CHAPTER – 11

Photosynthesis In Higher Plants

EXERCISES

2 Mark Questions

Q1: By looking at a plant externally can you tell whether a plant is C_3 or C_4 ? Why and how?

Answer: It is not possible to distinguish externally between a C_3 and C4 plant, but generally tropical plants are adapted for C_4 cycle.

Q2: Why is the colour of a leaf kept in the dark frequently becomes yellow, or pale green? Which pigment do you think is more stable?

Answer: Carotenoid pigments are found in all photosynthetic cells. They are accessory pigments also found in roots, petals etc. These pigments do not breakdown easily thus temporarily reveal their colour due to unmasking, following breakdown of chlorophylls. Thus the colour of leaf kept in dark is yellow or pale green.

Q3: Look at leaves of the same plant on the shady side and compare it with the leaves on the sunny side. Or ompare the potted plants kept in the sunlight with those in the shade. Which of them has leaves that are darker green? Why?

Answer:The leaves of the shaded side are darker green than those kept in sunlight due to two reasons:

(i) The chloroplasts occur mostly in the mesophyll cells along their walls for receiving optimum quantity of incident light.
(ii)The chloroplasts align themselves in vertical position along the lateral walls of high light intensity and along tangential wails in moderate light.

Q4: Suppose there were plants that had a high concentration of chlorophyll b, but lacked chlorophyll a, would it carry out photosynthesis? Then why do plants have chlorophyll b and other accessory pigments?

Answer: Plants that do not possess chlorophyll a will not carry out photosynthesis because it is the primary pigment and act as the reaction centre. It performs the primary reactions of photosynthesis or conversion of light into chemical or electrical energy. Other photosynthetic pigments are called accessory pigments. They absorb light energy of different wavelengths and hence broaden the spectrum of light absorbed by photosynthetic pigments. These pigments hand over the absorbed energy to chlorophylla.

Q5: How do photosynthetic bacteria such as Cyanobacteria conduct photosynthesis in the absence of chloroplasts?

Answer:They are prokaryotes containing photosynthetic pigments in a membranous form that are primitive in nature, that can trap and use solar energy. Hence they can carry out photosynthesis.

Q6:a) Where is the enzyme NADP reductase located?

b) What does the breakdown of proton gradient cause the release of?

Answer:**a)** It is located on the outer side of the thylakoid membrane.

b) ATP molecules. In the presence of enzyme ATP synthase, it is coupled with the movement of ions across the membrane and formation of ATP synthesis.

4 Mark Questions

Q1:The given figure shows the effect of light on the rate of photosynthesis. Based on the graph, answer the following questions.

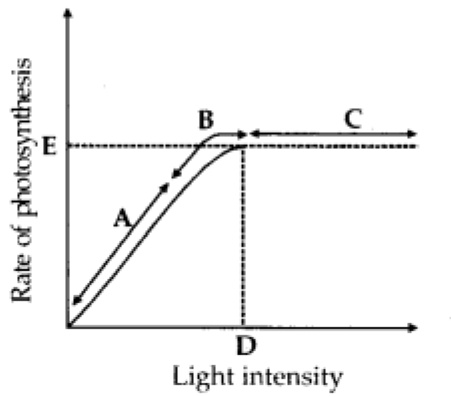


Fig.: Graph showing effect of light intensity on the rate of photosynthesis

(a) At which point/s (A, B or C) in the curve is light limiting factor?
(b) What could be the limiting factor/s in region A?
(c) What do C and D represent on the curve?

Answer: (a) At regions A and B light is the limiting factor.
(b) In the region A', light can be a limiting factor.

(c) C is the region where the rate of photosynthesis is not increased when light intensity is increased. D is the point where some other factors become limiting.

Q2:By looking at which internal structure of a plant can you tell whether a plant is C_3 or C_4 ? Explain.

Answer:C_4 plants live in hot moist or arid and nonsaline or saline habitats. Internally the leaves show kranz anatomy. In kranz anatomy, the mesophyll is undifferentiated and its cells occur in concentric layers around vascular bundles. Vascular bundles are surrounded by large sized bundle sheath cells which are arranged in a wreath-like manner (kranz – wreath). The mesophyll and bundle sheath cells are connected by plasmodesmata or cytoplasmic bridges. The chloroplasts of the mesophyll cells are smaller. They have well developed grana and a peripheral reticulum but no starch. Mesophyll cells are specialised to perform light reaction, evolve 02 and produce assimilatory power (ATP and NADPH). They also possess enzyme PEPcase for initial fixation of CO_2 The chloroplasts of the bundle sheath cells are agranal.

Q3:Even though very few cells in a C_4 plant carry out the biosynthetic – Calvin pathway, yet they are highly productive. Can you discuss why?

Answer: Since, through C_4 cycle, a plant can photosynthesise even in presence of very low concentration of CO_2 (upto 10 parts per million), the partial closure of stomata due to xeric conditions would not bring much effect. Therefore, the plants can adapt to grow at low water content, high temperature and bright light intensities. This cycle is specially suited to such plants which grow in dry climates of tropics and subtropics. Besides, the photosynthetic rate remains higher due to absence of photorespiration in these plants. It can be visualised that both C_4 cycle and photorespiration are the result of evolution or might have been one of the reasons of evolution for the adaptation of plants to different environments. C_4 plants are about twice to efficient as C_3 plants in converting solar energy into production of dry matter.

Q4:Briefly explain the chemiosmotic hypothesis?

Answer:The mechanism of ATP synthesis in chloroplasts was explained by the chemiosmotic hypothesis. ATP generation in photosynthesis is tied to the formation of a proton gradient across a membrane. These are thylakoids membranes. The proton accumulation is toward the membrane's interior (in the lumen).

The mechanisms that happen during electron activation and transit to establish the steps that lead to the formation of a proton gradient. The establishment of a proton gradient is linked to the synthesis of ATP.

7 Mark Questions

Q1:Give comparison between the following:

(a) C_3 andC_4 pathways

(b) Cyclic and non-cydic photophosphorylation

(c) Anatomy of leaf in C3 and C_4 plants.

Answer: (a) The differences between C_3 and C_4

	C_3 pathway	C_4 pathway
(i)	Ribulose biphosphate is the first acceptor of CO_2.	Phosphoenol pyruvate is the first acceptor of CO_2, while ribulose biphosphate is the second acceptor.
(ii)	Phosphoglyceric acid is the first product.	Oxaloacetic acid is the first product.
(iii)	The plants operate only Calvin cycle.	Plants operate a dicarboxylic acid cycle in addition to Calvin cycle.
(iv)	CO_2 compensation point is 25 – 100 ppm.	CO_2 compensation point is 0 – 10 ppm.
(v)	Mesophyll cells perform complete photosynthesis.	Mesophyll cells perform only initial fixation.

(vi)	The rate of carbon assimilation is slow.	The rate of carbon assimilation is quite rapid.
(vii)	The plants are unable to perform photosynthesis at very low CO_2 concentration (say 10 – 50 ppm).	Photosynthesis continues even at very low CO_2 concentration of 10 – 50 ppm.
(viii)	The cycle operates in all plants.	The cycle is found only in some plants like maize, sugarcane etc.
(ix)	Fixation of one molecule of CO_2 uses 3 ATP and 2NADPH.	Fixation of one molecule of CO_2 requires 5 ATP and 2NADPH.

(b) The differences between cyclic and non- cyclic photophosphorylation are as follows :

	Cyclic photophosphoryaltion	Non-cyclic photophosphorylation
(i)	It is performed by photosystem I independently.	It is performed by collaboration of both photosystems I and II.
(ii)	It is not connected with photolysis of water. Therefore, no oxygen is evolved.	It is connected with photolysis of water and liberation of oxygen.
(iii)	It synthesises only ATP.	Non-cyclic photophosphorylation is not only connected with ATP synthesis but also production of NADPH.
(iv)	It operates under low light intensity, anaerobic conditions or when CO_2 availability is poor.	Non-cyclic photophosphorylation takes place under optimum light, aerobic conditions and in the presence of carbon dioxide.
(v)	It occurs mostly in stromal or intergranal thylakoids.	It occurs in the granal thylakoids.

(vi)	ATP synthesis is not affected by DCMU.	DCMU inhibits non-cyclic photo-phosphorylation.

(c) Differences between the leaf anatomy of C_3 and C_4plants are as follows :

	C_3 plants	C_4 plants
(i)	The leaves do not possess kranz anatomy.	The leaves have kranz anatomy.
(ii)	Chloroplasts do not have peripheral reticulum.	Chloroplasts have peripheral reticulum.
(iii)	Chloroplasts are of one type (monomorphic).	There are two types of chloroplasts (dimorphic).
(iv)	Bundle sheath cells usually do not contain chloroplasts.	Bundle sheath cells possess prominent chloroplasts.
(v)	In higher plants, operating C_3 cycle, all the chloroplasts are granal.	There are two types of chloroplasts, granal in mesophyll cells and agranal in bundle sheath cells.
(vi)	Mesophyll cells perform complete photosynthesis.	Mesophyll cells perform only initial fixation.
(vii)	Perform photosynthesis only when stomata are open.	Perform photosynthesis even when stomata are closed (from CO_2 produced in respiration).

Q2:RuBisCO is an enzyme that acts both as a carboxylase and oxygenase. Why do you think RuBisCO carries out more carboxylation in C_4 plants?

Answer:RuBisCO is an enzyme which acts both as carboxylase (carboxylation during photosynthesis) and oxygenase (during photorespiration). But RuBisCO carries out more carboxylation in C4 plants. In C_4 plants, initial fixation of carbon dioxide occurs in mesophyll cells. The primary acceptor of C02 is phosphoenol pyruvate or PER It combines with carbon dioxide in the presence of PEP carboxylase or PEPcase to form oxaloacetic acid or oxaloacetate. 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 . CO_2 is again fixed inside the bundle sheath Cells through Calvin cycle. RuBP of Calvin cycle is called secondary or final acceptor of CO_2 in C_4 plants. Pyruvate is sent back to mesophyll cells.

(c) C is the region where the rate of photosynthesis is not increased when light intensity is increased. D is the point where some other factors become limiting.

Q3:Does photosynthesis occur in leaves only? If no, what are the other parts that are capable of carrying out photosynthesis? Justify.

Answer:The process of photosynthesis primarily occurs in leaves of all green plants. The leaves are designed in such a way that they capture sunlight and convert solar energy into chemical energy effectively. However, in some plants, modified parts other than leaves carry out photosynthesis. In some plants, roots develop chlorophyll and initiate photosynthesis, they are referred to as assimilatory roots. Example – Tinospora, Trapa. The stem in some plants such as the Opuntia gets modified and adapts to perform the functions of leaves, be turning thick, succulent and flattened, performing photosynthesis, these structures are referred to as phylloclade. In Australian Acacia, the petiole takes the shape and function of photosynthesis when stamina of leaf fails.

Q4: (a) suggest some habitats or natural circumstances in which

(i) Light intensity

(ii) CO2 concentration

(iii) temperature might be a limiting factor in photosynthesis.

(b) In C4 plants which type of chloroplast is specialized for light reactions and which for dark reactions?

(c) Why is it an advantage that bundle sheath chloroplast lacks grana?

Answer:Some circumstances are as follows:

(i) In a shaded neighborhood; dawn and twilight in a hot climate.

(ii) Carbon dioxide is typically limiting, but it may be particularly so in a densely packed plant standing under bright, warm conditions.

(iii) On a sunny winter day.

(b) Light reaction in mesophyll chloroplast and bundle sheath chloroplast for dark reaction

(c) The synthesis of oxygen is linked to grana, because oxygen would compete with CO2 for RuBP carboxylase, stimulating photorespiration. Grana take up a considerable portion of the chloroplast. In their absence from the bundle sheath, there is more stroma, which means more RuBP carboxylase and greater starch storage capacity.

Q5:Explain the process of the biosynthetic phase of photosynthesis occurring in the chloroplast.

Answer:Biosynthetic phase (Dark Reaction): It is the carbon fixation in plants by which carbon - dioxide is converted to carbohydrates during the biosynthetic phase (Dark Reaction). Carbon is fixed in the stroma of chloroplasts via a series of enzyme-catalyzed processes.

C_3 pathway: It is referred to as the Calvin cycle. Melvin Calvin traced the pathway of carbon in the dark reaction using autoradiography and 14C and therefore, this pathway is known as the Calvin cycle.

Calvin Cycle Consist of Three Phases:

(i) Carboxylation: Six molecules of Ribulose 1, 5 bisphosphates combine with six molecules of carbon dioxide to produce six molecules of carbon dioxide and six molecules of a short-lived 6C – compound. The process is catalyzed by RuBP – carboxylase (Rubisco). Six molecules of the 6C – compound combines to form 12 molecules of 3-phosphoglyceric acid (PGA), the first stable chemical in this pathway.

(ii) Reduction: Using ATP and NADPH molecules, 12 molecules of phosphoglyceric acid are transformed into 12 molecules of 1,3 diphosphoglycerate, which is subsequently reduced to phosphoryl acetaldehyde (PGAL). Two molecules of PGAL are diverted for sugar production and then into starch.

(iii) Regeneration of RuBP – The principal acceptor of carbon dioxide, i.e., RuBP, must be regenerated by converting 10 molecules of PGAL into 6 molecules of 5C – chemical, RuBP, via a series of complicated reactions. Six ATP molecules are required for the formation of six RuBP molecules.

Multiple Choice Questions

1. Photosynthetic pigments found in the chloroplasts occur in

a) Chloroplast envelope

b) Matrix

c) Plastoglobules

d) Thylakoid membranes

Answer: Thylakoid membranes

2. Which of the following pigments acts as a reaction-centre during photosynthesis?

a) Cytochrome

b) P_{700}

c) Carotene

d) Phytochrome

Answer: P_{700}

3. In photosynthesis, energy from light reaction to dark reaction is transferred in the form of

a) Chlorophyll

b) ATP

c) ADP

d) RuDP

Answer: ATP

4. In photosystem I, the first electron acceptor is

a) Plastocyanin

b) Cytochrome

c) Ferredoxin

d) An iron-sulphur protein

Answer: An iron-sulphur protein

5. In the leaves of C4 plants malic acid formation during carbon dioxide fixation occurs in the cells of

a) Mesophyll

b) Epidermis

c) Phloem

d) None of these

Answer: Mesophyll

6. Stroma in the chloroplasts of higher plants contains

a) Light-independent reaction enzymes

b) Ribosomes

c) Chlorophyll

d) Light-dependant reaction enzymes

Answer: Light-independent reaction enzymes

7. CAM helps the plant in

a) Reproduction

b) Disease resistance

c) Secondary growth

d) Conserving water

Answer: Conserving water

8. A process that makes an important difference between C3 and C4 plants is

a) Photorespiration

b) Photosynthesis

c) Transpiration

d) Glycolysis

Answer: Photorespiration

9. Which element is located at the centre of the porphyrin ring in chlorophyll?

a) Magnesium

b) Manganese

c) potassium

d) calcium

Answer: Magnesium

10. In Hatch and slack pathway, the primary carbon dioxide acceptor is

a) Phosphoenolpyruvate

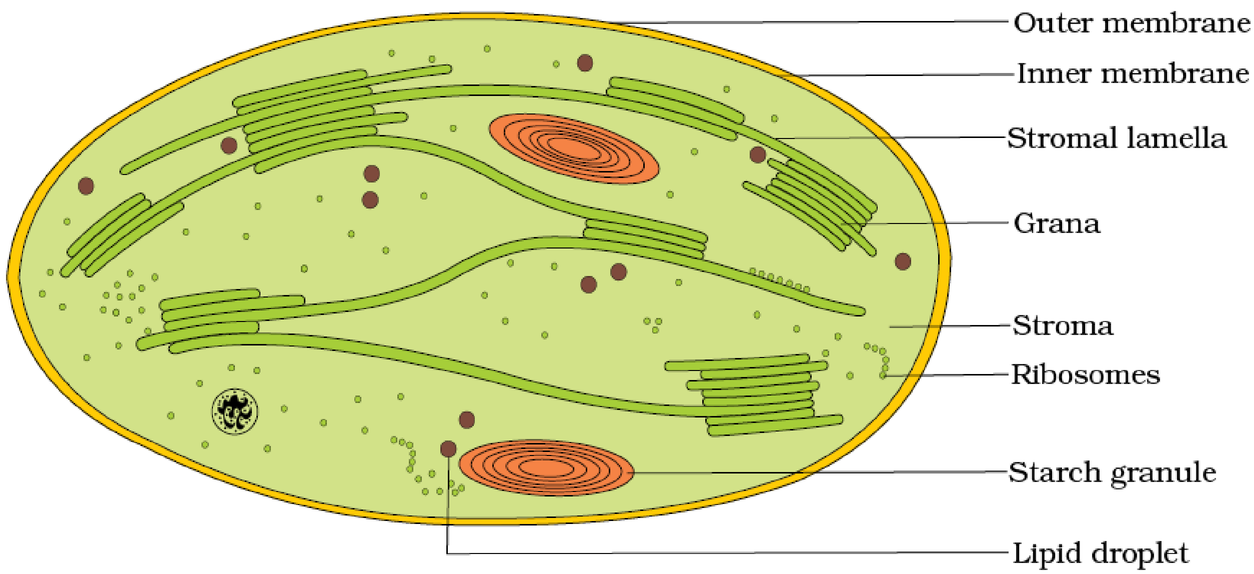
b) Phosphoglyceric acid

c) Oxaloacetic acid

d) Rubisco

Answer: Phosphoenolpyruvate

DIAGRAMS



SUMMARY

Green plants make their own food by photosynthesis. During this process carbon dioxide from the atmosphere is taken in by leaves through stomata and used for making carbohydrates, principally glucose and starch. Photosynthesis takes place only in the green parts of the plants, mainly the leaves. Within the leaves, the mesophyll cells have a large number of chloroplasts that are responsible for CO2 fixation. Within the chloroplasts, the membranes are sites for the light reaction, while the chemosynthetic pathway occurs in the stroma. Photosynthesis has two stages: the light reaction and the carbon fixing reactions. In the light reaction the light energy is absorbed by the pigments present in the antenna, and funnelled to special chlorophyll a molecules called reaction centre chlorophylls. There are two photosystems, PS I and PS II. PS I has a 700 nm absorbing chlorophyll a P700 molecule at its reaction centre, while PS II has a P680 reaction centre that absorbs red light at 680 nm. After absorbing light, electrons are excited and transferred through PS II and PS I and finally to NAD forming NADH. During this process a proton gradient is created across the membrane of the thylakoid. The breakdown of the protons gradient due to movement through the F0 part of the ATPase enzyme releases enough energy for synthesis of ATP. Splitting of water molecules is associated with PS II resulting in the release of O_2, protons and transfer of electrons to PS II. In the carbon fixation cycle, CO_2 is added by the enzyme, RuBisCO, to a 5carbon compound RuBP that is converted to 2 molecules of 3-carbon PGA. This is then converted to sugar by the Calvin cycle, and the RuBP is regenerated. During this process ATP and NADPH synthesised in the light reaction are utilised. RuBisCO also catalyses a wasteful oxygenation reaction in C3 plants: photorespiration. Some tropical plants show a special type of photosynthesis called C4 pathway. In these plants the first product of CO_2 fixation that takes place in the mesophyll, is a 4-carbon compound. In the bundle sheath cells the Calvin pathway is carried out for the synthesis of carbohydrates.