CHAPTER 13

Photosynthesis in Higher Plants

EXAM DRILL

ANSWERS

1. **(d) :** C_4 plants possess Kranz anatomy. In Kranz anatomy, the mesophyll is undifferentiated and it cells occur in concentric layers around vascular bundles. Vascular bundles are surrounded by large size bundle sheath cells which are arranged in wreath like manner in one to several layers.

2. **(b) :** Cytochromes are electron transferring proteins often regarded as enzymes. They contain iron porphyrin or copper porphyrin as prosthetic groups. Cytochrome *a*, *b* and *c* are pigments widely occurring in cells and acting as oxygen carriers during cellular respiration.

3. **(c) :** During photosynthesis, dark reactions being enzymatic are temperature controlled. The C_4 plants respond to higher temperature and show higher rate of photosynthesis while C_3 plants are more efficient in lower temperature.

4. **(a) :** The C_4 plants show carbon dioxide saturation at about 360 $\mu l\ L^{-1}$ while C_3 responds to increased CO_2 concentration and saturation is seen only beyond 450 $\mu l\ L^{-1}$.

5. **(c) :** By employing C^{14} labelled carbon dioxide $^{14}CO_2$ in photosynthesis and observing the appearance of characteristics radiations in different reactions intermediates and products. Calvin and his co-workers were able to formulate the complete metabolic path of carbon assimilation in the form of cycle known as Calvin cycle.

6. Magnesium

7. A photosynthetic unit consists of P_{680} and P_{700} reaction centres of photosystems.

8. The point at which the rate of photosynthesis is equal to the rate of respiration is called compensation point.

9. NADP reductase enzyme breaks down the proton gradient to release energy, *i.e.*, NADPH.

10. (i) In both C_3 and C_4 cycle, dark reaction occurs in the stroma.

(ii) Photolysis of water and photophosphorylation in the light reaction.

11. **(b)**

12. **(c) :** The chlorophylls are associated with both lipids and proteins while carotenoids are associated with lipids only.

OR

(d) : Reduction step of Calvin cycle involves 2 molecules of ATP for phosphorylation and 2 of NADPH for reduction per CO_2 molecule fixed.

13. **(b)**

14. **(b) :** Chlorophyll *a* is the major pigment responsible for trapping light, other thylakoid pigments like chlorophyll *b*, xanthophylls and carotenoids, which are called accessory pigments, also absorb light and transfer the energy to chlorophyll *a*.

15. **(i)** **(a) :** P is chlorophyll *b*, Q is carotenoids and R is chlorophyll *a*.

(ii) **(c) :** R, *i.e.*, chlorophyll *a* is the major (Primary) pigment responsible for trapping light.

(iii) **(b)**

(iv) **(d) :** The graphical curve showing the amount of energy of different wavelengths of light absorbed by a pigment is called absorption spectrum. It is studied with the help of spectrophotometer. The absorption spectra of chlorophylls *a* and *b* show that they absorb maximum light in the blue-violet and red wavelengths. The pigments are often known after the wavelength which is absorbed to the maximum, *e.g.*, Chl a_{673}, Chl a_{683} (P_{680}), Chl a_{703} (P_{700}).

(v) **(d)**

16. **(i)** **(c)**

(ii) **(a) :** PS II (A) is located on the inner surface of appressed part of grana thylakoids whereas PS I (B) is located on the non appressed part of grana thylakoids as well as stroma thylakoids.

(iii) **(d) :** During Z-scheme, the electron extruded by PS I passes through special chlorophyll X, Fe-S, ferredoxin, to finally reach $NADP^+$. $NADP^+$ is ultimately reduced by combining with H^+ (released during photolysis) with the help of $NADP^+$ reductase enzyme.

(iv) **(d)**

(v) **(c)**

17. Differences between light and dark reaction are as follows :

S.No.	Light reaction	Dark reaction
(i)	It is a light dependent process. Involves two photosystems – PS I and PS II.	This process does not require light. No photosystem is required.

(ii)	It occurs over thylakoids.	It occurs in the matrix of chloroplast.
(iii)	Photolysis of water takes place and O_2 is liberated.	Photolysis of water does not take place. Glucose is end molecule.
(iv)	It produces ATP and NADPH.	It consumes ATP and NADP.

18. No, they will not synthesise glucose due to the lack of enzymes of dark reaction which are found in the stroma of chloroplast.

19. PGA remains in the chloroplast where it enters into Calvin cycle. Glycine enters into mitochondria where it gets converted to serine and release carbon dioxide.

20. **(a)** Carotene and xanthophyll

(b) *Opuntia* and *Kalanchoe*

OR

The stroma contains enzymes which are capable of utilising ATP and $NADPH_2$ to produce carbohydrate during dark reaction. The carbon fixation occurs in the stroma by a series of enzymes catalysed steps which are located outside the thylakoids.

21. (i) C_4 plants are more efficient in picking up CO_2 even when it is found in low concentration because of the high affinity of PEP. (ii) Concentric arrangement of mesophyll cells produces a smaller area in relation to volume for better utilisation of available water and reduce the intensity of solar radiations. (iii) Normal oxygen concentration is not inhibitory for the growth in contrast to C_3 plants. (iv) They are adapted to high temperature and intense radiation of tropics.

22. Photosynthesis is considered as the most important process in the biosphere because of following reasons :

(i) It is the only natural process that evolves molecular oxygen for use by other living organisms.

(ii) It consumes carbon dioxide which is being continuously added by the respiration of organisms and burning of organic fuels.

(iii) It produces carbohydrates.

23. PEP stands for phosphoenol pyruvate. It is produced in the mesophyll cells of leaves of C_4 plants. It is the primary acceptor of carbon dioxide and is converted into oxaloacetic acid. Thus, it helps in carbon fixation in these plants.

24. **(a)** The two main functions of accessory pigments are :

(i) To absorb light energy and transfer it to chlorophyll *a* for photosynthesis

(ii) To protect the chlorophyll *a* molecule from photo-oxidation.

(b) Increase in incident light beyond saturation point causes the breakdown of chlorophyll. This results in decline in the rate of photosynthesis.

25. Formation of ATP in chloroplast in the presence of light is called photophosphorylation. It takes place in two ways :

(i) Cyclic photophosphorylation where one light system (PS I) is involved.

(ii) Non-cyclic photophosphorylation where two light systems (PS I and PS II) are involved.

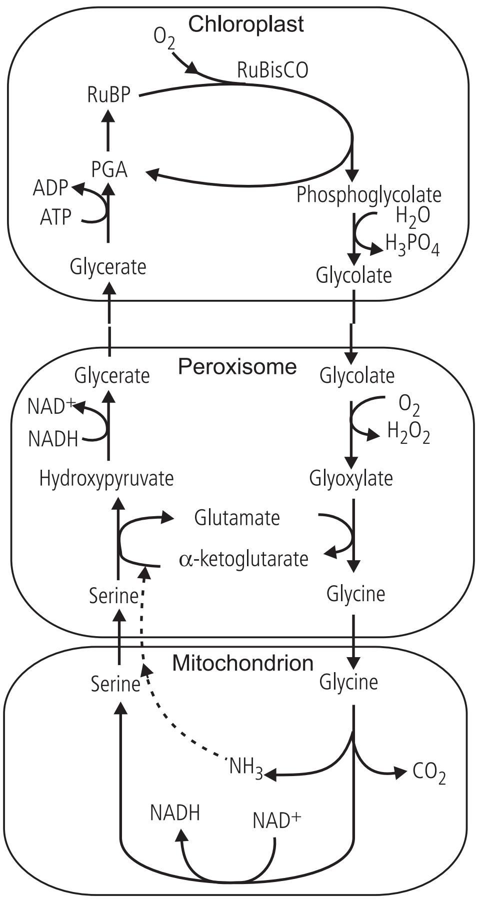
26. Photosynthesis in *Chlorella* and higher plants is biochemically similar but *Chlorella* was used for experimentation due to following reasons :

(i) *Chlorella* culture is a chloroplast culture as a large volume of every cell is occupied by single chloroplast.

(ii) A synchronous culture may easily be obtained in a short span of time.

(iii) Cells are very quickly exposed to radioactive carbon dioxide and are quickly killed, thus handling it for experiment is eaiser.

27. The pathway of photorespiration is represented by the following diagram :



28. Structure of chlorophyll molecule was first studied by Wilstatter, Stoll and Fischer in 1912. Each chlorophyll molecule shows a tadpole like configuration consisting of a porphyrin head and phytol tail. The porphyrin head is made up of porphyrin system in which four pyrrole (tetrapyrrole) rings, linked together by methine bridge (–CH=). The centre is occupied by a divalent magnesium (Mg^{++}) which is complexed with the nitrogen atoms of the four pyrrole rings. The porphyrin ring has several side groups which specify the properties of the pigment molecule. The phytol tail is made up of long chain of alcohol. Phytol is an insoluble chain with formula of $C_{20}H_{39}OH$. It anchors the chlorophyll molecule into the lipid part of thylakoid membranes.

The chemical formula and distribution of chlorophyll *a* and *b* are :

Chlorophyll *a* - $C_{55}H_{72}O_5N_4Mg$; all photosynthetic organism except photosynthetic bacteria.

Chlorophyll *b* - $C_{55}H_{70}O_6N_4Mg$; Chlorophyta, Euglenophyta and in all higher plants.

OR

Carotenoids are yellow, brown to reddish pigments usually found in close association of chlorophylls inside the chloroplast but occur alone inside the chromoplast. They act as accessory pigments of photosynthesis. They absorb light energy in the mid region of visible spectrum and transfer their absorbed energy to chlorophyll *a* molecule. They pick up nascent oxygen, released during photooxidation of water and change them into molecular state. Thus, they protect chlorophyll molecules from photooxidation.

29. Absorption spectrum is the curve plotted on a graph paper representing the amount of energy of different wavelength of light absorbed by a substance. To determine the absorption spectrum of a particular pigment, a purified sample of that pigment is placed in the path of visible light inside an instrument called spectrophotometer. This instrument measures the amount of light that passes through the pigment solution and from this it can be calculated how much light of a particular wavelength was absorbed. Then the result is plotted on a graph which represents the absorption spectrum of that pigment.

30. (i) Thylakoid membranes

(ii) Chloroplast

(iii) PS II

(iv) Stroma

(v) Ganong's light screen

(vi) ATP and ADP

31. C_3 pathway or Calvin cycle can be studied by splitting the complete cycle into three phases :

(i) Carboxylation phase

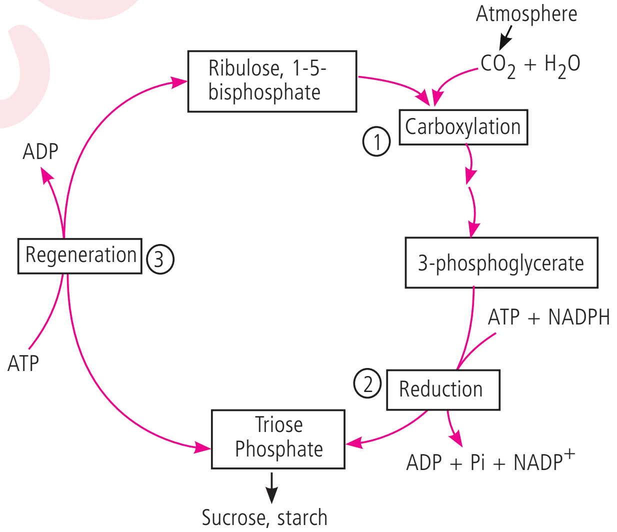
(ii) Reduction phase

(iii) Regeneration phase

(i) Carboxylation : Carboxylation is the fixation of CO_2 into a stable organic intermediate. Carboxylation is the most crucial step of the Calvin cycle where CO_2 is utilised for the carboxylation of RuBP. This reaction is catalysed by the enzyme RuBP carboxylase which results in the formation of two molecules of 3-PGA. Since this enzyme also has an oxygenation activity it is called RuBP carboxylase-oxygenase or RuBisCO.

(ii) Reduction : These are a series of reactions that lead to the formation of glucose. The steps involve utilisation of 2 molecules of ATP for phosphorylation and two of NADPH for reduction per CO_2 molecule fixed. The fixation of six molecules of CO_2 and 6 turns of the cycle are required for the formation of one molecule of glucose from the pathway.

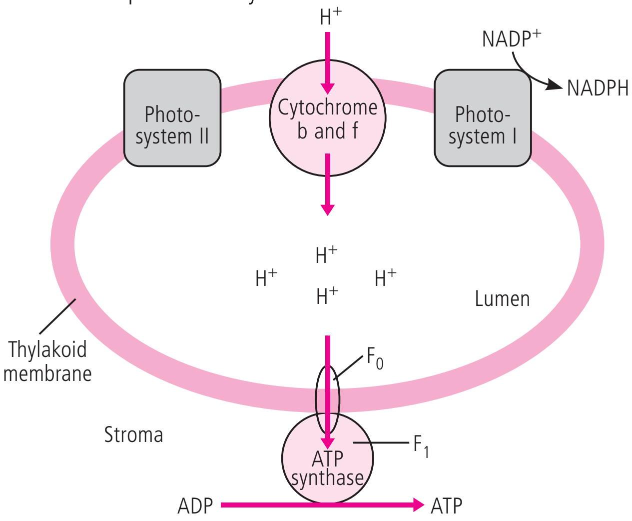
(iii) Regeneration : Regeneration of the CO_2 acceptor molecule RuBP is crucial if the cycle is to continue uninterrupted. The regeneration steps require one ATP for phosphorylation to form RuBP.



OR

(a) The major photosynthetic pigments are chlorophyll *a*, chlorophyll *b* and carotenoids. The chlorophyll molecules are non-covalently associated with proteins forming pigment protein complexes. They are located in the thylakoid membranes of chloroplast. There are four types of complexes (i) photosystem I (PS I) complex, (ii) photosystem II (PS II) complex, (iii) cyt b_6-f complex and (iv) ATPase complex. The pigment molecules associated with PS I complex are located in the non appressed parts as well as stroma thylakoids whereas those associated with PS II complex are located more towards the appressed regions of the grana thylakoids.

(b) The diagram showing distribution of PS I, PS II and ATPase complexes in thylakoid membranes is as follows :



32. (a) (i) To fix one molecule of CO_2, 3 molecules of ATP and 2 molecules of NADH are required.

(ii) The given process occurs in the stroma of the chloroplast.

(b) The following molecules are used and produced during synthesis of one glucose molecule:

C_3 cycle		C_4 cycle	
Used	**Produced**	**Used**	**Produced**
$6CO_2$	1 glucose	$6CO_2$	1 glucose
18 ATP	18 ADP	30 ATP	30 ADP
12 NADPH	12 NADP	12 NADPH	12 NADP

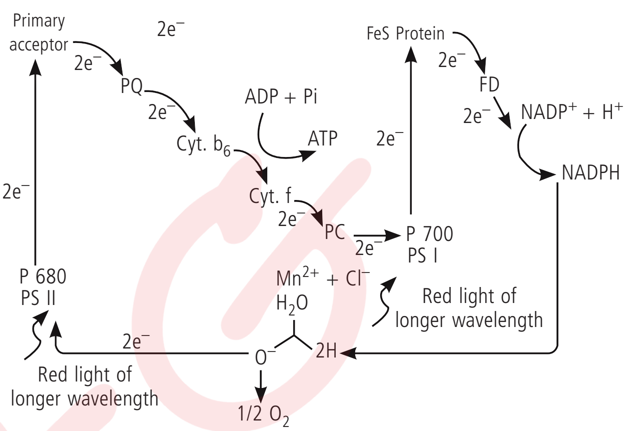
OR

(a) We observe different shades of green in plant leaves due to many pigments like chlorophyll *a* (*i.e.*, blue green), chlorophyll *b* (*i.e.*, yellow green), xanthophylls (*i.e.*, yellow) and carotenoids (yellow orange). All these are of different colours or shades and hence their composition in a leaf decides its colour.

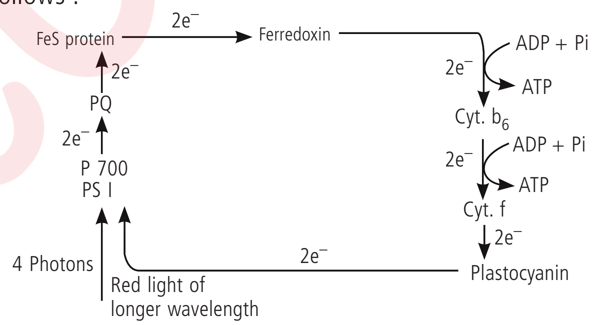
(b) Ribulose biphosphate carboxylase oxygenase (RuBisCO), the main enzyme of Calvin cycle which fixes CO_2, acts both as oxygenase and carboxylase. In presence of high concentration of O_2, RuBisCO acts as oxygenase and photorespiration occurs. In C_4 plants like *Atriplex*, RuBisCO is located only in bundle sheath cells where photosynthetic release of oxygen does not occur. Bundle sheath cells have a high intracellular concentration of CO_2 due to flow of C_4 acids and their decarboxylation to release CO_2. Therefore, RuBisCO functions purely as carboxylase in C_4 plants and no photorespiration occurs.

(c) At low temperature, rate of photosynthesis decreases that retards the plant growth. In greenhouse, the heat from the sunlight is captured and hence optimum temperature is maintained for photosynthesis inside the greenhouse. This temperature helps in restoring the optimum activity of photosynthetic enzymes, so rate of photosynthesis increases.

33. (i) A neat line diagram of non-cyclic photo phosphorylation is as follows :

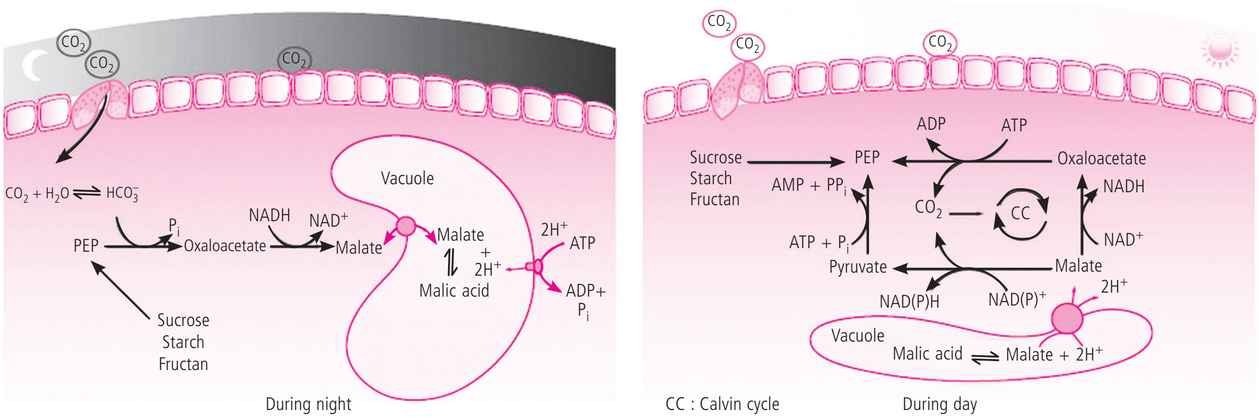


(ii) A neat line diagram of cyclic photophosphorylation is as follows :



OR

Crassulacean acid metabolism (CAM) refers to a mechanism of photosynthesis that is different from C_3 and C_4 pathways. This occurs only in succulents and other plants that normally grow in dry conditions. In CAM plants, CO_2 is taken up by the leaves on green stems through stomata, which remains open in the night. However, during the day , the stomata remain closed in these plants to conserve moisture. The CO_2 taken up in the night is fixed in the same way as it happens in C_4 plants to form malic acid, which is stored in the vacuole. The malic acid thus formed during the night, is used during the day as a source of CO_2 for photosynthesis to proceed *via* the C_3 pathway. Thus, CAM is a kind of adaptation that allows certain plants such as pineapple to carry out photosynthesis without much loss of water, which is inevitable in plants with C_3 and C_4 mechanisms. The diagrammatic representation of mechanism of crassulacean acid metabolism is given as follows :


CO2
CO2
CO2
CO2 + H2O ⇌ HCO3−
PEP
Pi
Oxaloacetate
NADH
NAD+
Malate
Vacuole
Malate
+
2H+
Malic acid
2H+
ATP
ADP+
Pi
Sucrose
Starch
Fructan
During night
CO2
CO2
CO2
Sucrose
Starch
Fructan
PEP
ADP
ATP
Oxaloacetate
AMP + PPi
NADH
CO2
CC
ATP + Pi
NAD+
Pyruvate
Malate
NAD(P)H
NAD(P)+
2H+
Vacuole
Malic acid ⇌ Malate + 2H+
CC : Calvin cycle
During day