructure of chloroplast. *Refer Q.6.*
Q.3. Describe Hill's reaction. [Sept 2009] *Refer Q.30.*
Q.4. Write a short note on Hill's reaction. *Refer Q.30.*
Q.5. Give diagrammatic representation of non-cyclic photophosphorylation. *Refer Q.33.*
Q.6. Explain the process of cyclic photophosphorylation. [Mar 2013 Old Course] *Refer Q.36.*
Q.7. Explain briefly Calvin cycle. [Sept 2009] *Refer Q.43.*
Q.8. Describe C_3 pathway and give its significance. [Mar 2008] *Refer Q.43.*
Q.9. Give schematic representation of Calvin Cycle. *Refer Q.43.*
Q.10. Describe H.S.K. pathway of photosynthesis. [Mar 2010] *Refer Q.48.*
Q.11. Give schematic representation of HSK pathway. *Refer Q.48.*
Q.12. Describe dicarboxylic acid cycle. *Refer Q.48.*
Q.13. Draw a labelled diagram ofT.S. ofa leaf showing Kranz anatomy. [Oct 2014] *Refer Q.51.*
Q.14. What is photorespiration? Give its diagrammatic representation. [Oct 2013] *Refer Q.52.*
Q.15.Explain how photosynthesis takes place during day in spite of stomata being closed, in certain plants. *Refer Q.54.*
Q.16. Describe the ultrastructure of chloroplast. Add a note on the significance of photosynthesis. [Mar 2013] *Refer Q.6 and 62.*







- **Scientists and their contribution**

No.	Scientists	Contribution	Year
i)	C. Van Neil	Reported that O_2 is released by Photolysis of water and	1930
ii)	Robert Hill	not from CO_2 Demonstrated 'Photolysis of water' by isolated chloroplasts in the presence of light and suitable electron acceptor.	1937
iii)	Ruben and Kamen	Confirmed and proved that the source of O_2 evolved during photosynthesis is water, with use of heavy isotope of oxygen.	1941
iv)	Emerson et.al.	Reported two photosystem PS I and PS II.	1957
v)	Blackman	Explained and formulated the law of limiting factor	1905
vi)	Melvin Calvin	Traced the path of carbon in Nobel Prize, 1960 Photosynthesis and established C_3 cycle.	1954
vii)	Hatch Slack	Reported C_4 pathway for CO_2 fixation in certain tropical grasses	1965
viii)	Park and Biggins	Isolated the photosynthetic unit from chloroplast Iamellar	1946
ix)	Pater Mitchell	Proposed chemiosmotic hypothesis for ATP synthesis.	1961

- **Abbreviations**

*** ATP : Adenosine triphosphate**
*** ADP : Adenosine diphosphate**
*** Co-Q : Co-enzyme quinone**
*** FRS : Ferredoxin Reducing Substance**
*** PC : Plastocyanin**
*** PQ : Plastoquinone**
*** RuBP : Ribulose-1 , 5-bisphosphate**
*** RuMP : Ribulose monophosphate**
*** RuBisCO : Ribulose bisphosphate carboxylase**
*** PGA : Phosphoglyceric acid**
*** PGAL : Phosphoglyceraldehyde**
*** DHAP : Dihydroxy acetone phosphate**
*** NADP : Nicotinamide adenine dinucleotide phosphate**
*** $NADPH_2$: Nicotinamide adenine dinucleotide phosphate hydrogen**
*** PEPA : Phosphoenol pyruvic acid**
*** OAA : Oxaloacetic acid**

Multiple Choice Question

1. Photosynthesis is reaction.
a) oxidation b) reduction
c) redox d) electrochemical
2. Oxygen liberated during photosynthesis comes from
a) CO_2 b) glucose
c) H_2O d) chlorophyll
3. Which of the following is not required for Hill's reaction ?
a) Sunlight b) Chlorophyll
c) Water d) Carbon dioxide
4. C_4 cycle was discovered by
a) Hill b) Calvin
c) Hatch and Slack d) Blackmann
5. Which of the following shows' chloroplast dimorphism ?
a) Sugar beet b) Sugar cane
c) Potato d) Papaya
6. Which one of the following is C_4 plant ? **[Oct 2014J**
a) Sunflower b) Soyabean
c) Sugarcane d) Spinach
7. PS – I gets de-energized electrons from
a) water b) plastoquinone
c) plastocyanin d) cytochrome-f
8. Which of the following was used in the study of dark reactions of photosynthesis ?
a) *Hydrilla*
b) *Chlorella and Scenedesmus*
c) *Chlamydomonas*
d) *Chlorella and Spirogyra*
9. During light reaction of photosynthesis, how many photons are required for evolution of one O_2?
a) Six b) Eight
c) Four d) Two
10. One-sixth part of the total PGAL produced, is used for the synthesis of
a) glucose b) RUBP
c) RUMP d) DHAP
11. CAM plants are mostly
a) Tropical plants b) Succulents
c) Monocots d) Mangroves
12. The internal source of CO_2 in CAM plants is
a) oxaloacetic acid
b) malic acid
c) RUBP
d) phosphoenol pyruvic acid
13. Which pigment is absent in chloroplast ?
a) Xanthophyll b) Anthocyanin
c) Chlorophyll-b d) Carotene
14. ATP is a source of energy for____
a) light reaction in C_4 plants.
b) photophosphorylation.
c) biochemical reaction.
d) photolysis of water.
15. In C_4 pathway, in which of the following cells is metabolic CO_2 fixed ?
a) Bundle sheath cells b) Mesophyll cells
c) Epidermal cells d) Cortical cells
16. During photosynthesis, the process which occurs first is
a) photolysis of water.
b) ionization of chlorophyll.
c) synthesis of ATP
d) synthesis of $NADPH_2$
17. Grana are connected by
a) inter-granal membranes
b) stroma lamellae
c) both a) and b)
d) thylakoids
18. Granum is made up of
a) stroma b) matrix
c) grana lamallae d) thylakoids
19. Quantasomes contain____ molecules 'of pigments.
a) 150-200 b) 200-250
c) 250-280 d) 280-320
20. The molecular formula for chlorophyll-a is
a) $C_{55}H_{72}O_5N_4Mg$
b) $C_{55}H_{70}O_6N_4Mg$
c) $C_{40}H_{56}$ d) $C_{40}H_{56}O_2$
21. Photosynthesis is minimum in____ light.
a) green b) blue
c) red d) yellow
22. From the visible spectrum of light, which component is reflected by the green leaves ? **[Mar 2014J**
a) Blue b) Red
c) Green d) Orange
23. Chlorophyll a and b absorb and ____light respectively.
a) blue and green b) red and green
c) blue and red d) red and violet
24. Which of the following lights are absorbed by carotene and xanthophylls ?
a) Green b) Blue
c) Yellow d) Violet
25. Which of the following is not an accessory pigment ?
a) Chlorophyll-b b) Xanthophyll
c) Chlorophyll-a d) Carotene
26. The energy of each photon is called
a) quantasome b) radiant
c) quantum d) wavelength
27. Which of the following was used in Hill's reaction ?
a) Chloroplast b) Fe salts
c) Haemoglobin d) Both b) and c)
28. Light reactions occur in
a) stroma b) grana
c) matrix d) fret
29. In cyclic photophosphorylation, the first electron acceptor is
a) FRS b) CO-Q
c) Plastocyanin d) Cytochrome f

30. In non-cyclic photophosphorylation, the first electron acceptor is
a) FRS b) CO-Q
c) Plastocyanin d) Cytochrome f

31. In cyclic photophosphorylation,ATP IS synthesized during
a) ferrodoxin – cytochrome b_6
b) cytochrome b_6– cytochrome f
c) cytochrome f – plastocyanin
d) cytochrome b_6 - plastocyanin

32. In non-cyclic photophosphorylation, the electrons released by Ferredoxin are accepted by
a) PQ b) Plastocyanin
c) NADP d) Water

33. Dark reaction takes place in
a) Stroma b) Grana
c) Matrix d) Thylakoid

34. Due to photorespiration, approximately____ of photosynthetically fixed CO_2 is lost.
a) 25% b) 50%
c) 60% d) 80%

35. In dark reaction, the first compound to accept CO_2 is
a) RuMP b) RuBP
c) PGAL d) PGA

36. Which of the following is the first stable product of photosynthesis in Maize ?
a) PGA b) PGAL
c) PEPA d) OAA

37. Which of the following is immediately used to produce sugar and then starch in C3 pathway?
a) PGAL b) PGA
c) OAA d) DPGA

38. How many Calvin cycles are required to produce one molecule of glucose?
a) 3 b) 4
c) 5 d) 6

39. How many $NADPH_2$ molecules are required to produce one glucose molecule?
a) 8 b) 10
c) 12 d) 14

40. Which of the following is a photochemical reaction?
a) Light reaction b) C_3 pathway
c) C_4 pathway d) CAM pathway

41. Which of the following is a biochemical reaction ?
a) Light reaction
b) Cyclic electron transfer
c) Photolysis of water
d) Dark phase

42. The first CO_2 acceptor in C_4 pathway is
a) Pyruvic acid
b) Phosphoenol pyruvic acid
c) OAA
d) Malic acid

43. Which of the following enzymes fix CO_2 in C_4 pathway ?
a) RuBP carboxylase b) PEP carboxylase
c) Both a) and b) d) PEP kinase

44. C_4 plants show
a) Kranz anatomy b) Wreath anatomy
c) Both a) and b) d) Mosaic anatomy

45. Photolysis of water is a characteristic feature of
a) cyclic photophosphorylation
b) non-cyclic photophosphorylation
c) C_3 pathway
d) C_4 pathway

46. NADP stands for
a) Nicotinamide Adenine Diphospho Nucleotide
b) Nicotinamide Adenine Dinucleotide Phosphate
c) Nicotine Adenine Dinucleotide Phosphate
d) Both a) and b)

47. Which of the following is not a 4_C compound in C_4 pathway ?
a) RuBP b) OAA
c) Malic acid d) Aspartic acid

48. If light is cut and CO2 supply is continued, then which of the following substances will get. disappeared from photosynthesizing algal cells?
a) RuBP b) PGAL
c) RUMP d) PGA

49. Which of the following factors is not limiting ?
a) CO_2 concentration b) Light intensity
c) Temperature d) Water

Answer Keys

1. c)	2. c)	3. d)	4. c)	5. b)	6. c)	7. c)	8. b)	9. c)	10. a)
11. b)	12. b)	13. b)	14. c)	15. a)	16. b)	17. c)	18. d)	19. b)	20. a)
21. a)	22. c)	23. c)	24. c)	25. c)	26. c)	27. d)	28. b)	29. a)	30. b)
31. b)	32. c)	33. a)	34. a)	35. b)	36. d)	37. a)	38. d)	39. c)	40. a)
41. d)	42. b)	43. c)	44. a)	45. b)	46. b)	47. a)	48. a)	49. d)	