MtG

5500+Chapterwise-Topicwise MCQs

Strictly based on MAHARASHTRA Board

SAMPLE CHAPTER

• This is an actual chapter pulled out of this book

• This most awaited book will hit the book-shops by 10th March' 16

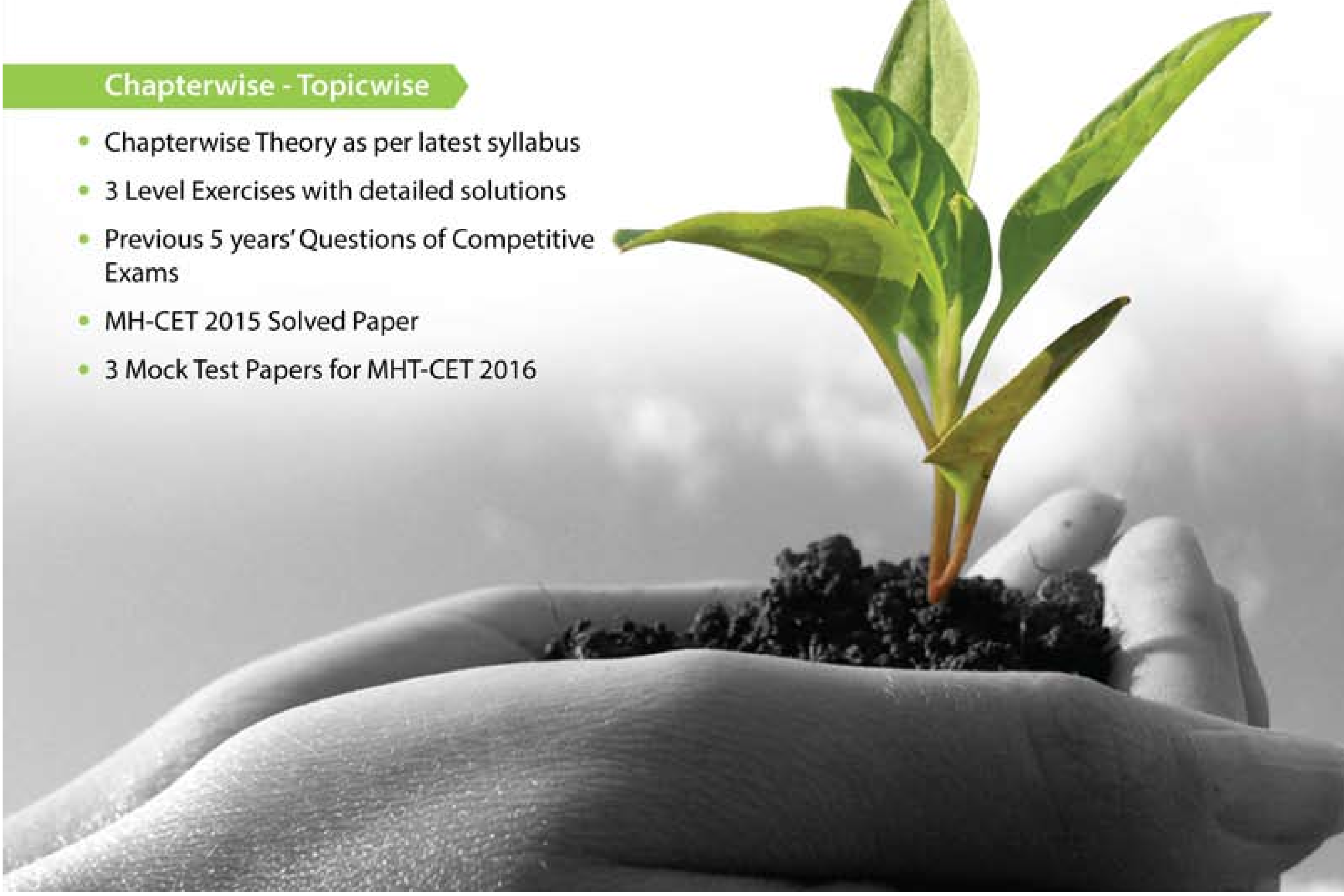
OBJECTIVE MHT-CET

MAHARASHTRA MEDICAL ENTRANCE EXAMINATION

BIOLOGY

Chapterwise - Topicwise

- Chapterwise Theory as per latest syllabus
- 3 Level Exercises with detailed solutions
- Previous 5 years' Questions of Competitive Exams
- MH-CET 2015 Solved Paper
- 3 Mock Test Papers for MHT-CET 2016



6 Photosynthesis

Contents at a Glance

Introduction

- Photosynthesis (Gk. *photos* – light, *synthesis* – putting together) is an enzyme regulated anabolic process of manufacturing organic compounds inside the chlorophyll containing cells from carbon dioxide and water with the help of sunlight as a source of energy. The overall equation of photosynthesis is as follows :

$$6CO_2 + 12H_2O \xrightarrow[\text{Radiant Energy (686 kcal)}]{\text{Chlorophyll } a\text{, Enzymes}} C_6H_{12}O_6 + 6H_2O + 6O_2 \uparrow$$

Autotrophic nutrition

- Organisms which prepare their own food are said to be autotrophs having autotrophic mode of nutrition.
- Most of the members of Kingdom Plantae, Protists like diatoms, prokaryotes like cyanobacteria, few bacteria like purple sulphur bacteria (*Chromatium*) and green sulphur bacteria (*Chlorobium*) use solar energy to synthesise their own food by a physico-chemical process. These are photosynthetic autotrophs also called **photoautotrophs**.
- There are some organisms, which prepare their food by chemosynthesis, *i.e.* they use energy released during chemical reactions for synthesis of food. They are known as chemoautotrophs. Bacteria such as, nitrifying bacteria (*Nitrosomonas*), sulphur bacteria (*Thiobacillus*), and iron bacteria (*Ferrobacillus*) are chemosynthetic autotrophs. They do not have photosynthetic pigments.

Early experiments

- However, the function of water is to provide hydrogen for the synthesis of organic compounds. All the liberated oxygen comes from it.

Table : History of photosynthesis

1.	Blackman (1905)	Discovered two steps, *i.e.*, light and dark reactions in photosynthesis. He further proposed the 'law of limiting factors'.
2.	Van Niel (1930)	Observed that during bacterial photosynthesis hydrogen sulphide was broken down to hydrogen and sulphur. He also propounded that oxygen is evolved from water.
3.	Robert Hill (1937)	He proved that during photosynthesis water splits. It is called photolysis of water or Hill reaction.
4.	Ruben and Kamen (1941)	They proved that the source of O_2 evolved during photosynthesis is water.
5.	Dr. Arnon (1954)	He discovered that the substance present in the chloroplast acting as H-acceptor is a co-enzyme, Nicotinamide Adenine Dinucleotide Phosphate (NADP).

- It was **Van Niel** (1930), a graduate student, who observed that during bacterial photosynthesis hydrogen sulphide was broken down to hydrogen and sulphur. The hydrogen reduces carbon dioxide to synthesise carbohydrate and sulphur is accumulated as a waste product. He also propounded that oxygen is evolved from **water.**

$$12H_2S + 6CO_2 \xrightarrow[\text{Bacterio-chlorophyll}]{\text{Light}} C_6H_{12}O_6 + 12S + 6H_2O$$

- **Robert Hill** in 1937 suspended isolated chloroplast from spinach leaves in water which lacks CO_2. He added ferric salts as hydrogen acceptor to it and exposed the suspension to sunlight. The ferric salts are reduced to ferrous and O_2 evolved, proving that H_2O splits. This is known as Hill reaction which is represented as:

$$2H_2O + 2A \xrightarrow[\text{Chlorophyll}]{\text{Sunlight}} 2AH_2 + O_2$$

where *A* represents hydrogen acceptor.

- **Ruben** and **Kamen** (1941) and **Ruben** *et al.* (1941) suspended *Chlorella* in water having heavy isotope of oxygen ^{18}O, instead of natural oxygen ^{16}O. The suspension was illuminated. Oxygen evolved was tested by means of mass spectrometer. It was found to be heavy isotope, ^{18}O. It proves that oxygen evolved during photosynthesis comes from splitting of water.

$$6CO_2 + 12H_2{}^{18}O \xrightarrow[\text{Chlorophyll, Enzymes}]{\text{Light}} C_6H_{12}O_6 + 6H_2O + 6{}^{18}O_2\uparrow$$

6.1 Site of Photosynthesis

- Chloroplasts are the green plastids which occur in all green parts of the plants. They are the actual sites of photosynthesis. They occur mostly in the chlorenchymatous cells (particularly in mesophyll) of leaves and young stems. Each chloroplast of a higher plant is an organelle consisting of a double membrane. The outer and inner membrane are collectively called **peristromium.**
- The chloroplast envelope encloses a liquid proteinaceous matrix called **stroma.** Stroma is hyaline, slightly electron dense, granular matrix and contains all the necessary enzymes of photosynthesis. The stroma is the site of **dark reaction** of photosynthesis.
- Stroma, the colloidal matrix also contains 70S ribosomes and DNA. The DNA structure is circular, closed, naked ring and is called **plastidome.** Because of the presence of DNA, chloroplast is self-replicating and semi-autonomous cell organelle.
- The lamellar system within the stroma forms flattened sac like lamellae called **thylakoids** (Gk. *thylakos* = sac, *oid* = like). These thylakoids are stacked in some places to form **grana.**
- The grana stacks are interconnected by membranous lamellae called **stroma lamellae** or **intergrana** or **fret channels.** The major function of thylakoids is to perform photo-synthetic **light reaction** (photochemical reaction). The pigments and other factors of light reaction are usually located in thylakoid membranes. Thylakoids possess four types of major complexes; photosystem I, photosystem II, Cyt b_6-f complex and coupling factor (ATP synthetase).

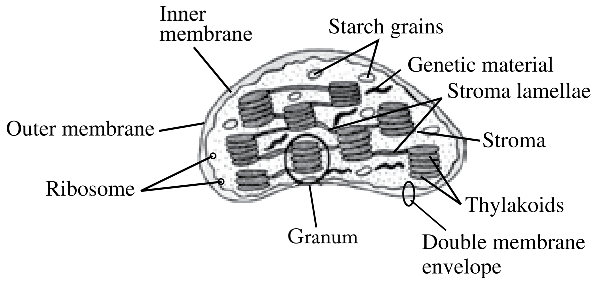


Fig.: Ultrastructure of chloroplast

According to Park and Biggins, photosynthetic pigments are located in the specific areas of thylakoids membranes (called quantasomes). A quantasome is a photosynthetic unit. Later on, Emerson established the presence of two distinct groups, PS-I and PS-II.

6.2 Photosynthetic Pigments and Their Role

- Photosynthesis is a photo-biochemical reaction which is mediated through the absorption of light energy.
- Those pigments which occur on photosynthetic thylakoids of chloroplasts and take part in absorption of light energy for the purpose of photosynthesis are known as photosynthetic pigments.
- Photosynthetic pigments have capacity to absorb light of certain wavelengths and reflect light of other wavelengths, imparting different colours to different pigments.

Types of photosynthetic pigments

- Photosynthetic pigments are of three types – chlorophylls, carotenoids and phycobilins.

Chlorophylls

- Chlorophylls are the green photosynthetic pigments. Five types of chlorophylls occur in plants other than bacteria – *a*, *b*, *c*, *d* and *e*. Bacteria possess two types of related pigments – bacteriochlorophyll (further of several subtypes) and bacterioviridin. Chlorophyll *a* is present in all photosynthetic organisms (except photosynthetic bacteria). Cholorophyll *b* is also predominant and found in green algae, bryophytes and all vascular plants.
- **Chlorophyll *a*** is bluish-green in the pure state. It has an empirical formula of $C_{55}H_{72}O_5N_4Mg$. **Chlorophyll *b*** is yellow green in the pure state with an empirical formula of $C_{55}H_{70}O_6N_4Mg$. Chlorophyll *c*, *d* and *e* are found in brown and red algae along with chlorophyll *a*.
- Chlorophyll structure was first studied by **Willstatter, Stoll** and **Fischer** in 1912. It has a head called **porphyrin** and a tail made up of long chain alcohol called **phytol.** Porphyrin head is made up of four pyrrole rings which are linked by **methine bridges** (— CH =). The skeleton

of each pyrrole ring is made up of 5 atoms – 4 carbon and one nitrogen. A non-ionic **magnesium atom** is held in the **centre of porphyrin head** by nitrogen atoms of pyrrole rings (through two covalent and two coordinate bonds). Phytol is an insoluble long chain of carbon and hydrogen atoms with a formula of $C_{20}H_{39}OH$. It anchors the chlorophyll molecule into the lipid part of thylakoid membrane. Chlorophyll *b* differs from chlorophyll *a* in having formyl group (— CHO) instead of a methyl (— CH_3) group at carbon atom 3.

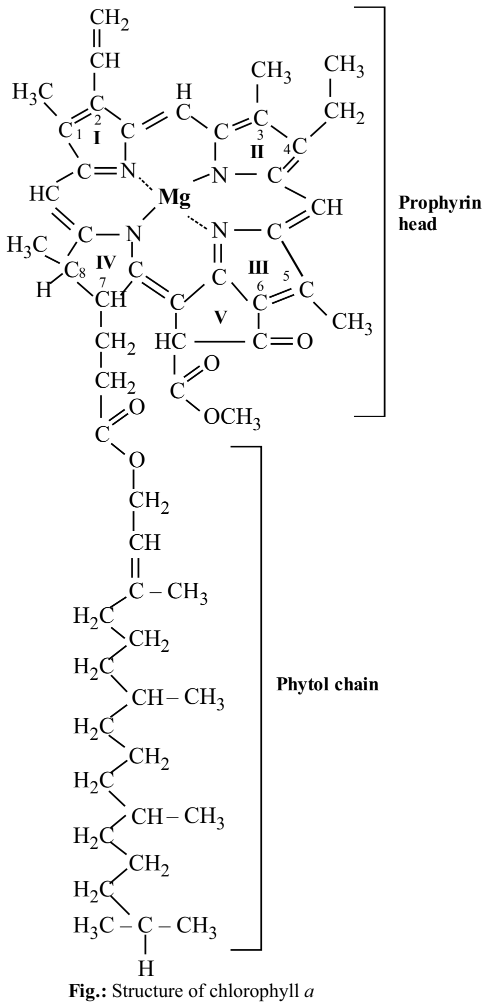


Fig.: Structure of chlorophyll *a*

Carotenoids

- Carotenoids are a group of **yellow, brown to reddish** pigments which are associated with the chlorophylls inside the chloroplasts but occur alone inside the chromoplasts. Alongwith chlorophyll *b* the carotenoids are also called **accessory pigments** because they handover the energy absorbed by them to chlorophyll *a*. Carotenoids have **conjugate double bonds** (— C = C — C = C —). They are of two types, **carotenes** and **xanthophylls.**
- **Carotenes (orange) :** These are hydrocarbons with empirical formula $C_{40}H_{56}$. The major carotene found in plants is β carotene.
- **Xanthophylls (yellow) :** These are oxygenated hydrocarbons, $C_{40}H_{56}O_2$. Lutein is the major xanthophyll present in plants.
- In higher plants, there are chlorophyll *a*, chlorophyll *b*, carotene and xanthophyll, as main photosynthetic pigments. (Anthocyanin, purple coloured pigment present in flower is not photosynthetic).
- Both carotenes and xanthophylls are soluble in organic solvents.

Phycobilins

- Phycobilins are present in only cyanobacteria (blue green algae) and red algae. There are two types of phycobilins – phycocyanins (blue) and phycoerythrins (red).
- Phycobilins are water soluble.

Nature of light

- Photosynthesis is influenced by quantity (intensity) as well as quality (wavelength) of light.
- During propagation light behaves as wave form (wave theory) and on interaction with matter it behaves as a stream of **discrete packets** of energy known as **photons** (corpuscular theory). Thus, showing dual nature of light. The amount of energy in the photon is called a quantum. The pigments absorb the energy of photon.
- The amount of energy present in the photon is inversely proportional to the wavelength of light *i.e.*, longer the wavelength, lesser is the energy content and *vice versa*.
- Part of the spectrum used in photosynthesis has a wavelength between 390-760 nm. It is called **photosynthetically active radiation** (PAR). Maximum absorption of visible light by photosynthetic pigments occurs in red and blue region and little absorption in yellow and orange region. Green light is least effective in photosynthesis. The highest rate of photosynthesis in green plants is in red and blue region of spectrum. The action spectrum shows the highest peak in red region and another smaller peak in blue region.

Role of pigments

- Chlorophyll *a* is known as essential pigment as it is the only pigment that can absorb and convert light energy into chemical energy, and thus, it acts as reaction center. Initially chlorophyll *a* is at the **ground state.** When it absorbs or receives photons, it gets activated and expels an electron at higher energy level and this is called **excited state.** The expelled electron is with extra amount of light energy (radiation energy) which is accepted by many electron carriers one after the other, *i.e.* there is an electron transfer. During this electron transfer energy is released and that is used in the synthesis of ATP, an energy rich molecule. Thus, light energy is converted into chemical energy. When the electron is with the carriers, chlorophyll *a* molecule becomes positively charged and this is called **ionized state.** Chlorophyll *a* molecule cannot remain in this state for more than 10^{-9} seconds. Thus, electron transfer is very fast.

- Chlorophyll *b* and carotenoids absorb light energy of different wavelengths and transfer it to the chlorophyll *a* by resonance. They broaden the spectrum of light absorbed and help in absorbing light energy more efficiently; hence they are called **accessory pigments.**
- The accessory pigments act as antenna complexes and harvest light from different regions of the spectrum than the chlorophyll. The light (radiation energy) captured by these pigments is funneled into the reaction centre for conversion into the chemical energy. Carotenoids also protect the essential pigment chlorophyll *a*, from photo-oxidation.
- The **accessory pigments** and the **reaction centre** together form **pigment system** or **photo system**.
- There are two photosystems, PS I and PS II. Each photosystem consists of Core Complex (CC) and Light harvesting complex (LHC). CC is composed of single specific chlorophyll *a* molecules as reaction centre and few other chlorophyll molecules and electron carriers. LHC is composed of about 200 chlorophyll *a*, few chlorophyll *b* and 50 carotenoid molecules. Chlorophyll *a* exists in different forms, which show maximum absorption at different wavelengths of light, such as chl-*a* 650, chl-*a* 673, chl-*a* 680, chl-*a* 700, etc.
- In PS I, chlorophyll *a*, with maximum absorption at 700 nm (P_{700}) is the reaction centre while in PS II, reaction centre has chlorophyll *a* molecules with absorption at 680 nm (P_{680}). In PS-II, manganese, calcium and chloride ions are also present that play important role in photolysis of water.

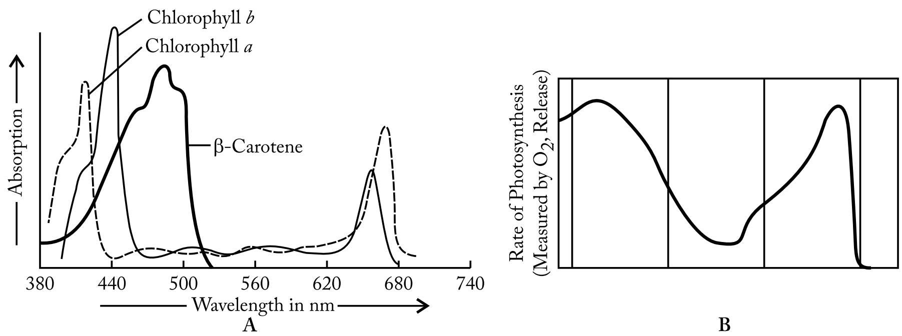


Fig.: Absorption and action spectra. A, absorption spectra of three photosynthetic pigments (chl *a*, chl *b* and β-carotene). B, action spectrum of photosynthesis (relative rates of photosynthesis at different wavelengths of light) is measured by oxygen release.

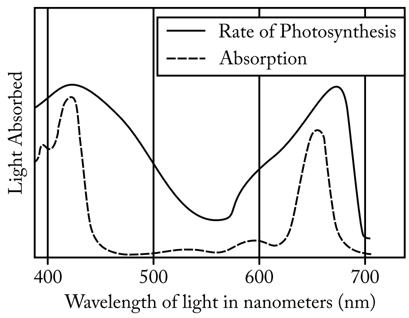


Fig. : Action spectrum of photosynthesis and absorption spectrum of chlorophyll *a*.

- Photosynthesis occurs in two phases – photochemical and biosynthetic. Photochemical phase is called **light** or **Hill reaction** (after the name of the scientist Robert Hill who discovered its details). Biosynthetic phase is termed as **dark** or **Blackman's** (after the name of the scientist who first postulated it) **reaction**.

6.3 Light-Dependent Reactions

- It occurs inside the thylakoids, especially those of grana region. Photochemical step is **dependent upon light**. The function of this phase is to produce assimilatory power consisting of reduced co-enzyme NADPH and energy rich ATP molecules. Photochemical phase involves photolysis of water leading to liberation of O_2 and production of assimilatory power ($NADPH_2$ and ATP).

Photophosphorylation

- The term phosphorylation was coined by Arnon and others in 1954. Formation of ATP in the chloroplast by photosynthesis is called photophosphorylation.

$$ADP + iP \xrightarrow[\text{Light}]{\text{Chlorophyll } a} ATP$$

- There are two types of photophosphorylation :

1. Non-cyclic photophosphorylation (Z-Scheme)

- It is the normal process of photophosphorylation in which the electron expelled by the excited photocentre does not return to it.
- Non-cyclic photophosphorylation is carried out in collaboration of both photosystem I and II.
- There is continuous unidirectional flow of electrons from water to PS-II. From PS-II it passes to PS-I *via* cytochromes and finally to **NADP**.

Photo-excitation of PS-II and flow of electrons from PS II to PS I: The electrons released during photolysis of water are picked up by photocentre of PS II, called P_{680}. The same is extruded out when the photocentre absorbs light energy (hν). It passes through a series of electron carriers – plastoquinone (PQ), cytochrome $b_6 - f$ complex and plastocyanin. During the transfer of electrons from cyt-b_6 to cyt-*f*, the energy released is used in the **synthesis of ATP**.

Photo-excitation of PS I **:** The electron is handed over to photocentre P_{700} of PS I by plastocyanin. P_{700} extrudes the electron after absorbing light energy. The extruded electron passes through special chlorophyll *a* or P_{700} molecule, Fe-S, ferredoxin, to finally reach $NADP^+$. The latter then combines with H^+ (released during photolysis) with the help of NADP-reductase to form **NADPH.** This is called **Z scheme** due to its characteristic zig-zag shape based on redox potential of different electron carriers.

Photolysis of water

- The phenomenon of breaking up of water into hydrogen and oxygen in the illuminated chloroplast is called **photolysis** or photocatalytic splitting of water.
- Light energy, an oxygen evolving complex (OEC) and an electron carrier are required for photolysis of water.
- Oxygen evolving complex was formerly called Z-enzyme. It is attached to the inner surface of thylakoid membrane.
- The enzyme has four Mn ions. Light energised changes in Mn (Mn^{2+}, Mn^{3+}, Mn^{4+}) removes electrons from OH^- component of water forming oxygen.
- It requires two other ions Ca^{2+} and Cl^- also.

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

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

- The electrons released during photolysis of water are picked up by P_{680} photocentre of photosystem II through a carrier. The protons ($4H^+$) are accepted by $2NADP^{2-}$ to form $2NADPH_2$. An enzyme ferredoxin NADP reductase carried out this reaction.

2. Cyclic photophosphorylation

- This involves only PS I and the flow of electrons is in cyclic manner as the same expelled electrons come back to the reaction centre. Photolysis of water is not associated with this.

  Photo excitation of PS-I and flow of electrons : Cyclic photophosphorylation is performed by photosystem I only. Its photocentre P_{700} extrudes an electron after absorbing a photon of light. The expelled electron passes through a series of carriers including an iron containing red protein called ferredoxin (Fd) through an unknown electron acceptor called ferredoxin – reducing substance (FRS), cyt b_6–f and plastocyanin before returning to photocentre.
- During the transfer of electrons from cytochrome b_6 to cytochrome-*f*, energy from electrons is released, and is used in the **synthesis of ATP**. Formation of ATP may also take place during the electrons transfer from ferredoxin to cytochrome-b_6.
- Cyclic photophosphorylation is a significant process as it produces additional ATP molecules required for synthesis of glucose. Synthesis of one glucose molecule requires 18 ATP and 12 $NADPH_2$ molecules.

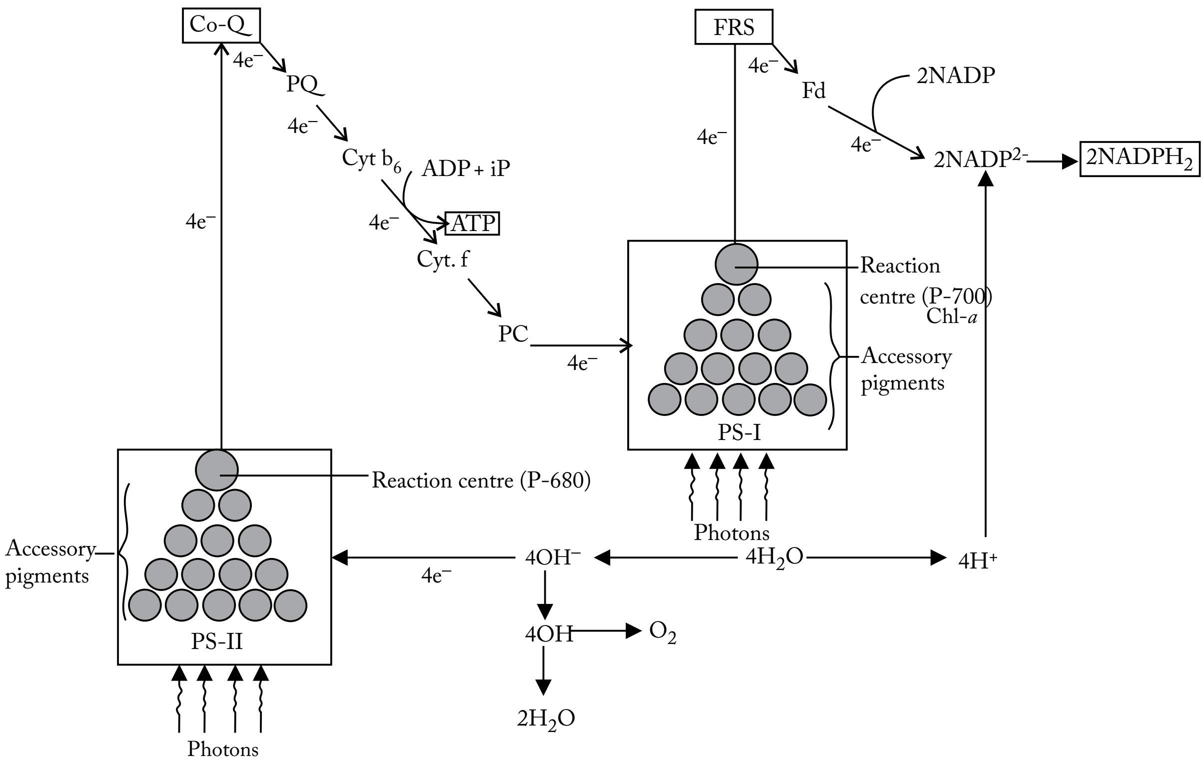


Fig.: Diagrammatic representation of non-cyclic photophosphorylation.

- When CO_2 fixation is stopped or CO_2 concentration is low and NADP is not available, electrons from Fd come back to PS-I.
- PS-I and PS-II work in harmony with each other and harvest light energy in a very efficient manner. In photosynthetic bacteria, only cyclic photophosphorylation is present while in all other photoautotrophs, both cyclic and non-cyclic photophosphorylation occur.

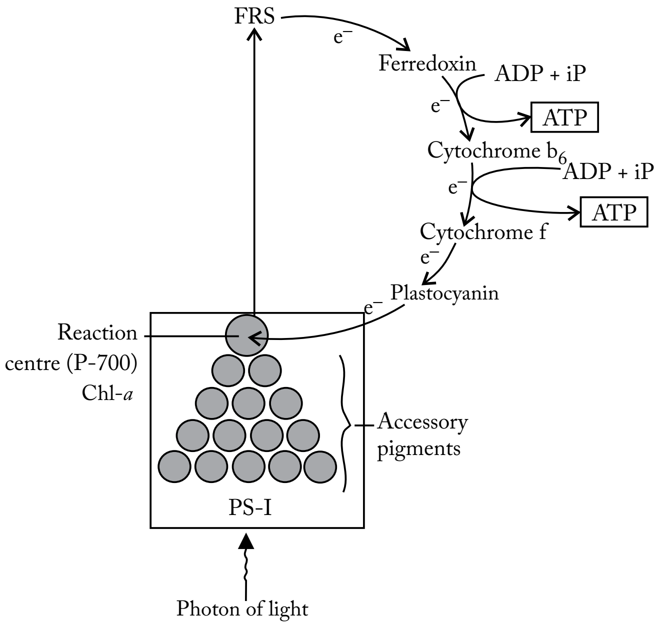


Fig.: Diagrammatic representation of cyclic photophosphorylation.

Chemiosmotic hypothesis (proton pump)

- This view was propounded by Peter Mitchell in U.K. in 1961 in the case of mitochondria and chloroplast. Mitchell's chemiosmotic theory was confirmed by **G. Hind** and **Andre Jagendorf** at Cornell University in 1963. According to this view, electron transport, both in respiration and photosynthesis produces a proton gradient (pH gradient). The gradient develops in the outer chamber or intermembrane space of mitochondria and inside the thylakoid lumen in chloroplasts.
- Lumen of thylakoid becomes enriched with H^+ ion due to photolytic splitting of water.
- Primary acceptor of electron is located on the outer side of thylakoid membrane. It transfers its electrons to a H-carrier. The carrier removes a proton from matrix while transporting electron to the inner side of membrane. The proton is released into the lumen while the electron passes to the next carrier.
- NADP reductase is situated on the stroma side of thylakoid membrane. It obtains electron from PS I and protons from matrix to reduce $NADP^+$ to NADP + H^+ state. The consequences of these events is that concentration of proton decreases in matrix or stroma region while their concentration in thylakoid lumen rises resulting in decrease in pH.
- A proton gradient develops across the thylakoid. The proton gradient is broken down due to movement of protons through transmembrane channels, CF_0 of ATPase ($CF_0 - CF_1$ particle). As protons move to the other side of ATPase, they bring about conformational changes in CF_1 particle of ATPase or coupling factor. The transient CF_1 particle of ATPase enzyme form ATP from ADP and inorganic phosphate.
- Therefore, ATP synthesis through chemiosmosis requires a membrane, a proton pump, a proton gradient and $CF_0 - CF_1$ particle or ATPase. One molecule of ATP is formed when $3H^+$ are used by the ATP synthase.

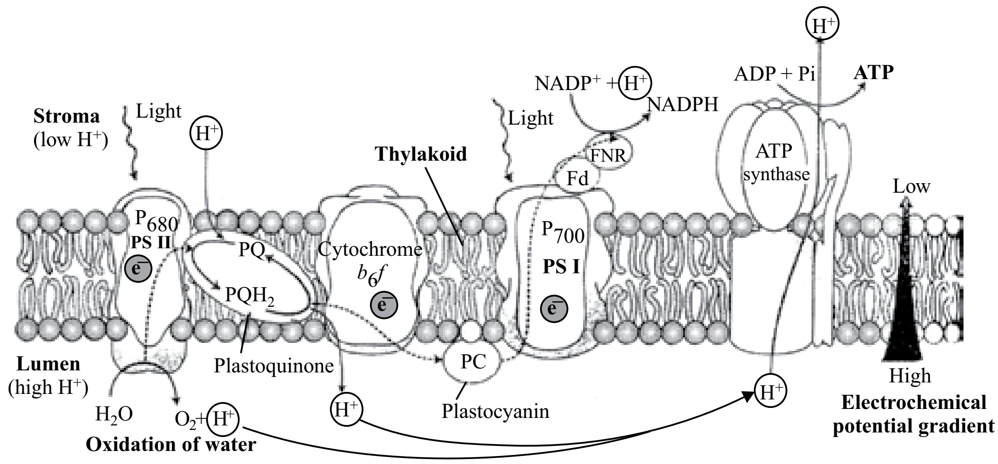


Fig.: Mechanism of chemiosmotic synthesis of ATP in chloroplast (FNR = Flavoprotein ferredoxin - NADP reductase).

6.4 Light-Independent Reactions

- It is the second phase of photosynthesis in which CO_2 is fixed or reduced to glucose.
- Dark reaction does not require the presence of light but requires assimilatory power (ATP + $NADPH_2$) produced during the photochemical reaction. It **occurs in stroma or matrix of chloroplast.** All the enzymes required for the process are present in the matrix or stroma of the chloroplast. The presence of dark reaction was first established by **F.F. Blackman** in 1905 and hence named as **Blackman's reaction:**

$$CO_2 + 2NADPH_2 + ATP \rightarrow (CH_2O) + H_2O + 2NADP + 2ADP + 2iP$$

- There are two main pathways for the biosynthetic or dark phase – **Calvin cycle (C_3 cycle) and Dicarboxylic acid cycle (C_4 cycle)**.

Calvin cycle (C_3 pathway)

- Carbon dioxide fixation in the presence of ATP and $NADPH_2$ and its conversion to glucose, through a series of reaction, catalysed by specific enzymes is termed as **Calvin cycle**. The cycle was discovered by Calvin, Benson and their colleagues in California, U.S.A. They fed *Chlorella* and *Scenedesmus* with carbon dioxide containing radioactive, ^{14}C. Radioactive carbon ^{14}C has a half life of 5568 years. Therefore, the path of CO_2 fixation can be easily traced with its help. Phosphoglyceric acid, a 3C compound is the first stable product of photosynthesis. Hence, Dr. Calvin called it **C_3 cycle** or **C_3 pathway.** For this work Dr. Melvin Calvin and Dr. Benson was awarded a Nobel prize in 1961.
  - Calvin cycle is divided into three phases : 1. Carboxylation, 2. Reduction and 3A. Synthesis and 3B. Regeneration.

1. Carboxylation

- Photosynthetic carboxylation requires ribulose-1, 5-biphosphate or RuBP as acceptor of carbon dioxide and RuBP carboxylase-oxygenase or RuBisCO as enzyme. The enzyme was previously called carboxydismutase. RuBisCO is the most abundant protein of the biological world. Carbon dioxide combines with ribulose-1, 5 biphosphate to produce a transient intermediate 6-carbon unstable compound. The intermediate splits up immediately in the presence of water to form two molecules of 3-phosphoglyceric acid or PGA. It is the first stable product of photosynthesis.

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

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

2. Reduction (utilisation of assimilatory power)

- These are a series of reactions that lead to the formation of glucose.
- 3-Phosphoglyceric acid or 3-PGA is further phosphorylated by ATP with the help of enzyme triose phosphate kinase (phosphoglycerate kinase). It give rise to 1, 3 di-phosphoglyceric acid.

  $3PGA + ATP \rightarrow 1, 3\text{ di-PGA} + ADP$
- Diphosphoglyceric acid is reduced by $NADPH_2$ to produce glyceraldehyde 3-phosphate or 3-phosphoglyceraldehyde and inorganic phosphate is released.

  $1, 3\text{ di-PGA} + NADPH_2 \rightarrow 3\ PGAL + NADP + iP$
- Some part of 3PGAL is converted into its isomer Dihydroxyacetone phosphate (DHAP) in the presence of enzyme triose phosphate isomerase.

3A. Synthesis

- For the synthesis of one glucose molecule, six turns of Calvin cycle are required or six molecules of RuBP and six molecules of CO_2 are required.
- 1/6 part of PGAL *i.e.* out of 12 molecules, 2 are utilised for the synthesis of glucose.
- 2(3C) = 1(6C). One molecule of PGAL and one molecule of DHAP combine together to form one molecule of fructose 1, 6-diphosphate.

$$\underset{(3C)}{3PGAL} + \underset{(3C)}{DHAP} \longrightarrow \underset{(6C)}{\text{Fructose 1, 6- diphosphate.}}$$

- Fructose diphosphate molecules are dephosphorylated to fructose-6-phosphate by the action of fructose phosphatase which then isomerizes into glucose-6-phosphate. Glucose-6-phosphate loses a phosphate group (dephosphorylation) to produce glucose. Glucose is converted into either sucrose or starch.
- The processes involved in reduction and synthesis phases are reversal of the processes found during glycolysis part of respiration. Therefore named **glycolytic reversal.**

3B. Regeneration

- RuBP gets regenerated through several biochemical reactions. These reactions are called sugar phosphate interconversions. All the compounds/intermediates formed are sugar phosphates, for example, erythrose-4 phosphate (4-C), xylulose-5-phosphate (5-C), Ribose-5-phosphate (5-C), Sedoheptulose-7-phosphate (7-C) etc.
- 5/6 part of PGAL *i.e.* out of 12 molecules, remaining 10 molecules are utilised to regenerate 6 molecules of RuBP by utilising 6ATP.
- The initial acceptor of CO_2 gets regenerated and keeps the process going. One molecule of glucose is formed from $6CO_2$ by utilising 18ATP and 12 $NADPH_2$.

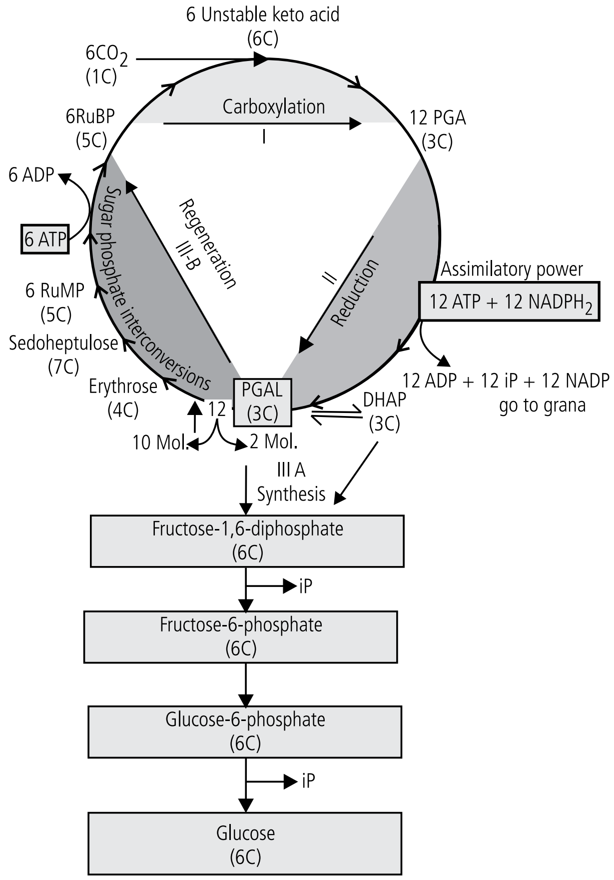


Fig.: Diagrammatic representation of Calvin cycle.

- The net reaction of C_3 dark fixation of carbon dioxide is

$$6RuBP + 6CO_2 + 18\ ATP + 12\ NADPH \rightarrow 6RuBP + C_6H_{12}O_6 + 18\ ADP + 18iP + 12\ NADP^+$$

C_3 plants

- Most of the plants fix CO_2 through Calvin cycle and are called C_3 plants. RuBisCO, the main enzyme of Calvin cycle that fixes CO_2 is thermolabile and requires higher concentration of CO_2 for its activity. At high temperature the stomata close partially so that availability of CO_2 falls. Moreover, at high temperature and at low CO_2 concentration, RuBPcarboxylase, (*i.e.* RuBisCO-Ribulose Bis phosphate Carboxylase Oxygenase), functions as oxygenase and brings about oxidation of RuBP instead of carboxylation. Due to this a considerable (approximately 25%) part of photosynthetically fixed CO_2 goes back to atmosphere.

Photorespiration

- Photorespiration is the light dependent process of oxygenation of RuBP and release of carbon dioxide by the photosynthetic organs of a plant. The process occurs in **chloroplast, peroxisome** and **mitochondria.**
- Photorespiration is also known as photosynthetic carbon oxidation cycle. It protects the C_3 plants from photo-oxidative damage.
- Ribulose biphosphate carboxylase (RuBisCO), acts as ribulose biphosphate oxygenase under low atmospheric concentration of CO_2 and increased concentration of O_2.
- In presence of high concentration of O_2 the enzyme RuBP oxygenase splits a molecule of Ribulose–1,5 biphosphate into one molecule each of **3-Phosphoglyceric acid** and **2-phosphoglycolic acid.**

$$\text{Ribulose-1, 5 bisphosphate} \xrightarrow{O_2} \text{2-Phosphoglycolic acid} + \text{3-Phosphoglyceric acid}$$

- The 2-Phosphoglycolic acid loses its phosphate group in presence of enzyme **phosphatase** and is converted into **glycolic acid**.

$$\text{2 Phosphoglycolic acid} + H_2O \xrightarrow{\text{Phosphatase}} \text{Glycolate} + \text{Phosphate}$$

- The glycolic acid, **synthesised in chloroplast** as an early product of photosynthesis, is **then transported to the peroxisome.**

$$\text{Glycolic acid} + O_2 \rightarrow \text{Glyoxylic acid} + H_2O_2$$
$$\text{Glyoxylic acid} + \text{Glutamic acid} \rightarrow \text{Glycine} + \alpha\text{-ketoglutarate}$$

- The glycine is transported out of peroxisomes into mitochondria.

$$\text{2 Glycine} + NAD^+ \xrightarrow{\text{Decarboxylase}} \text{Serine} + CO_2 + NH_3 + NADH$$

- The CO_2 is then released in photorespiration from mitochondria. The NH_3 released during glycine decarboxylation is transported to cytoplasm or chloroplast, where it is incorporated into synthesis of glutamic acid.

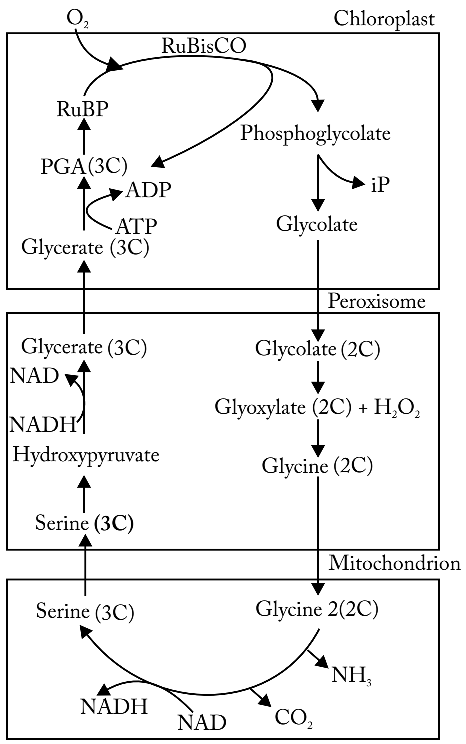


Fig.: Schematic representation of photorespiratory pathway.

- The amino acid serine returns to peroxisome where it is deaminated and reduced to **hydroxypyruvic** acid and finally to **glyceric acid.**

Serine + α-ketoglutarate $\rightarrow$ Hydroxypyruvate + Glutamate
Hydroxypyruvic acid + NADH $\rightarrow$ Glyceric acid + NAD^+

- The glyceric acid finally enters the chloroplast where it is phosphorylated to 3-Phosphoglyceric acid, which enters into C_3 cycle.

Glyceric acid + ATP $\rightarrow$ 3-Phosphoglyceric acid + ADP

C_4 plants

- C_4 plants have a characteristic leaf anatomy called **Kranz anatomy.** The mesophyll is not differentiated into palisade and spongy tissue. It is homogenous. Here vascular bundles are surrounded by sheaths of large parenchymatous cells called **bundle sheaths,** which are surrounded by **mesophyll cells.** So here **two types of chloroplasts** are present, *i.e.*,
  - **Bundle sheath chloroplasts:** Larger in size, lack grana (agranal chloroplasts) and contain starch grains.
  - **Mesophyll chloroplasts:** Smaller in size, contain grana (granal chloroplasts) and lack starch grains.
- Thus, chloroplasts show dimorphism in C_4 plants. The enzyme, PEP carboxylase is present in mesophyll chloroplast and RuDP or RuBP carboxylase (RuBisCO) in bundle sheath chloroplast.
- In C_4 plants, 2 carboxylation reactions occur. First, in mesophyll chloroplast and second, in bundle sheath chloroplast.

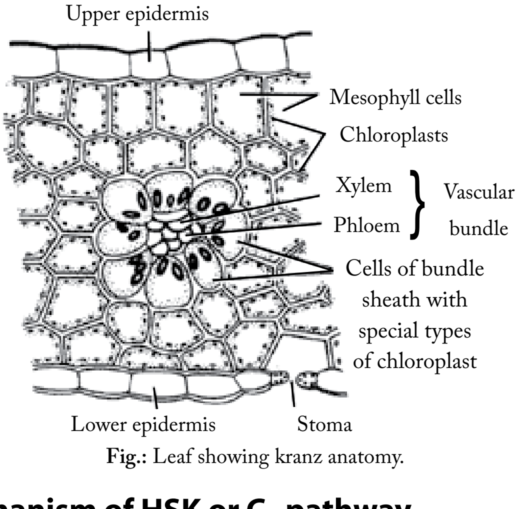


Fig.: Leaf showing kranz anatomy.

Mechanism of HSK or C_4 pathway

- For a long time, Calvin cycle (C_3 cycle) was considered to be the only photosynthetic pathway for reduction of CO_2 into carbohydrates. **H.P. Kortschak** (1965) reported that rapidly photosynthesising sugarcane leaves produced a 4-C compound oxaloacetic acid (OAA) as a result of CO_2 fixation.
- This was later supported by **M.D. Hatch** and **C.R. Slack** (1966) and they reported that a 4-C compound oxaloacetic acid (OAA) is the first stable product in CO_2 reduction process. They outlined the entire series of reactions hence is known as **Hatch and Slack's cycle** or **C_4 cycle** (as 4-C compound is first stable product).
- The reactions occurring in this pathway are completed in two parts at two different sites.

Part I- Reactions in mesophyll cells

Carboxylation (First CO_2 fixation) : In C_4 plants, **initial fixation** of carbon dioxide occurs in mesophyll cells. The primary acceptor of CO_2 is **phosphoenol pyruvate** or PEP. It combines with carbon dioxide in the presence of PEP carboxylase or PEPcase to form oxaloacetic acid (OAA) or oxaloacetate a 4C compound.

$$PEP + CO_2 + H_2O \xrightarrow{\text{PEP Carboxylase}} OAA + H_3PO_4$$

- PEP carboxylase can function even if the concentration of CO_2 in atmosphere is as low as 2 ppm.

Reduction : Oxaloacetic acid is reduced to malic acid or transaminated to form aspartic acid in the presence of $NADPH_2$ and an enzyme malate dehydrogenase or transaminase (in case of aspartic acid).

$$\text{Oxaloacetic acid} + NADPH_2 \xrightarrow{\text{Malate dehydrogenase}} \underset{(4C)}{\text{Malic Acid}} + NADP^+$$

$$\text{Oxaloacetic acid} + NADPH_2 + NH_3 \xrightarrow{\text{Transaminase}} \underset{(4C)}{\text{Aspartic acid}} + NADP + H_2O$$

Part II - Reactions in bundle sheath cells

Decarboxylation : Malic acid or aspartic acid is translocated to bundle sheath cells through plasmodesmata. Inside the bundle sheath cells they are decarboxylated (and deaminated in case of aspartic acid) to form pyruvate and CO_2.

$$\text{Malate} + NADP \xrightarrow[\text{dehydrogenase}]{\text{Malate}} \text{Pyruvate} + CO_2 + NADPH_2$$

(Aspartic acid formed undergoes deamination to form pyruvic acid).

Second CO_2 fixation : CO_2 released in bundle sheath cells is fixed through Calvin cycle. RuBP of Calvin cycle is called **secondary** or **final acceptor** of CO_2 in C_4 plants.

- Pyruvate and PEP formed in bundle sheath cells are transported back to mesophyll cells. Here, pyruvate is changed to phosphoenol pyruvate. Energy is required for this and the same is provided by ATP.

$$\text{Pyruvate} + ATP + H_3PO_4 \xrightarrow[\text{dikinase}]{\text{Phosphopyruvate}} PEPA + ADP$$

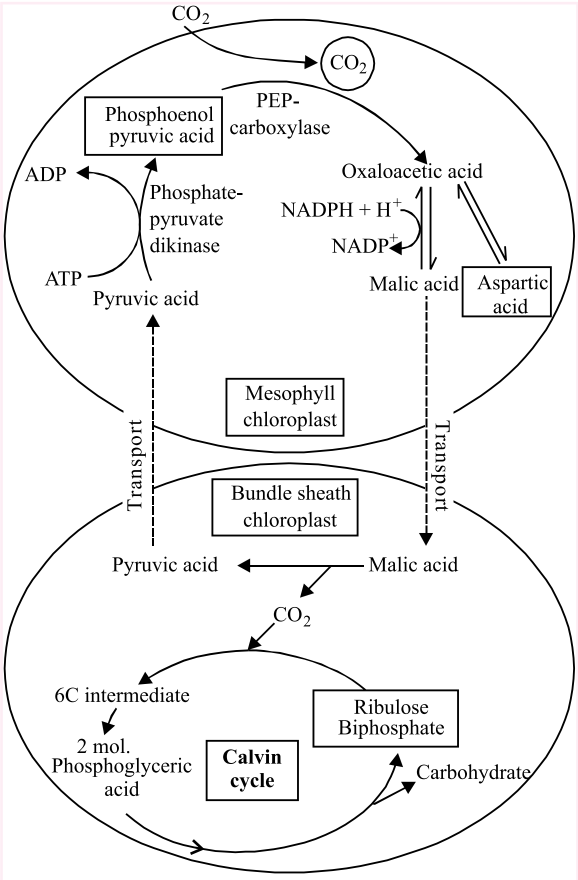


Fig.: Hatch and Slack cycle.

- Photorespiration is avoided in C_4 plants as PEP carboxylase fixes CO_2 at very low CO_2 concentration in the mesophyll cell and RuBisCO functions as carboxylase at high CO_2 concentration in bundle sheath cell. Therefore C_4 pathway is also known as CO_2 concentrating mechanism.

Crassulacean acid metabolism

- This metabolism was first of all reported in *Bryophyllum*, a member of Family **Crassulaceae** and hence is called crassulacean acid metabolism. This occurs in mostly **succulents** (xerophytes) like *Opuntia, Agave, Aloe, Sedum, Kalanchoe,* etc.
- The most characteristic feature of these plants is that their stomata remain open at night (in dark) but closed during the day (in light). Thus, CAM is a kind of adaptation in succulents to carry out photosynthesis without much loss of water.
- In these plants, there is no kranz anatomy but there occurs **dark acidification,** *i.e.*, during night malic acid is formed. This malic acid breaks up into CO_2 and pyruvic acid in daytime and CO_2 released is utilised in C_3 cycle.
- In CAM plants **OAA** (oxaloacetic acid) is formed due to carboxylation as in C_4 plants. Like C_4 plants, OAA is reduced to **malic acid** in CAM plants and is accumulated in the vacuole. Stomata are open at night. CO_2 is absorbed from outside. With the help of PEP carboxylase, it is immediately fixed. The acceptor is phosphoenol pyruvate or PEP. Absorption of CO_2 during night and its storage as organic acid (malic acid) is called **acidification**.

$$PEP + HCO_3^- \xrightarrow{\text{PEP carboxylase}} OAA + H_3PO_4$$

$$OAA + NADPH \xrightarrow{\text{Dehydrogenase}} \text{Malic acid} + NADP^+$$

- **Malic acid is the end product of dark fixation of CO_2.** It is stored inside cell vacuoles.
- During day time malic acid undergoes oxidative decarboxylation and CO_2 is released. Liberation of CO_2 from an organic acid during day time is called **deacidification.**

$$\text{Malic acid (malate)} + NADP^+ \xrightarrow[\text{dehydrogenase}]{\text{Malate}} \text{Pyruvate} + CO_2 + NADPH$$

- The diurnal acidification and de-acidification during the night and day time respectively is a characteristic feature of **CAM (Crassulacean Acid Metabolism) plants.**
- In C_4 plants initial carboxylation and final carboxylation are separated by space but in CAM plants initial carboxylation and final carboxylation are separated by time. All reactions of CAM occur in mesophyll cells. Chloroplasts are absent in bundle sheath cells of CAM plants. CAM pathway is important for the survival of succulents.

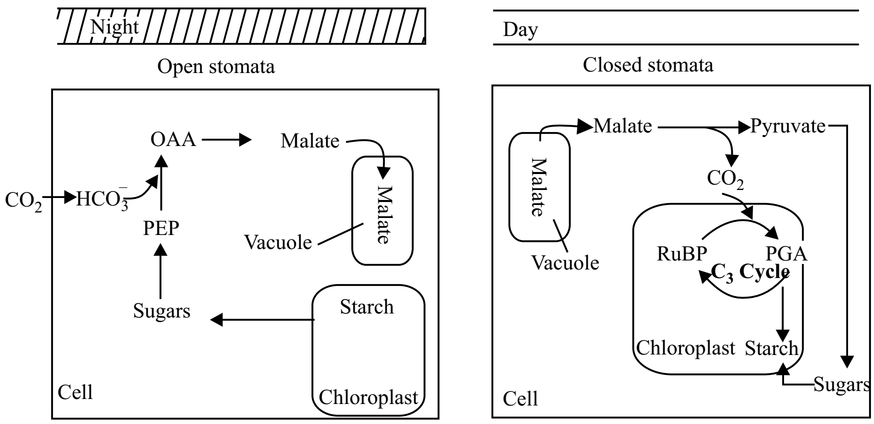


Fig.: An outline of CAM pathway.

Interdependence of light and dark reaction

- The two phases of photosynthesis, *i.e.* light and dark reactions are **interdependent.**
- The products of light reaction *i.e.* ATP and $NADPH_2$ (assimilatory power) are required for dark reaction *i.e.* for reduction of CO_2 into glucose and the product of dark reaction, *i.e.*, ADP, iP and NADP are required for the synthesis of ATP and $NADPH_2$ during light reaction. Thus the two are interdependent. The dark reactions also take place during day.

6.5 Significance of Photosynthesis

- Photosynthesis is the most significant, natural process during which light energy is trapped and converted into chemical form of energy.
- Photosynthesis involves synthesis of food as a source of energy for all living organisms. Thus, all living organisms, (except chemoautotrophs) directly or indirectly depend on this process for energy.
- Photosynthesis helps in maintaining balance of O_2 and CO_2 in the atmosphere and helps in purifying air.
- As photosynthesis is more than respiration in plants, biomass is built in plants which provides feeding, hiding and nesting places for animals.
- Various fossil fuels like coal, petroleum and natural gas are the bi-products of photosynthesis.
- The plant products such as, timber, cotton, alkaloids, resins, gums, tannins, steroids, rubber, etc. are the economically important products of photosynthesis.

6.6 Factors Affecting Rate of Photosynthesis

- Photosynthesis is affected by several internal and external factors.
- **Internal factors :** They are mostly genetic like number, size, age and orientation of leaves, amount of chlorophyll, rate of translocation etc.
- **External factors :** They are environmental factors such as follows:

Light

- There are three aspects of light as a factor; light quality, intensity and duration.
- Plants are broadly classified into two groups depending upon their inability or ability to tolerate high **light intensity** : shade plants (sciophytes, *e.g.*, *Oxalis*) and sun plants (heliophytes, *e.g.*, *Dalbergia*).
- At low light intensity the rate of photosynthesis is reduced.
- There is a point in light intensity where there is no gaseous exchange in photosynthesis. It is called **light compensation point.**
- A plant cannot survive for long at compensation point because there is a net loss of organic matter due to respiration of non-green organs and respiration in dark.
- Beyond the compensation point, there is a breakdown of chlorophyll which causes a decrease in the photosynthetic rate.
- Maximum photosynthesis occurs in blue-violet and red regions of the light spectrum where most of the absorption is carried out by chlorophylls.

Carbon dioxide concentration

- **CO_2 concentration** of the atmosphere is between 0.03% to 0.04%.
- Increase in its concentration upto 0.05% increases the rate of photosynthesis in most C_3 plants. Beyond this a decline is observed and it can become damaging over longer period.
- When CO_2 concentration is reduced, there comes a point at which illuminated plant parts stop absorbing carbon dioxide from their environment. **It is known as CO_2 compensation point or threshold value.** At this value CO_2 fixed in photosynthesis is equal to CO_2 evolved in respiration and photorespiration.

Temperature

- **Temperature** does not influence photochemical part of photosynthesis (light reaction) but affects the biochemical part (dark reactions). The optimum temperature for photosynthesis is 10-25°C for C_3 plants and 30-45°C for C_4 plants.

Water

- The amount of **water** used in photosynthesis is very small. The rate of photosynthesis falls in water deficient soils.
- Water stress causes closure of stomata leading to low availability of CO_2. It brings about loss of turgidity in leaves and wilting.

Law of limiting factors

- **F.F. Blackman** (1905) formulated the principle of limiting factors and stated that, when a process is conditioned as to its rapidity by a number of separate factors, the rate of the process is limited by the pace of the slowest factor (*i.e.*, factor present in minimum amount).

- The law can be explained best by the following illustration :

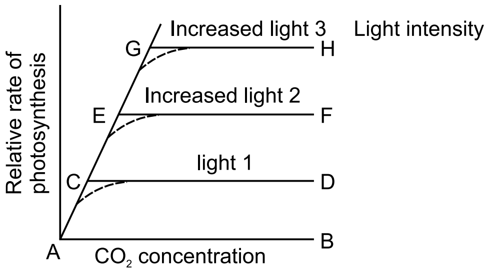


Fig.: Blackman's law of limiting factor with more than one factor.

- At A no photosynthesis occurs due to non-availability of CO_2.
- If concentration is increased from 0 to 1 mg, rate of photosynthesis will increase from A to C.
- Now even if the CO_2 concentration is further increased to 5 mg, the rate becomes constant along the line C to D.
- Further increase from C to E is possible only when light intensity is increased, which is at this time working as limiting factor. The rate again becomes constant along the line E to F unless there is a further increase in the supply of light intensity. With the increase in the intensity of light to a high level the rate of photosynthesis increases along the line E to G thereafter the rate again becomes constant G to H. Thus the diagram reveals that with the increase in the supply of limiting factor, the rate of photosynthesis will go on increasing unless any other factor becomes limiting.
- Thus, at a time only one factor controls the rate and is called limiting factor.
- This law of limiting factors is applicable to any biochemical reaction; it states that, "If a chemical/ biochemical process is affected by more than one factor, then the rate will be determined by the factor which is nearest to its minimal value." It is the factor which directly affects the rate, if its quantity is changed.

CONCEPT MAP

Photosynthesis

Formation of glucose from CO_2 and water in the presence of sunlight and chlorophyll.

Factors affecting photosynthesis

(Light, CO_2 conc., temperature, water)

Site of photosynthesis

Photosynthesis occurs in double membrane bound chloroplasts that consist of stroma, grana stacks, thylakoids and stroma lamellae. Thylakoids contain photosynthetic pigments.

Photosynthetic pigments

They include chlorophylls, carotenes and phycobilins. Chlorophylls are the major pigments while other two are accessory ones. They may be of various types and form two major pigment systems.

- **PS I** → Includes P_{700} as photocentre and LHC (light harvesting complex) with electron carriers.
- **PS II** → Includes P_{680} as photocentre and LHC.

Photosynthetic mechanism

An enzymatic anabolic reaction involving many intermediates.

Photochemical Phase

Light dependent phase occurring in thylakoids.

- **Photolysis**

  Water molecule is broken down into O_2 and H_2 by absorbing light energy. It produces e^-.

- **Photophosphorylation**

  Electrons released in photolysis of water are used for production of ATP through photophosphorylation. It may be of two types:

  - **Cyclic**: Involves only PS I and produces only ATP.
  - **Non-cyclic**: Involves both PS I and PS II and produces both ATP and NADPH.

Biosynthetic Phase

Light independent reaction that occurs in stroma. It can occurs in three ways.

- **C_3 cycle**

  CO_2 combines with RuBP and produces glucose *via* many intermediate steps. Also called as Calvin cycle. 3C-phosphoglyceric acid is the first stable product.

- **C_4 cycle**

  Glucose is formed by CO_2 fixation but initial acceptor is PEP in mesophyll cells and first stable product is 4C compound oxaloacetic acid. C_4 plants have kranz anatomy and are more efficient than C_3 plants.

- **CAM cycle**

  In xerophytes, CAM cycle is observed where CO_2 is fixed at night, similar to C_4 plants, but two steps are separated by time (day and night) not in space. It helps in reducing transpiration.

Photorespiration

Light dependent oxygenation of RuBP and release of CO_2 in photosynthetic cells of plant. It involves chloroplasts, peroxisomes and mitochondria. It consumes energy and wastes the work of photosynthesis.

Work it Out

Multiple Choice Questions

LEVEL - 1

Introduction

1. What is photosynthesis?
   (a) A simple process where chemical energy is converted into light energy.
   (b) A process which has no relation with us.
   (c) A process for the synthesis of carbohydrates.
   (d) A process which produces energy rich inorganic compounds from organic compounds.

2. How many molecules of water are needed by a green plant to produce one molecule of glucose?
   (a) 6 (b) 12
   (c) 36 (d) 1 only

3. Which is a chemosynthetic autotroph bacteria?
   (a) *Nitrosomonas* (b) *Thiobacillus*
   (c) *Ferrobacillus* (d) All of these

4. In 1930, who predicted that H_2O must be splitting into H_2 and O_2 based on his experiment on green sulphur bacteria?
   (a) Van Niel (b) Robert Hill
   (c) Ruben (d) Prof. Arnon

5. In bacterial photosynthesis, hydrogen donor is
   (a) H_2O (b) H_2O_2
   (c) H_2SO_4 (d) H_2S.

6. Photolysis of water was demonstrated by
   (a) Robert Hill (b) Calvin
   (c) Van Niel (d) Ruben and Kamen.

7. Photosynthetic autotrophs get their energy from
   (a) heat (b) sunlight
   (c) chemical reactions (d) organic molecules.

8. NADP is a H–acceptor present in the chloroplast, was discovered by
   (a) Robert Hill (b) Dr. Arnon
   (c) Emerson (d) Hatch and Slack.

9. NADP is abbreviation for
   (a) Nicotinamide Adenine Dinucleotide Phosphate
   (b) Nicotinamide Adenosine Dinucleate Phosphate
   (c) Nicotinamide Adenosine Dinucleoside Phosphate
   (d) Nicotinamine Adenosine Dinucleotide Phosphate.

10. What is the main feature of photosynthesis?
    (a) Formation of sugar
    (b) Conversion of light energy into chemical energy
    (c) Evolution of O_2
    (d) Formation of CO_2

11. In the process of photosynthesis
    (a) both CO_2 and water get oxidised
    (b) both CO_2 and water get reduced
    (c) water is oxidised and CO_2 is reduced
    (d) water is reduced and CO_2 is oxidised.

12. Photosynthesis is a
    (a) oxidative, exergonic and anabolic process
    (b) redox, exergonic and catabolic process
    (c) redox, endergonic and anabolic process
    (d) oxidative, endergonic and catabolic process.

13. During photosynthesis, the oxygen in glucose is contributed by
    (a) carbon dioxide (b) water
    (c) oxygen (d) all of these.

14. Which among the following is a photoautotroph?
    (a) *Chlorobium* (b) *Chromatium*
    (c) Both (a) and (b) (d) None of these

15. Which of the following isotopes have proved useful in researches on photosynthesis ?
    (a) P^{32} and C^{14} (b) $^{18}O_2$ and C^{14}
    (c) O^{18} and O^{14} (d) $^{11}O_2$ and $^{16}O_2$

16. What kind of organism would die, if photosynthesis was to stop altogether?
    (a) Cyanobacteria
    (b) Green sulphur bacteria
    (c) Purple sulphur bacteria
    (d) All of these

17. Similarity between chemosynthesis and photosynthesis is
    (a) association with heterotrophs
    (b) dependent on solar energy
    (c) found in spermatophytes
    (d) autotrophic nutrition.

18. Which of the following is an iron bacteria?
(a) *Thiobacillus* (b) *Ferrobacillus*
(c) *Chromatium* (d) Both (a) and (b)

19. During photosynthesis plant releases more amount of O^{18} than the normal oxygen, this shows that the plant has been supplied with
(a) water containing O^{18}
(b) sugar containing O^{18}
(c) carbon dioxide containing O^{18}
(d) all of these.

20. Hill used _____ as hydrogen acceptor, to prove that H_2O splits.
(a) hydrogen (b) FAD
(c) NADP (d) ferric salt

21. Hill demonstrated reaction
(a) in the absence of water
(b) in the absence of carbon dioxide
(c) in the presence of carbon dioxide
(d) both (a) and (c).

6.1 Site of Photosynthesis

22. Chloroplast is a semi-autonomous body due to the presence of
(a) photons (b) ribosomes
(c) DNA (d) proteins.

23. The grana are connected by
(a) plasmodesmata
(b) intergrana
(c) fret membranes (d) both (b) and (c).

24. A quantasome comprises of
(a) PS I only
(b) PS II only
(c) Both PS I and PS II
(d) None of these.

25. Chloroplast is a double membrane bound structure due to the presence of
(a) stroma (b) plastidome
(c) peristromium (d) quantasomes.

26. Enzymes required in dark reaction are present in ________ of chloroplast.
(a) thylakoids (b) grana
(c) stroma (d) lamellae

27. Plastidome is a
(a) circular, closed DNA
(b) colourless, colloidal matrix
(c) 70S ribosome
(d) inner and outer membrane.

28. Grana remain embedded in
(a) thylakoids (b) stroma
(c) fret membranes (d) peristromium.

29. Photosynthetic pigments in bacteria are located in
(a) thylakoid (b) DNA
(c) chloroplast (d) ribosomes.

30. In which of the following quantasomes are present?
(a) Stroma (b) Grana
(c) Peristromium (d) DNA

31. The thylakoids are aggregated to form stacks of small discs called
(a) stroma (b) grana
(c) stroma thylakoids (d) fret membranes.

32. The enzymatic reaction which incorporates CO_2 into the plants leads to the synthesis of sugar in
(a) stroma (b) stroma lamella
(c) grana (d) thylakoids.

33. Fret membrane is another name for
(a) stroma-lamellae
(b) intergranal-lamellae
(c) space present in stroma lamellae
(d) both (a) and (b).

34. Stroma consists of which of the following?
(a) RNA (b) 70S ribosomes
(c) Quantasomes (d) PS I

35. DNA present in chloroplast is called as
(a) peristromium (b) episome
(c) plastidome (d) plasmid.

36. The process of photosynthesis takes place in
(a) Golgi complex (b) mitochondria
(c) lysosomes (d) chloroplasts.

37. Arrange the sequence from 'in' to 'outwards'.
(a) Quantasome, Grana, Chloroplast, Chlorophylls
(b) Chlorophylls, Quantasomes, Grana, Chloroplast
(c) Chlorophylls, Quantasome, Chloroplast, Grana
(d) Chloroplast, Chlorophyll, Quantasome, Grana

38. Green plastids are called
(a) chloroplasts (b) leucoplasts
(c) chromoplasts (d) both (b) and (c).

39. Chloroplasts fix
(a) O_2 (b) H_2O
(c) CO_2 (d) N_2.

40. Which among the following is a feature of chloroplast?
(a) Completely dependent on nucleus
(b) Completely independent from nucleus
(c) Autonomous
(d) Semi-autonomous

41. Fret channel helps in
(a) oxidation of H_2O
(b) reduction of CO_2
(c) transport of materials
(d) ATP synthesis.

6.2 Photosynthetic Pigments and their Role

42. Chlorophyll *a* and *b* show maximum absorption in
(a) blue region of visible light
(b) red region of visible light
(c) blue, violet and red regions of visible light
(d) yellow and violet regions of visible light.

43. Which of the following is a feature of chlorophyll?
(a) Soluble in organic solvents
(b) Soluble in water
(c) Soluble in both organic solvents and water
(d) Insoluble in both organic solvents and water

44. Which among the following is not a part of chlorophyll molecule?
(a) Copper (b) Nitrogen
(c) Carbon (d) Magnesium

45. Carotenes and chlorophyll *b* are also known as
(a) respiratory pigments (b) accessory pigments
(c) essential pigments (d) none of these.

46. How many oxygen atoms are present in chlorophyll *a* molecule?
(a) 3 (b) 7
(c) 5 (d) 6

47. Major carotene found in plants is
(a) α – carotene (b) β – carotene
(c) γ – carotene (d) δ – carotene.

48. Lutein is a
(a) phycobilin (b) xanthophyll
(c) chlorophyll (d) carotene.

49. The red coloured phycobilin is
(a) phycocyanin (b) phycoerythrin
(c) anthocyanin (d) both (a) and (b).

50. A purple coloured, non-photosynthetic pigment present in flower is
(a) phycocyanin (b) xanthophyll
(c) anthocyanin (d) none of these.

51. PAR is abbreviation for
(a) photoreactive radiation
(b) photosynthetically active radiation
(c) photochemical active radiation
(d) both (b) and (c).

52. When electron is with electron carriers, which state does the chlorophyll *a* molecule attain?
(a) Ground state (b) Excited state
(c) Ionized state (d) None of these

53. Which among the following is a yellow pigment?
(a) Chlorophyll *a* (b) Chlorophyll *b*
(c) β-carotene (d) Xanthophyll

54. The maximum absorption of visible light by photosynthetic pigments occur in which region of spectrum?
(a) Violet (b) Orange
(c) Yellow (d) Red

55. The antenna pigments transfer light energy to chlorophyll *a* by
(a) photon transport (b) diffusion
(c) trap mechanism (d) resonance.

56. According to the wave theory during propagation, light behaves as
(a) wave (b) electron
(c) photon (d) none of these.

57. Photosynthetically least efficient radiation is
(a) orange (b) yellow
(c) green (d) red.

58. Photosynthetically active radiation (PAR) represents the following range of wavelength
(a) 340–450 nm (b) 400–700 nm
(c) 500–600 nm (d) 390–760 nm.

59. By which plant pigment, maximum absorption of radiations takes place in the blue-violet and red regions of absorption spectrum?
(a) Chlorophyll *a* (b) Chlorophyll *b*
(c) Xanthophyll (d) Both (a) and (b)

60. Which of the following pigments prevent the photo-oxidation of chlorophyll *a* molecules?
(a) Phycobilins (b) Carotenoids
(c) Phosphorylase (d) None of these

61. The pigment chlorophyll *a* is absent in
(a) gymnosperms (b) bacteria
(c) algae (d) none of these.

62. Fraction of visible spectrum primarily absorbed by carotenoids is
(a) red and blue (b) violet and blue
(c) blue and green (d) green and red.

63. Absorption of light at different wavelengths is represented by
(a) absorption spectrum (b) action spectrum
(c) both (a) and (b) (d) none of these.

64. Rate of photosynthesis at different wavelengths of light is represented by
(a) absorption spectrum
(b) action spectrum
(c) both (a) and (b)
(d) none of these.

65. Phytol tail is present at
(a) 5^{th} carbon of II ring
(b) 2^{nd} carbon of III ring
(c) 7^{th} carbon of IV ring
(d) 5^{th} carbon of IV ring.

66. Which of the following is a oxygen containing carotenoid?
(a) β-carotene (b) Lycopene
(c) Lutein (d) Both (b) and (c)

67. Bacteriochlorophyll is found in
(a) blue green alga
(b) photosynthetic bacteria
(c) chemosynthetic bacteria
(d) both (a) and (b).

68. Main function of carotenoids is
(a) to absorb light energy
(b) to convert light energy into chemical energy
(c) both (a) and (b)
(d) none of these.

69. Photosystem I and photosystem II refers to composite group of
(a) chlorophyll *a* and chlorophyll *c*
(b) chlorophyll *a* and xanthophyll
(c) chlorophyll *a*, chlorophyll *b* and carotenoids
(d) carotenoids and xanthophyll.

70. In chlorophyll, the pyrrole ring consists of
(a) four carbon (b) one nitrogen
(c) three carbon (d) both (a) and (b).

71. A cell that lacks chloroplast does not
(a) evolve CO_2 (b) utilise carbohydrate
(c) both (a) and (b) (d) liberate O_2.

72. Ionisation of chlorophyll *a* means
(a) development of negative charge
(b) development of both negative and positive charges
(c) development of positive charge
(d) none of these.

73. In which state pigment molecules are present in the chloroplast before the absorption of light energy?
(a) Ground state (b) Ionised state
(c) Reduced state (d) Excited state

74. The number of grana in higher plants ranges between
(a) 10 - 25 (b) 150 - 300
(c) 20 - 250 (d) 40 - 60.

75. The relation between absorption spectrum and action spectrum is
(a) if a pigment shows absorption spectrum, it will never show action spectrum
(b) all pigments showing absorption spectrum, will show action spectrum
(c) if a pigment shows action spectrum, it will never show absorption spectrum
(d) both (a) and (c).

76. A particle of light containing a packet of energy is called
(a) quantum (b) photon
(c) both (a) and (b) (d) none of these.

77. In which of the following, photosynthesis does not take place?
(a) Artificial light
(b) Sunlight
(c) Visible spectrum
(d) Non-visible spectrum

78. Pyrrole ring II of chlorophyll *a* molecule, at its 3 carbon atom contains a
(a) carboxylic group (b) magnesium
(c) aldehyde group (d) methyl group.

79. The 700 nm (P_{700}) is reaction centre of
(a) PS I
(b) PS II
(c) both (a) and (b)
(d) none of these.

80. Photosystem II is located in
(a) grana
(b) entire chloroplast
(c) stroma
(d) chloroplast membrane.

81. The chemical structure of chlorophyll *a* varies from chlorophyll *b* due to the difference between
(a) CH_3 and C_2H_5
(b) CH_3 and $HCH=CH_2$
(c) CH_3 and CHO
(d) CHO and $CH=CH_2$.

82. P_{700} is named because
(a) it is 700 times more efficient than other pigment molecules
(b) its absorption and action spectra show peaks at 700nm
(c) it is rendered ineffective at wave length above 700nm
(d) it is a unit consisting of 700 chlorophyll molecules.

83. Number of chlorophyll *a* molecules arranged per reaction centre in the light harvesting complex are
(a) 100 (b) 200
(c) 300 (d) 400.

84. Reaction centre of photosystem-I in green plants is
(a) P_{660} (b) P_{690}
(c) P_{680} (d) P_{700}.

85. Which of the following element is needed for chlorophyll formation?
(a) Copper (b) Magnesium
(c) Calcium (d) Chlorine

86. Molecular formula $C_{40}H_{56}O_2$ represents
(a) xanthophyll (b) carotenes
(c) chlorophyll *a* (d) chlorophyll *b*.

87. e^- emitted from chl *a* at excited state returns back to the chlorophyll molecule within
(a) 10^{-7} seconds (b) 10^{-11} seconds
(c) 10^{-9} seconds (d) 10^{-10} seconds.

88. Chl *a* is called as universal photosynthetic pigment because it occurs in
(a) all eukaryotic photoautotrophs
(b) all photoautotrophs
(c) all oxygenic photoautotrophs
(d) both oxygenic and anoxygenic photoautotrophs.

89. Which of the following is sensitive to shorter wavelength of light?
(a) Photolysis (b) PS I
(c) PS II
(d) Photophosphorylation

6.3 Light-Dependent Reactions

90. PS-I gets the de-energised electrons from
(a) cytochrome b_6 (b) plastoquinone
(c) plastocyanin (d) cytochrome *f*.

91. The light energy on interaction with matter behaves as a stream of packets of energy known as
(a) quantasome (b) photons
(c) photosomes (d) all of these.

92. Photophosphorylation takes place in
(a) mitochondria (b) chloroplast
(c) cytoplasm (d) peroxisomes.

93. What does ATP stands for?
(a) Adenosine triphosphate
(b) Adenosine triose phosphate
(c) Adenine triphosphate
(d) Adenine triose phosphate

94. Which among the following is believed to be the first electron carrier molecule from P_{700} to $NADP^+$?
(a) Cytochrome (b) Cu protein
(c) FRS (d) Fe- Mg protein

95. Iron-rich red protein ferredoxin is a component of
(a) photosystem II
(b) bacterial photosynthesis
(c) photosystem I
(d) Hill's reaction.

96. Splitting of water is associated with
(a) pigment system I (P_{700})
(b) pigment system II (P_{680})
(c) both (a) and (b)
(d) none of these.

97. $NADPH_2$ in photosynthesis process acts as
(a) oxidising power
(b) reducing power
(c) both (a) and (b)
(d) none of these.

98. Which theory explains ATP synthesis in chloroplasts during photosynthesis and mitochondria during cellular respiration?
(a) Lipman and Lohmann theory
(b) Lock and key theory of Fischer
(c) Induced fit theory of Koshland
(d) Chemiosmotic hypothesis of Mitchell

99. Proton gradient establishment leads to formation of
(a) ATP (b) ADP
(c) $NADPH_2$ (d) NADPH.

100. In photosynthetic bacteria, which type of photophosphorylation takes place?
(a) Only non-cyclic
(b) Only cyclic
(c) Both cyclic and non-cyclic
(d) None of these

101. Photophosphorylation means synthesis of
(a) NADP from $NADPH_2$
(b) PGA from RuBisCO
(c) ATP from ADP
(d) ADP from ATP.

102. Which of the following phenomenons is observed during cyclic phosphorylation as well as non-cylic phosphorylation?
(a) Formation of $NADPH_2$
(b) Involvement of both PS–I and PS–II pigment systems
(c) Release of O_2
(d) Formation of ATP

103. Electrons which gets excited in PS-I is replaced by
(a) ATP (b) H_2O
(c) PS-II (d) NAD.

104. The proton gradient developed during chemiosmosis leads to
(a) oxygen (b) water
(c) energy (d) protons.

105. In light reaction of photosynthesis
(a) ADP is phosphorylated and NADPH is oxidised
(b) ADP is phosphorylated and NADP is reduced
(c) ADP is phosphorylated and NADPH is reduced
(d) ATP is phosphorylated and NADPH is reduced.

106. Another name for Z-scheme of electron transport is
(a) cyclic photophosphorylation
(b) non-cyclic photophosphorylation
(c) both (a) and (b)
(d) none of these.

107. Cyclic photophosphorylation occurs in
(a) thylakoids or lamellae
(b) stroma
(c) peristromium (d) plastidome.

108. Cyclic phosphorylation occurs at
(a) wavelength beyond 800 nm
(b) wavelength beyond 680 nm
(c) wavelength at 800 nm
(d) wavelength below 500 nm.

109. What happens during light reaction?
(a) Synthesis of OAA
(b) Synthesis of PGA
(c) Photolysis of water molecule
(d) CO_2 combines with RuBP

110. The non-cyclic photophosphorylation involves
(a) photolysis of water
(b) evolution of oxygen
(c) synthesis of assimilatory power
(d) all of these.

111. Unidirectional flow of e^- in non-cyclic photophosphorylation is
(a) PS II $\xrightarrow{e^-}$ NADP $\xrightarrow{e^-}$ PS I $\xrightarrow{e^-}$ Water
(b) Water $\xrightarrow{e^-}$ PS II $\xrightarrow{e^-}$ PS I $\xrightarrow{e^-}$ NADP
(c) PS I $\xrightarrow{e^-}$ NADP $\xrightarrow{e^-}$ Water $\xrightarrow{e^-}$ PS II
(d) PS I $\xrightarrow{e^-}$ Water $\xrightarrow{e^-}$ PS II $\xrightarrow{e^-}$ NADP.

112. Donor and acceptor of electrons is the same chlorophyll molecule in
(a) cyclic photophosphorylation
(b) photooxidation
(c) non-cyclic photophosphorylation
(d) none of these.

113. Electron acceptors in cyclic photophosphorylation is in sequence as
(a) FRS $\rightarrow$ Fd $\rightarrow$ Cyt b_6 $\rightarrow$ Cyt f $\rightarrow$ PC
(b) FRS $\rightarrow$ Fd $\rightarrow$ Cyt f $\rightarrow$ Cyt b_6 $\rightarrow$ PC
(c) FRS $\rightarrow$ Cyt b_6 $\rightarrow$ Cyt f $\rightarrow$ PC $\rightarrow$ Fd
(d) FRS $\rightarrow$ Fd $\rightarrow$ PC $\rightarrow$ Cyt f $\rightarrow$ Cyt b_6.

114. Which of the following will not be formed if PS II is not working ?
(a) ATP (b) $NADPH_2$
(c) CO_2 (d) ADP

115. The gap electron of PS II is filled due to supply of electrons from
(a) plastoquinone (b) photolysis of water
(c) cytochrome f (d) PS I.

116. Light dependent reactions are responsible for the formation of
(a) ATP and $C_6H_{12}O_6$
(b) ATP, hydrogen and oxygen donor
(c) Hydrogen, oxygen and sugar
(d) ATP, $NADPH_2$ and oxygen.

117. Which among the following is not an aspect of light phase?
(a) Evolution of O_2
(b) Photophosphorylation
(c) CO_2 fixation
(d) Photolysis of water

118. Which of the following best represent Hill reaction?
(a) Photolysis of water
(b) Photolysis of water releasing oxygen
(c) Photolysis of water in light resulting in reduction of NADP and release of oxygen
(d) Photolysis of water and release of hydrogen

119. In bacterial photosynthesis light reaction involves
(a) PS I only (b) PS II only
(c) both PS I and PS II (d) none of these.

120. Using analogy of bacterial photosynthesis Van Niel suggested that in higher plant
(a) H_2S is hydrogen source
(b) H_2O is hydrogen source
(c) O_2 is liberated from CO_2
(d) photosynthesis needs light.

121. Both ATP and $NADPH_2$ are synthesised in
(a) cyclic phosphorylation
(b) non-cyclic phosphorylation
(c) both (a) and (b)
(d) none of these.

122. Which of the following possess both PS–I and PS–II?
(a) Purple sulphur bacteria
(b) Green sulphur bacteria
(c) Cyanobacteria
(d) Purple non-sulphur bacteria

123. Light reaction in photosynthesis occurs in
(a) stroma (b) lamellae
(c) grana (d) outer membrane.

124. Cyclic photophosphorylation results in the
(a) formation of ATP
(b) formation of $NADPH_2$ and ATP
(c) formation of $NADPH_2$
(d) formation of ADP + iP.

125. How much assimilatory power is required to produce one molecule of $C_6H_{12}O_6$?
(a) 12 ATP (b) 38 ATP
(c) 18 ATP and 12 $NADPH_2$
(d) 12 ATP and 6 $NADPH_2$

126. Chemiosmotic theory of ATP synthesis is based on
(a) proton gradient
(b) accumulation of Na^+ ions
(c) accumulation of K^+ ions
(d) none of these.

127. Chemiosmotic hypothesis given by Peter Mitchell proposes the mechanism of
(a) synthesis of ATP (b) synthesis of ADP
(c) synthesis of NADP
(d) synthesis of NADPH.

6.4 Light - Independent Reactions

128. Out of the total PGAL produced one-sixth part is used for synthesis of
(a) Glucose (b) RuBP
(c) RuMP (d) DHAP.

129. The internal source of CO_2 in CAM plants is
(a) oxalo-acetic acid (b) malic acid
(c) pyruvate (d) PEPA.

130. CAM plants are
(a) tropical plants (b) xerophytes
(c) monocots (d) mangroves.

131. Which of the followings is the first stable product of photosynthesis in maize?
(a) PGA (b) PGAL
(c) PEPA (d) OAA

132. Due to photorespiration approximately what percentage of photosynthetically fixed CO_2 is lost?
(a) 25 % (b) 50 %
(c) 75 % (d) 80 %

133. Which part of the photosynthetic process does not require direct light?
(a) Hill's reaction (b) Blackman's reaction
(c) Warburg's reaction
(d) Emmerson's reaction

134. What are the pre-requisites of Calvin cycle?
(a) $NADPH_2$, ATP, CO_2 (b) ATP, H_2O, CO_2
(c) ATP, $NADPH_2$, H_2O
(d) $NADPH_2$, H_2O, CO_2

135. In Calvin cycle PGAL is formed from PGA by which process?
(a) Regeneration (b) Oxidation
(c) Reduction (d) Photolysis

136. RuBP fix CO_2 for sugar synthesis in
(a) C_3 plants (b) CAM plants
(c) C_4 plants (d) all of these.

137. On a hot summer day, a green plant start evolving CO_2 instead of O_2 due to
(a) photorespiration
(b) phosphorylation
(c) high rate of respiration
(d) non-availability of H_2O.

138. Location of ribulose biphosphate carboxylase oxygenase is
(a) chloroplasts (b) mitochondria
(c) golgi bodies (d) peroxisomes.

139. Synthesis of glucose in C_4 pathway occurs in chloroplasts of
(a) spongy mesophyll (b) bundle sheath
(c) guard cells (d) palisade tissue.

140. The C_4 plants differs from C_3 plants due to difference in
(a) substrate that accept CO_2 in carbon assimilation
(b) type of end product of photosynthesis
(c) type of pigments involved in photosynthesis
(d) none of these.

141. Agranal chloroplasts are characteristic feature of
(a) bundle sheath of sugarcane leaves
(b) mesophyll of jowar leaves
(c) bundle sheath of mango leaves
(d) mesophyll of maize leaves.

142. What is the first product of CO_2 fixation in Hatch and Slack pathway in plants?
(a) Formation of oxaloacetate by carboxylation of phosphoenol pyruvate (PEP) in bundle sheath cells.
(b) Formation of oxaloacetate by carboxylation of phosphoenol pyruvate (PEP) in the mesophyll cells.
(c) Formation of phosphoglyceric acid in mesophyll cells.
(d) Formation of phosphoglyceric acid in bundle sheath cells.

143. PEP carboxylase has
(a) low affinity for CO_2
(b) high affinity for CO_2
(c) high affinity for O_2
(d) both (a) and (c).

144. C_4 plants produce more sugars than C_3 plants on hot, dry days because
(a) in C_4 plant more and more CO_2 enters the leaves
(b) they shows photorespiration
(c) they show little or no photorespiration
(d) there is an increase in rate of photosynthesis.

145. C_4 plants can absorb CO_2 at
(a) low concentration
(b) high concentration
(c) both (a) and (b)
(d) none of these.

146. In C_4 plants, enzyme which fixes the CO_2 released during decarboxylation of malate is
(a) RuBisCO
(b) malate dehydrogenase
(c) PEP carboxylase
(d) malate carboxylase.

147. CAM pathway of photosynthesis
(a) occurs in desert plants that close their stomata during the day
(b) is an adaptation to cold environments
(c) is the same as C_3 pathway
(d) occurs in plants that live in tropical areas.

148. In succulent xerophytes, there is accumulation of malic acid in night, this path of CO_2 metabolism is known as
(a) Hatch and Slack pathway
(b) Crassulacean Acid Metabolism
(c) Calvin cycle
(d) none of these.

149. In CAM pathway sugar is stored in form of
(a) fats (b) lipids
(c) proteins (d) starch.

150. The fate of phosphoglycolate formed during photorespiration is
(a) it get converted to RuBP
(b) it get converted to PGA and enters Calvin cycle
(c) it get converted to malic acid
(d) it get converted to OAA.

151. Dark reaction is named so because
(a) it takes place only at night
(b) it require direct light
(c) it does not require direct light
(d) it occurs slowly during light.

152. The first stable compound formed during the Calvin cycle is a
(a) 3C compound (b) 4C compound
(c) 6C compound (d) 2C compound.

153. In C_3 plants, during dark reaction first acceptor of CO_2 is
(a) phosphoglyceric acid
(b) ribulose–5–phosphate
(c) phosphoenol pyruvate
(d) ribulose 1, 5–di phosphate.

154. PGA is a
(a) 3C compound (b) 5C compound
(c) 7C compound (d) 4C compound.

155. The process of respiration that takes place in chloroplast during daytime is
(a) photorespiration (b) phosphorylation
(c) photosynthesis (d) oxidation.

156. The five carbon compound formed during regeneration phase in C_3 cycle is
(a) glucose (b) sedoheptulose
(c) xylulose (d) erythrose.

157. C_4 plants are adapted to
(a) hot and dry climate (b) temperate climate
(c) cold and dry climate (d) both (b) and (c).

158. Chloroplast dimorphism is found in
(a) C_4 plants (b) C_3 plants
(c) CAM plants (d) all of these.

159. OAA can be reduce to
(a) malic acid (b) aspartic acid
(c) fumaric acid (d) both (a) and (b).

160. Name the most important acid for CAM plants.
(a) Aspartic acid (b) Carbonic acid
(c) Malic acid (d) Both (a) and (c)

161. CAM plants contains
(a) only mesophyll cells and no bundle sheath cells
(b) only bundle sheath cell and no mesophyll cells
(c) both mesophyll and bundle sheath cells
(d) none of these.

162. During formation of malic acid in CAM cycle, stomata are
(a) open (b) closed
(c) semi-open (d) none of these.

163. Why biosynthetic phase is called as dark reaction?
(a) It depends on the light.
(b) It does not depends on the light.
(c) It does not depends on NADPH.
(d) It does not depends on ATP.

164. Every CO_2 molecule entering the Calvin cycle needs
(a) 2 molecule of NADPH and 3 molecule of ATP for its fixation
(b) 2 molecule of NADPH and 2 molecule of ATP for its fixation
(c) variable amount of ATP
(d) NADPH.

165. The enzyme responsible for primary carboxylation in C_3 plants is
(a) triose-phosphate isomerase
(b) succinic dehydrogenase
(c) pyruvate carboxylase
(d) RuBP carboxylase.

166. Algae used by Calvin in photosynthesis experiments is
(a) *Spirulina* (b) *Chlorella*
(c) *Euglena* (d) *Chara.*

167. Name the first enzyme of Calvin cycle.
(a) Cytochrome oxidase (b) Hexokinase
(c) RuBP carboxylase (d) Both (a) and (b)

168. Plants adapted to dry tropical conditions have different type of pathway named as
(a) C_2 pathway (b) C_3 pathway
(c) photorespiration (d) C_4 pathway.

169. PEP is absent in
(a) mesophyll cell (b) bundle sheath cell
(c) C_4 plant (d) both (a) and (b).

170. RuBisCO enzyme is absent in
(a) mesophyll cell (b) bundle sheath cell
(c) C_3 plants (d) all of these.

171. CO_2 released in bundle sheath cell is used in the
(a) C_4 cycle (b) C_3 cycle
(c) respiration (d) none of these.

172. In C_4 plants, bundle sheath cells are the large cells arranged radially around the
(a) vascular bundles of C_4 plant
(b) vascular bundles of C_3 plant
(c) vascular bundles of C_2 plant
(d) all of these.

173. The C_4 plants are photosynthetically more efficient than C_3 plants because
(a) the carbon dioxide compensation point is more
(b) carbon dioxide generated during photorespiration is trapped and recycled through PEP carboxylase
(c) the carbon dioxide efflux is not prevented
(d) they have more affinity for carbon dioxide fixation at low concentration.

174. C_4 plants differ from C_3 plants in respect to
(a) number of CO_2 molecules used
(b) the first stable product
(c) the final product
(d) both (a) and (c).

175. In photorespiration peroxisomes
(a) helps in the oxidation of glycolate
(b) helps in the reduction of glycolate
(c) helps in the reduction of glyoxylate
(d) both (a) and (b).

176. C_4 plant minimises the photorespiration because
(a) in it RuBisCO functions as carboxylase only
(b) it do not carry out the Calvin cycle in low CO_2 level
(c) both (a) and (b)
(d) none of these.

177. RuBisCO performs oxygenase activity at
(a) low CO_2 concentration
(b) low O_2 concentration
(c) high H_2O concentration
(d) high CO_2 concentration.

178. Photorespiration is occurred at
(a) high oxygen and low carbon dioxide concentration
(b) high carbon dioxide and low oxygen concentration
(c) high temperature and low oxygen concentration
(d) high carbon dioxide and high oxygen concentration.

179. In CAM plants, CO_2 required for photosynthesis enters the plant body during
(a) daytime through the lenticels
(b) night when the stomata are open
(c) daytime when the stomata are open
(d) night when the hydathodes are open.

180. In a CAM plant, the concentration of organic acid
(a) increases during the day
(b) decreases during the day
(c) increases during night
(d) both (b) and (c).

181. The two enzymes responsible for primary carboxylation in C_3 and CAM pathway, respectively are
(a) RuBP carboxylase and RuBP oxygenase
(b) PEP carboxylase and RuBP carboxylase
(c) RuBP carboxylase and PEP carboxylase
(d) PEP carboxylase and pyruvate carboxylase.

182. How many Calvin's cycle round are required to form one glucose molecule?
(a) 2 (b) 6
(c) 5 (d) 9

183. Ribose-5-phosphate (5C) is formed during
(a) carboxylation
(b) reduction of PGA (c) synthesis of glucose
(d) regeneration of RUDP.

184. Glycolytic reversal takes place at the time of
(a) formation of PGA (b) reduction of PGA
(c) regeneration of RuBP
(d) none of these.

185. How many turns of Calvin's cycle are required for formation of 3 glucose molecules?
(a) 6 turns of Calvin's cycle
(b) 9 turns of Calvin's cycle
(c) 18 turns of Calvin's cycle
(d) 24 turns of Calvin's cycle

186. If 48 molecules of PGAL are formed during C_3 cycle, how much of them are converted into glucose and regeneration of RUBP respectively?
(a) 40 and 8 (b) 8 and 40
(c) 38 and 10 (d) 36 and 12

187. Which plant will show comparatively higher photorespiration?
(a) Jowar (b) *Amaranthus*
(c) Maize (d) Neem

188. Successful completion of dark reaction depends upon
(a) presence of light energy
(b) supply of PGA
(c) steady supply of assimilatory power
(d) photorespiration.

189. The most abundant enzyme on earth is
(a) PEP carboxylase (b) carboxylase
(c) RuBP carboxylase (d) none of these.

190. The phosphate donor in formation of 1, 3 diphosphoglyceric acid from 3 phosphoglyceric acid is
(a) ADP (b) ATP
(c) $NADPH_2$ (d) H_3PO_4.

191. Carbon path during C_3 pathway was traced using
(a) *Chlorella* (b) spinach
(c) *Scenedesmus* (d) both (a) and (c).

192. The correct sequence of substages in Calvin cycle are
(a) carboxylation, regeneration, synthesis, reduction
(b) carboxylation, reduction, synthesis, regeneration
(c) carboxylation, synthesis, reduction, regeneration
(d) carboxylation, regeneration, reduction, synthesis.

193. Chloroplast dimorphism is not seen in
(a) sugarcane (b) jowar
(c) maize (d) none of these.

194. Another name for chloroplast dimorphism is
(a) law of limiting factors
(b) biological significance of C_4 plants
(c) fate of C_4 mechanism
(d) kranz anatomy.

195. High efficiency of CO_2 fixation in sugarcane is due to
(a) HSK pathway (b) C_3 pathway
(c) TCA cycle (d) CAM.

196. The enzyme PEPcase is active in
(a) vacuoles (b) mesophyll cells
(c) vascular bundle (d) bundle sheath cells.

197. C_3 and C_4 pathways of C_4 plants are separated respectively by
(a) mesophyll and bundle sheath cells
(b) time
(c) bundle sheath and mesophyll cells
(d) duration.

198. Which among the following compound gives pyruvic acid by decarboxylation?
(a) Aspartic acid (b) Malic acid
(c) Oxaloacetic acid (d) All of these

199. A plant is showing photosynthesis with normal rate at a very high temperature, probably it would be
(a) papaya (b) mango plant
(c) pea plant (d) sugarcane plant.

200. The family in which many plants are of C_4 type
(a) Brassicaceae (b) Moraceae
(c) Solanaceae (d) Poaceae.

201. Which of the following is CO_2 concentrating mechanism?
(a) C_4 pathway (b) CAM pathway
(c) EMP pathway (d) C_3 pathway

202. Hatch and Slack pathway originally discovered in
(a) sugarcane by Kortschak
(b) sugarcane by Hatch and Slack
(c) maize by Calvin
(d) maize by Hatch and Slack.

203. Respiration initiated in chloroplasts and takes place during day is called
(a) aerobic respiration
(b) anaerobic respiration
(c) photorespiration
(d) both (a) and (c).

204. Photorespiration is common in
(a) C_3 plants (b) C_4 plants
(c) both C_3 and C_4 plants
(d) none of these.

205. Photorespiration is also known as
(a) Photosynthetic carbon oxidation cycle
(b) Hatch and Slack pathway
(c) Calvin cycle (d) C_5 cycle.

206. In photorespiration, glycolate passes from
(a) chloroplast to peroxisome
(b) chloroplast to mitochondrion
(c) peroxisome to mitochondria
(d) mitochondrion to peroxisome.

207. During photosynthesis, energy is transferred from light reaction to dark reaction in the form of
(a) ADP (b) ATP
(c) RuDP (d) chlorophyll.

208. Photosynthesis in C_4 plants is relatively less limited by atmospheric CO_2 levels because
(a) effective pumping of CO_2 into bundle sheath cells
(b) RuBisCO in C_4 plants has higher affinity for CO_2
(c) four carbon acids are the primary initial CO_2 fixation products
(d) the primary fixation of CO_2 is mediated *via* PEP carboxylase.

209. How many cell organelles are involved in photorespiration?
(a) Five (b) Two
(c) Three (d) Four

210. Glycolate accumulate in chloroplasts when there is
(a) low CO_2 (b) bright light
(c) high CO_2 (d) low temperature.

211. Which of the following is correct?
(a) The bundle sheath cells surround the vascular bundles like a ring in C_4 plants. This is called kranz anatomy.
(b) In CAM plants stomata are open in daytime.
(c) Bundle sheath cells have PEPCO enzymes for CO_2 fixation.
(d) C_3 plants are superior to C_4 plants.

212. C_4 plants are also called
(a) Krebs' type (b) Blackman type
(c) Calvin type (d) Hatch-Slack type.

213. The RuBisCO stands for
(a) ribose biscomplex
(b) ribose bisphosphate
(c) ribulose bisphosphate carboxylase oxygenase
(d) none of the above.

214. In C_4 plants, the bundle sheath cells
(a) have thin walls to facilitate gaseous exchange
(b) have large intercellular spaces
(c) are rich in PEP carboxylase
(d) have agranal chloroplasts.

215. Melvin Calvin worked on
(a) ATP synthesis during photosynthesis
(b) water release during photosynthesis
(c) carbon fixation during photosynthesis
(d) capture of light during photosynthesis.

216. Which one is false about kranz anatomy?
(a) Bundle sheath have large chloroplast and less developed grana.
(b) Mesophyll cells have large chloroplast and more developed grana.
(c) It is found in sugarcane, maize and jowar.
(d) Plants having it have better photosynthesising power than C_3 plants.

217. Radioactive C^{14} is given to CO_2 and released to atmosphere. This CO_2 is taken by RuBP in a C_3 plant. First radioactive C^{14} is seen in which compound?
(a) PGAL (b) PEP
(c) RMP (d) PGA

218. Chloroplasts without grana are known to occur in
(a) bundle sheath cells of C_3 plants
(b) mesophyll cells of C_4 plants
(c) bundle sheath cells of C_4 plants
(d) mesophyll cells of all plants.

219. A molecule is reduced means it
(a) loses electron (b) gains proton
(c) loses proton and electrons
(d) gains electron.

220. Which organism does not evolve oxygen in photosynthesis?
(a) *Anabaena* (b) Maize
(c) *Funaria* (d) *Rhodospirillum*

221. Which among the following were used for study "the path of carbon" in photosynthesis?
(a) Diatoms (b) *Chlorella*
(c) Purple sulphur bacteria
(d) *Chlorobium*

222. Which of the following does not show chloroplast dimorphism?
(a) Jowar (b) Sugarcane
(c) Maize (d) Papaya

223. Chloroplast of mesophyll cells are
(a) large, agranal and more stroma
(b) large, granal and less stroma
(c) small, agranal and more stroma
(d) small, granal and less stroma.

224. Which among the following were used in the study of dark reactions of photosynthesis?
(a) *Hydrilla* and *Chlorella*
(b) *Chlorella* and *Scenedesmus*
(c) *Chlamydomonas* and *Hydrilla*
(d) *Chlorella* and *Spirogyra*

225. If light is cut and CO_2 supply is continued, then which among the following substances will get disappeared from photosynthesising algal cells?
(a) RuDP (b) PGAL
(c) RuMP (d) PGA

226. Assimilatory power of light reaction is utilised in reduction of
(a) PGA (b) PGAL
(c) RuBP (d) all of these.

6.5 Significance of Photosynthesis

227. Which among the following photosynthetic organism does not release oxygen?
(a) Green alga
(b) Blue green alga
(c) Green sulphur bacterium
(d) Algal component of lichen

228. Why protein synthesis is different from photosynthesis?
(a) It uses solar energy.
(b) It does not use solar energy.
(c) It is performed by only autotrophs.
(d) It occurs in chloroplasts.

229. Oxygen producing biological phenomenon is
(a) fermentation (b) photosynthesis
(c) respiration (d) photorespiration.

230. Which among the following is significant feature of photosynthesis?
(a) Release of O_2, which purifies the atmosphere
(b) Formation of food
(c) Release of CO_2 which maintain O_2-CO_2 balance
(d) Both (a) and (b)

231. All living organisms directly or indirectly depends on which process for energy?
(a) Photosynthesis (b) Respiration
(c) Fermentation (d) None of these

232. Which process yields various fossil fuels like coal, petroleum and natural gas?
(a) Respiration (b) Humification
(c) Photosynthesis (d) All of these

233. Plant products like timber, cotton, alkaloids, gums etc. are product of
(a) photosynthesis (b) respiration
(c) transpiration (d) photorespiration.

6.6 Factors Affecting Rate of Photosynthesis

234. At very high light intensity, the rate of photosynthesis
(a) increases with build up of more chlorophyll molecule
(b) remain unaffected
(c) decreases with breakdown of chlorophyll molecule
(d) decreases.

235. Upto what percentage an increase in CO_2 increases the rate of photosynthesis?
(a) 0.03% (b) 0.04%
(c) 0.05% (d) 0.06%

236. Tropical plants will show higher rate of photosynthesis at
(a) high temperature
(b) low temperature
(c) optimum temperature
(d) none of these.

237. Effect of water on plants can be observed during
(a) closure of stomata
(b) loss of turgidity in leaves and wilting
(c) both (a) and (b)
(d) none of these.

238. According to the law of limiting factor given by F.F. Blackman, rate of photosynthesis
(a) depends on the factor which is nearest to its minimal value
(b) depends on the factor which is at its maximal value
(c) depends on all the factors at optimum condition
(d) none of these.

239. The internal factors affecting photosynthesis of plant depends on the
(a) morphological predisposition
(b) genetic predisposition
(c) temperature
(d) water.

240. If a chemical process is affected by more than one factors, then its rate will be determined by
(a) all closely related factors at optimum value
(b) the factor, which is close to its minimal value
(c) one factor, which is close to its maximum value
(d) one factor, which is close to its optimum value.

241. Which among the following proposed law of limiting factor in relation to photosynthesis?
(a) Blackman (b) Weismann
(c) Kortshak (d) Emerson

242. Which among the following factors is not limiting?
(a) Water (b) Temperature
(c) CO_2 concentration (d) None of these

243. The rate of photosynthesis is higher in
(a) very high light (b) continuous light
(c) red light (d) green light.

244. Blackman's law is related to
(a) respiration (b) transpiration
(c) root pressure (d) photosynthesis.

245. Which of the following statements is true?
(a) Temperate plants have a higher temperature optimum than tropical plants.
(b) Tropical plants have a higher temperature optimum than temperate plants.
(c) Both plants have equal optimum temperature.
(d) None of these

246. Which among the following gas would disappear from the atmosphere if all the photosynthetic activities were stopped?
(a) Nitrogen (b) Carbon dioxide
(c) Hydrogen (d) Oxygen

247. Why CO_2 in atmosphere remains constant?
(a) It is converted into glucose during photosynthesis.
(b) It is released during respiration and used up in photosynthesis.
(c) It is released during respiration.
(d) None of these

248. The bacterial photosynthesis is different from that of higher plants as
(a) energy is not fixed
(b) light is not required
(c) oxygen is not released
(d) a host organism is required.

249. Yield of crop plants depends upon the rate of
(a) respiration (b) assimilation
(c) photosynthesis (d) transpiration.

250. Photosynthesis is affected by
(a) internal factors
(b) external factors
(c) genetic factors only
(d) both (a) and (b).

251. Dark reactions are controlled by enzymes and are more sensitive to ____________ than light reactions.
(a) light
(b) CO_2 concentration
(c) temperature
(d) water concentration

252. Water stress causes _________ of stomata, leading to _________ availability of CO_2.
(a) closure, low
(b) opening, high
(c) closure, high
(d) opening, low

253. The law of limiting factors is applicable to
(a) only photosynthetic reaction
(b) any biochemical reaction
(c) only respiration reaction
(d) none of these.

254. A plant is kept in 0.05% CO_2 concentration. What will happen to it?
(a) Plants will be soon die.
(b) Plant will grow well.
(c) Plant will show increase rate of photosynthesis.
(d) Respiration will be greatly reduced.

255. When light hours are increased during day, the rate of photosynthesis
(a) decreases (b) increases

LEVEL - 2

1. Photorespiration is favoured by
(a) high temperature and low O_2
(b) high humidity and temperature
(c) high O_2 and low CO_2
(d) high CO_2 and low O_2.

2. The core metal of chlorophyll is
(a) Ni (b) Cu
(c) Fe (d) Mg.

3. Carbon dioxide acceptor in C_3 plants is
(a) PGA (b) PEP
(c) RuBP (d) none of these.

4. For the synthesis of one glucose molecule the Calvin cycle operates for
(a) 2 times (b) 4 times
(c) 6 times (d) 8 times.

5. Which pair is wrong?
(a) C_3-maize
(b) C_4-kranz anatomy
(c) Calvin cycle-PGA
(d) Hatch and Slack cycle-OAA

6. In photosynthesis, energy from light reaction to dark reaction is transferred in the form of
(a) AMP (b) ATP
(c) RuBP (d) none of these.

7. Which of the following absorbs light energy for photosynthesis?
(a) Chlorophyll (b) Water molecule
(c) Oxygen (d) RuBP

8. Which of the following is wrong in relation to photorespiration?
(a) It occurs in chloroplast.
(b) It occurs in daytime only.
(c) It is a characteristic of C_4 plants.
(d) It is a characteristic of C_3 plants.

9. Stomata of CAM plants
(a) are always open
(b) open during the day and close at night
(c) open during the night and close during the day
(d) never open.

10. In C_3 plants, the first stable product of photosynthesis during the dark reaction is
(a) malic acid (b) oxaloacetic acid
(c) 3-phosphoglyceric acid
(d) phosphoglyceraldehyde.

11. Photosynthetically active radiation (PAR), ranges from, _______ wavelength.
(a) 500-600 nm (b) 450-950 nm
(c) 240-450 nm (d) 390-760 nm

12. During photosynthesis, oxygen in glucose comes from
(a) oxygen in air (b) water
(c) carbon dioxide (d) both (b) and (c).

13. The molecule which mainly absorbs light energy and converts it to chemical energy in photosynthesis is
(a) carotenoid (b) chlorophyll *a*
(c) xanthophyll (d) none of these.

14. The photosynthetic carbon-oxidation cycle involves the interaction of
(a) chloroplast (b) mitochondria
(c) peroxisomes (d) all of these.

15. Which of the following categories of organisms do not evolve oxygen during photosynthesis?
(a) Red algae
(b) Photosynthetic bacteria
(c) C_4 plants with kranz anatomy
(d) Blue green algae

16. During dark reaction, for the fixation of carbon, the three carbon atoms of each molecule of 3-phosphoglyceric acid (PGA) are derived from
(a) RuBP + CO_2 (b) CO_2 only
(c) RuBP only (d) RuBP + CO_2 + PEP.

17. In C_4 plants, CO_2 combines with
(a) phosphoenol pyruvate
(b) phosphoglyceraldehyde
(c) phosphoglyceric acid
(d) ribulose diphosphate.

18. Accessory photosynthetic pigments in most green plants are
(a) chlorophyll *a*
(b) chlorophyll *b*
(c) carotenes and xanthophylls
(d) both (b) and (c).

19. C_4 plants have an advantage over C_3 plants when the weather is
(a) only hot (b) hot and dry
(c) hot and wet (d) cold and dry.

20. Oxygen which is liberated during photosynthesis, comes from
(a) CO_2 (b) H_2O
(c) chlorophyll
(d) phosphoglyceric acid.

21. In photosynthesis light reaction occurs in which of the following parts of leaf?
(a) Inner membrane (b) Lamellae
(c) Grana (d) Outer membrane

22. During light reaction of photosynthesis, which of the following phenomenon is common during cyclic phosphorylation as well as non-cyclic phosphorylation?
(a) Release of O_2
(b) Formation of NADPH
(c) Formation of ATP
(d) Involvement of both the pigment systems

23. The primary acceptor during carbon dioxide fixation in C_3 plants is
(a) phosphoglyceric acid (PGA)
(b) phosphoenolpyruvate (PEP)
(c) ribulose monophosphate (RuMP)
(d) ribulose 1, 5-biphosphate (RuBP).

24. Reaction centre of photosystem II in green plants is
(a) P_{660} (b) P_{690}
(c) P_{680} (d) P_{700}.

25. In maize, PEP-carboxylation reaction takes place in
(a) epidermis
(b) bundle sheath cells
(c) mesophyll cells
(d) bundle sheath and cortex.

26. Photosystem II is present in
(a) grana
(b) entire chloroplast
(c) stroma
(d) chloroplast membrane.

27. Constituent of chlorophyll is
(a) Fe (b) Na
(c) Mg (d) Cu.

28. The first step in dark reaction of photosynthesis is
(a) formation of ATP
(b) ionisation of water
(c) attachment of CO_2 to a pentose sugar
(d) excitement of electron of chlorophyll by a photon of light.

29. Sugarcane show high efficiency of CO_2 fixation because of
(a) Calvin cycle
(b) Hatch and Slack cycle
(c) TCA cycle
(d) photorespiration.

30. The formula for chlorophyll *a* is
(a) $C_{55}H_{70}O_6N_4Mg$ (b) $C_{55}H_{72}O_5N_4Mg$
(c) $C_{22}H_{70}O_5N_4Mg$ (d) $C_{22}H_{72}O_5N_4Mg$.

31. The first electron acceptor in cyclic photophosphorylation is
(a) Fd (b) PQ
(c) PC (d) cyt.*b*.

32. In chlorophyll structure four pyrrole rings are united with Mg by their atoms of
(a) N (b) C
(c) H (d) O.

33. 'Assimilatory power' is
(a) $NADH_2$ (b) $NADPH_2$
(c) ATP (d) Both (b) and (c).

34. The synthesis of one molecule of glucose during Calvin cycle requires
(a) 12 molecules of ATP and 18 molecules of $NADPH_2$
(b) 6 molecules of ATP and 12 molecules of $NADPH_2$
(c) 18 molecules of ATP and 12 molecules of $NADPH_2$
(d) 12 molecules each of ATP and $NADPH_2$.

35. Photosynthesis cannot continue for long if during light reaction, only cyclic photophosphorylation takes place. This is because
(a) only ATP is formed, $NADPH^+ + H^+$ is not formed
(b) photosystem I stops getting exicted at a wavelength of light beyond 680 nm.
(c) there is unidirectional cyclic movement of the electrons
(d) there is no evolution of O_2.

36. Which statement about photosynthesis is false?
(a) The enzymes required for carbon fixation are located only in the grana of chloroplasts.
(b) In given plants, both PS I and PS II are required for the formation of $NADPH + H^+$.
(c) The electron carriers involved in photophosphorylation are located on the thylakoid membranes.
(d) Photosynthesis is a redox process in which water is oxidised and carbon dioxide is reduced.

37. How many number of chlorophyll *a* molecules are arranged in the light harvesting complex per reaction centre?
(a) 100 (b) 200
(c) 150 (d) 400

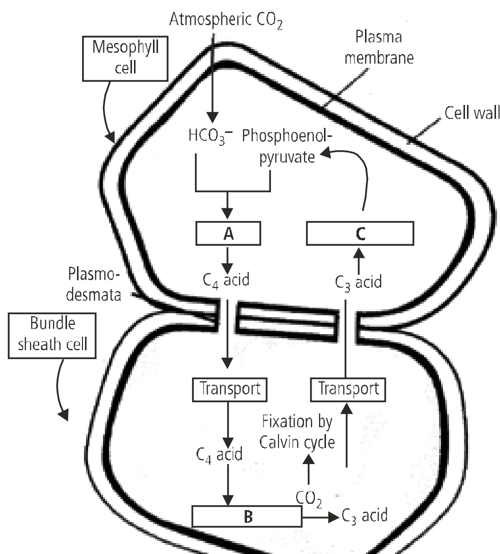
38. Dark reaction of photosynthesis is characterised by
(a) water splitting and production of NADP
(b) reduction of NADP to NADPH
(c) cyclic and non-cyclic phosphorylation
(d) enzyme mediated carbon fixation.

39. Which of the following characteristics out of A, B and C are exhibited by C_4 plants?
A. Kranz anatomy
B. The product of photosynthesis is oxaloacetic acid.
C. Both PEP carboxylase and ribulose bisphosphate carboxylase act as carboxylating enzymes.
The correct answer is
(a) only A and B, but not C
(b) only B and C, but not A
(c) only A and C, but not B
(d) all A, B and C.

40. Photophosphorylation differs from oxidative phosphorylation in requiring
(a) input of energy in the form of light
(b) input of energy in the form of heat
(c) input of energy in the form of AMP
(d) input of energy in the form of NAD.

41. Read the following four statements, (i), (ii), (iii) and (iv) and select the right option having both correct statements.
(i) Z scheme of light reaction takes place in presence of PS I only.
(ii) Only PS I is functional in cyclic photophosphorylation.
(iii) Cyclic photophosphorylation results into synthesis of ATP and $NADPH_2$.
(iv) Stroma lamellae lack PS II as well as NADP.
(a) (ii) and (iv) (b) (i) and (ii)
(c) (ii) and (iii) (d) (iii) and (iv)

42. Study the pathway given below:



In which of the following options correct words for all the three blanks A, B and C are indicated?

	A	B	C
(a)	Decarboxylation	Reduction	Regeneration
(b)	Fixation	Transamination	Regeneration
(c)	Fixation	Decarboxylation	Regeneration
(d)	Carboxylation	Decarboxylation	Reduction

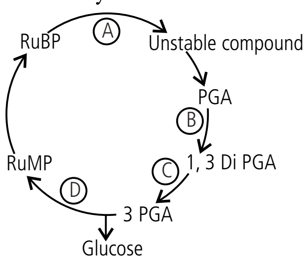
43. Which of the following is wrongly matched?
(a) Maize – Kranz anatomy
(b) PEP carboxylase – Mesophyll cells
(c) Photorespiration – C_3 plants
(d) PS II – P_{700}

44. Who among the following inferred that oxygen evolved during photosynthesis comes from water not from carbon dioxide?
(a) Arnon (b) Van Niel
(c) Ruben and Kamen (d) None of these

45. The bundle sheath cells in Kranz anatomy found in C_4 plants, are characterised by
(a) agranal chloroplast, smaller size chloroplast and less stroma.
(b) agranal chloroplast, bigger size chloroplast and more stroma
(c) granal chloroplast, bigger size chloroplast and more stroma
(d) agranal chloroplast, smaller size and no stroma.

46. Which of the following statements is true with regard to the light reaction of photosynthesis?
(a) In PSI the reaction centre chlorophyll *a* has an absorption maxima at 680 nm and is called P_{680}.
(b) The splitting of water molecule is associated with PSI.
(c) Photosystems I and II are involved in Z scheme.
(d) Lamellae of the grana have PSI and PS II and stroma lamellae membranes have PS II only.

47. In a condensed schematic representation of dark reaction of photosynthesis given below, steps are indicated by alphabets. Select the option where the alphabets are correctly identified.

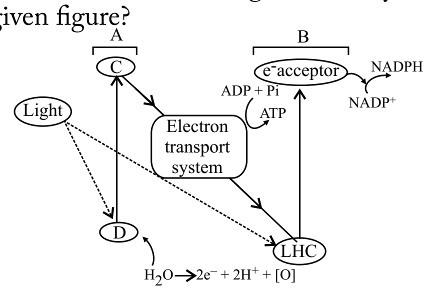


(a) A = CO_2 fixation, B = Reduction, C = Phosphorylation, D = Regeneration
(b) A = Regeneration, B = CO_2 fixation, C = Reduction, D = Phosphorylation
(c) A = CO_2 fixation, B = Phosphorylation, C = Reduction, D = Regeneration
(d) A = CO_2 fixation, B = Phosphorylation, C = Regeneration, D = Reduction

48. Consider the following statements with respect to photosynthesis.
A. The first carbon dioxide acceptor in C_4 cycle is PGA.
B. In C_3 plants, the first stable product of photosynthesis during dark reaction is RuBP.
C. Cyclic photophosphorylation results in the formation of ATP.
D. Oxygen which is liberated during photosynthesis comes from water.

Of the above statements
(a) A and B are correct (b) A and C are correct
(c) C and D are correct (d) B and C are correct.

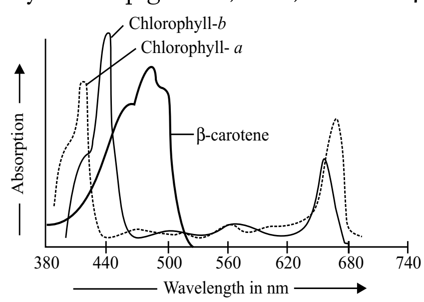
49. Which of the following is correctly labelled for the given figure?



(a) A : PS II ; B : PS I ; C : e^- acceptor; D: LHC
(b) A : LHC; B : e^- acceptor; C : PS I; D : PS II
(c) A : PS I ; B : PS II ; C : e^- acceptor; D : LHC
(d) A : e^- acceptor; B : LHC; C : PS II; D : PS I

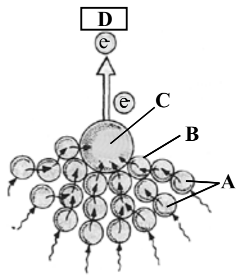
50. The two reducing powers of light reaction are used in dark reaction during formation of
(a) 3-phosphoglycerate from ribulose-1,5-bisphosphate
(b) glyceraldehyde 3-phosphate from 3-phosphoglycerate
(c) sucrose from triose phosphate
(d) ribulose-1, 5-bisphosphate from triose phosphate.

51. Given graph represents the absorption spectra of three photosynthetic pigments, chl *a*, chl *b* and β-carotene.



Select the correct statement regarding this.
(a) The curve showing the amount of absorption of different wavelengths of light by a photosynthetic pigment is called as absorption spectrum.
(b) Chl *a* and chl *b* absorb maximum light in blue and red wavelengths of light.
(c) Both (a) and (b) (d) None of these

52. Given figure depicts the light harvesting complex (LHC) of photosystem I (PS I).



Select the correct identification for A, B, C and D.

	A	B	C	D
(a)	Core molecules	Antenna molecules	P_{680}	Primary e^- acceptor
(b)	Antenna molecules	Core molecules	P_{700}	Primary e^- acceptor
(c)	Antenna molecules	Core molecules	P_{700}	Plasto-cyanin
(d)	Core molecules	Reaction centre	P_{680}	Plasto-cyanin

53. Select the correct statement regarding the first stable product formed in Hatch and Slack pathway in C_4 plants.
(a) Oxaloacetate is formed by carboxylation of phosphoenol pyruvate (PEP) in the bundle sheath cells.
(b) Oxaloacetate is formed by carboxylation of phosphoenol pyruvate (PEP) in the mesophyll cells.
(c) Phosphoglyceric acid is formed in the mesophyll cells.
(d) Phosphoglyceric acid is formed in the bundle sheath cells.

54. The correct sequence of flow of electrons in the light reaction is
(a) PS II, plastoquinone, cytochromes, PS I, ferredoxin
(b) PS I, plastoquinone, cytochromes, PS II, ferredoxin
(c) PS I, ferredoxin, PS II
(d) PS I, ferredoxin, PS II, plastoquinone, cytochromes.

55. In an experiment in which photosynthesis is performed during the day, you provide a plant with radioactive carbon dioxide ($^{14}CO_2$) as a metabolic tracer. The ^{14}C is incorporated first into oxaloacetic acid. The plant is best characterised as a
(a) C_4 plant (b) C_3 plant
(c) CAM plant (d) C_2 plant.

56. Read the given statements and select the correct option.
Statement 1: Photorespiration interferes with the successful functioning of Calvin cycle.
Statement 2 : Photorespiration oxidises ribulose-1,5 biphosphate which is an acceptor of CO_2 in Calvin cycle.
(a) Both statements 1 and 2 are correct and statement 2 is the correct explanation of statement 1.
(b) Both statements 1 and 2 are correct but statement 2 is not the correct explanation of statement 1.
(c) Statement 1 is correct and statement 2 is incorrect.
(d) Both statements 1 and 2 are incorrect.

57. The Z sheme of photophosphorylation follows the following sequence:

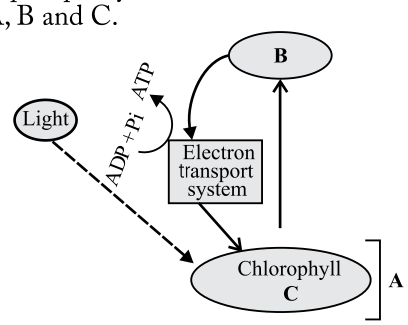
$$\text{PS II} \xrightarrow[A]{} e^- \text{ acceptor} \xrightarrow[B]{} \text{ETS} \xrightarrow[B]{} \text{PS I} \xrightarrow[C]{} e^-\text{acceptor} \xrightarrow[D]{} \text{NADP}^+$$

Which of the following options is correct for A, B, C and D transfer of electrons?

	A	B	C	D
(a)	Uphill	Downhill	Uphill	Downhill
(b)	Downhill	Uphill	Downhill	Uphill
(c)	Downhill	Uphill	Uphill	Downhill
(d)	Uphill	Downhill	Downhill	Uphill

58. Which one of the following equations suggests that O_2 released during photosynthesis comes from water?
(a) $6CO_2^{18} + 12H_2O \longrightarrow 6O_2^{18} + C_6H_{12}O_6 + 6H_2O^{18}$
(b) $6CO_2 + 12H_2O^{18} \longrightarrow 6O_2 + C_6H_{12}O_6 + 6H_2O^{18}$
(c) $6CO_2^{18} + 12H_2O \longrightarrow 6O_2^{18} + C_6H_{12}O_6 + 6H_2O$
(d) $6CO_2 + 12H_2O^{18} \longrightarrow 6O_2^{18} + C_6H_{12}O_6 + 6H_2O$

59. Study the given flow chart of cyclic photophosphorylation and select the correct answer for A, B and C.



	A	B	C
(a)	PS I	e^- acceptor	P_{680}
(b)	PS I	e^- acceptor	P_{700}
(c)	PS II	Cytochrome	P_{700}
(d)	PS II	Cytochrome	P_{680}

60. The end products of light reaction are
(a) ADP and $NADPH_2$
(b) ATP and NADP
(c) ADP and NADP
(d) ATP and $NADPH_2$.

61. The raw materials for light reaction are
(a) ADP and ATP (b) ADP and NADP
(c) NADP and ATP (d) ATP and $NADPH_2$.

62. In biochemical phase, fixation of carbon dioxide occurs by
(a) RuBisCO (b) PGA
(c) OAA (d) PGAL.

63. During photosynthesis, the source of oxygen is
(a) carbon dioxide (b) glucose
(c) water (d) energy.

64. C_4 plants are more efficient in photosynthesis than C_3 plants due to
(a) higher leaf area
(b) presence of larger number of chloroplasts in the leaf cells
(c) presence of thin cuticle
(d) lower rate of photorespiration.

65. Kranz anatomy is one of the characteristics of the leaves of
(a) potato (b) wheat
(c) sugarcane (d) mustard.

66. Which is the first CO_2 acceptor enzyme in C_4 plants?
(a) RuDP carboxylase (b) Phosphoric acid
(c) RuBisCO (d) PEP- carboxylase

67. In leaves of C_4 plants malic acid synthesis during CO_2 fixation occurs in
(a) bundle sheath (b) guard cells
(c) epidermal cells (d) mesophyll cells.

68. Kranz anatomy is seen in
(a) *Brassica juncea* (b) *Citrus indica*
(c) *Mangifera indica* (d) *Zea mays.*

69. Photophosphorylation was discovered by
(a) Arnon (b) Hill
(c) Ruben and Kamen (d) Calvin.

70. Bundle sheath cells are found in
(a) C_3 plants (b) C_4 plants
(c) CAM plants (d) both (b) and (c).

71. Primitive photosynthetic plants utilise solar energy by
(a) cyclic photophosphorylation
(b) non-cyclic photophosphorylation
(c) both (a) and (b)
(d) Calvin cycle.

72. How many molecules of glycine are required to release one CO_2 molecule in photorespiration?
(a) One (b) Two
(c) Three (d) Four

73. Bacterial photosynthesis involves
(a) PS I only
(b) PS II only
(c) both PS I and PS II
(d) either PS I or PS II.

74. The organelles involved with photorespiration, are
(a) nucleus (b) cytoplasm
(c) ribosome (d) peroxisomes.

75. In C_4 plants synthesis of sugars\final CO_2 fixation occurs in
(a) epidermis cells
(b) spongy cells
(c) undifferentiated mesophyll cells
(d) bundle sheath cells.

PREVIOUS 5 YEARS' MCQs

Competitive Exams

2015

1. Chloroplasts in higher plants are ________ shaped.
   (a) kidney (b) lens
   (c) bean (d) dome
   (MH-CET)

2. Manganese, calcium and chloride ions present in PSII play an important role in
   (a) absorption of light (b) CO_2 assimilation
   (c) photolysis of water (d) ATP synthesis.
   (MH-CET)

3. The visible portion of light spectrum useful in photosynthesis is referred to as
   (a) RFLP (b) PAR
   (c) VAM (d) VNTR.
   (MH-CET)

4. The time taken from the fixation of CO_2 to the formation of one glucose molecule is about _________ seconds.
   (a) 20 (b) 40
   (c) 60 (d) 90
   (MH-CET)

5. Which one of the following is a CAM plant ?
   (a) Maize (b) *Kalanchoe*
   (c) Sugarcane (d) Jowar
   (MH-CET)

6. In photosynthesis, the light-independent reactions take place at
   (a) photosystem II (b) stromal matrix
   (c) thylakoid lumen (d) photosystem I.
   (AIPMT)

2014

7. Synthesis of one glucose molecule requires ___ reduced NADP molecules.
   (a) 6 (b) 12
   (c) 18 (d) 24 *(MH-CET)*

8. Enzymes required for phosphorylation are located in ____ of chloroplast.
   (a) peristromium (b) plastidome
   (c) stroma (d) quantasome
   (MH-CET)

2012

9. Who described C_4 pathway for the first time?
   (a) Hatch and Slack (b) Robert Hill
   (c) Hans Krebs (d) Melvin Calvin
   (MH - CET)

10. In photosynthesis, for fixation of one mole of glucose number of ATP and $NADPH_2$ required is
    (a) 12 and 18 (b) 18 and 12
    (c) 6 and 12 (d) 18 and 18.
    (MH-CET)

11. What is the name of cycle, which generates energy and splits water into hydrogen and oxygen?
    (a) Glycolysis
    (b) Photophosphorylation
    (c) Citric acid cycle
    (d) Electron transport cycle *(MH-CET)*

12. A process that makes important difference between C_3 and C_4 plants is
    (a) transpiration
    (b) glycolysis
    (c) photosynthesis
    (d) photorespiration.
    (AIPMT Prelims)

13. The correct sequence of cell organelles during photorespiration is
    (a) chloroplast, Golgi bodies, mitochondria
    (b) chloroplast, rough endoplasmic reticulum, dictyosomes
    (c) chloroplast, mitochondria, peroxisome
    (d) chloroplast, vacuole, peroxisome.
    (AIPMT Prelims)

2011

14. Which is the evidence to show that O_2 released during photosynthesis comes from water?
(a) Synthesis of carbohydrates and formation of H_2O and sulphur by photosynthetic bacteria when supplied with H_2S and CO_2.
(b) Release of O_2 by isolated chloroplasts, when potassium ferrocyanide or some other reducing substance is supplied.
(c) Release of radioactive O_2 when water is supplied as H_2O^{18}.
(d) All of these

(MH - CET)

15. Which of the following is not required for photosynthesis?
(a) Oxygen (b) Carbon dioxide
(c) Sunlight (d) Water *(MH - CET)*

16. CAM helps the plants in
(a) conserving water (b) secondary growth
(c) disease resistance (d) reproduction.

(AIPMT Prelims)

17. Which one of the following is essential for photolysis of water?
(a) Manganese (b) Zinc
(c) Copper (d) Boron

(AIPMT Mains)

Hints & Explanations

LEVEL - 1

1. **(c) :** Photosynthesis is an intracellular, anabolic process in which carbohydrates are synthesised from carbon dioxide and water in the presence of light and chlorophyll. During this process, light energy is converted into chemical energy in the form of glucose (a carbohydrate) and oxygen is liberated as by product.

2. **(b) :** Twelve molecules of water are needed by a green plant to produce one molecule of glucose.

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

3. **(d) :** Chemosynthetic autotrophs are those which prepare their food by using energy released during chemical reactions. Bacteria such as, nitrifying bacteria (*Nitrosomonas*), sulphur bacteria (*Thiobacillus*), and iron bacteria (*Ferrobacillus*) are chemosynthetic autotrophs.

4. **(a) :** C.Van Niel in 1930, first demonstrated that photosynthesis is a light dependent reaction in which hydrogen reduces CO_2 to carbohydrates and oxygen is liberated. He suggested that oxygen is evolved from H_2O and not from CO_2.

5. **(d) :** During the experiment on green sulphur bacteria, C. Van Niel observed that purple and green sulphur bacteria use H_2S in photosynthesis and sulphur is set free.

6. **(a) :** Photolysis of water was first demonstrated by Robert Hill in 1937. According to him, water is oxidised in the presence of light and chlorophyll. Hydrogen is removed from water and oxygen is released.

$$2H_2O + 2A \xrightarrow[\text{Chlorophyll}]{\text{Sunlight}} 2AH_2 + O_2$$

Here, 'A' is unknown hydrogen acceptor.

7. **(b) :** Photosynthetic autotrophs use sunlight to prepare their food. *E.g.*, cyanobacteria, purple sulphur bacteria, green sulphur bacteria, etc. are photoautotrophs because they use solar energy to synthesise their food.

8. **(b) :** Dr. Arnon discovered that H^+ is accepted by a co-enzyme, Nicotinamide Adenine Dinucleotide Phosphate (NADP) in the chloroplast.

9. **(a) :** NADP is a H-acceptor present in the chloroplast. NADP stands for Nicotinamide Adenine Dinucleotide Phosphate.

10. **(b) :** *Refer to answer 1.*

11. **(c) :** During photosynthesis, carbon dioxide and water are transformed into simple carbohydrates and oxygen is liberated out into the atmosphere. In this process, CO_2 is reduced and water is oxidised.

$$6CO_2 + 12H_2O \xrightarrow[\text{Chlorophyll}]{\text{Sunlight}} C_6H_{12}O_6 + 6H_2O + 6O_2$$

12. **(c) :** Photosynthesis is a redox, endergonic and anabolic process. It is an endergonic reaction because energy is absorbed. During this process CO_2 is reduced and H_2O is oxidised. Thus, it is a redox reaction. At the end, glucose is formed from CO_2 and water. Therefore, it is an anabolic process.

13. **(b) :** *Refer to answer 4.*

14. **(c) :** Photoautotrophs are the organisms which prepare their own food by using solar energy. *E.g.*, *Chromatium* and *Chlorobium* have photosynthetic pigments hence, called photoautotrophs.

15. **(b) :** Ruben and Kamen (1941) used heavy isotope of oxygen, $^{18}O_2$ to prove that the source of O_2 evolved during photosynthesis is water. Dr. Melvin Calvin (1954) used radioactive isotope of carbon C^{14} to discover the sequence of biochemical reactions of CO_2 fixation into glucose.

16. **(d) :** *Refer to answer 7.*

17. **(d)** 18. **(b)**

19. **(a) :** *Refer to answer 15.*

20. **(d) :** During his experiment, Robert Hill (1937) suspended the chloroplasts isolated from spinach leaves in water which was without CO_2. He then added ferric salts as hydrogen acceptor. This suspension was exposed to sunlight. He observed that ferric salts are reduced to ferrous and oxygen bubbles evolve, which clearly proved that water splits.

21. **(b) :** *Refer to answer 20.*

22. **(c) :** DNA, also known as plastidome in chloroplast, is a circular, closed, naked ring and due to it chloroplast is a self-replicating and semi-autonomous cell organelle.

23. **(d) :** Grana are 40-60, green coloured structures located in stroma. They are interconnected by membranes called stroma-lamellae or intergrana or fret membranes, which help in rapid transport of materials.