13. Photosynthesis in Higher Plants

Question 1. By looking at a plant externally can you tell whether a plant is C_3 or C_4 ? Why and how?

Answer: One cannot distinguish whether a plant is C3 or C4 by observing its leaves and other morphological features externally. Unlike C3 plants, the leaves of C4 plants have a special anatomy called Kranz anatomy and this difference can only be observed at the cellular level. For example, although wheat and maize are grasses, wheat is a C3 plant, while maize is a C4 plant.

Question 2. By looking at which internal structure of a plant can you tell whether a plant is C_3 or C_4 ? Explain.

Answer: The internal structure of the leaves of c4 plants have a special anatomy known as the Kranz anatomy. This makes them different from the C3 plants. Certain special cells known as the bundle-sheath cells surround the vascular bundles and are present in several layers. They possess a number of chloroplasts. They are thick walled cells without intercellular spaces. They are also helpful in gaseous exchange.

Question 3. Even though a very few cells in a C_4 plant carry out the biosynthetic – Calvin pathway, yet they are highly productive. Can you discuss why?

Answer: The productivity of a plant is directly proportional to the rate of photosynthesis which in turn is dependent on the amount of carbon dioxide present in a plant. In C4 plants a mechanism for increasing the concentration of carbon dioxide is present. Here, the Calvin cycle occurs in the bundle-sheath cells. The C4 compound malic acid from the mesophyll cells is broken down inside the bundle-sheath cells. This causes the release of carbon dioxide gas. The increase in Carbon dioxide gas ensures that the enzyme RuBisCo does not act as an oxygenase, but as a carboxylase. This prevents losses by photorespiration thus increasing the rate of photosynthesis. Hence, it can be concluded that even though a very few cells in a C4 plant carry out the biosynthetic – Calvin pathway, yet they are highly productive.

Question 4. 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 stands for Ribulose Bisphosphate Carboxylase Oxygenase. It is formed by Ribulose bisphosphate (RuBP) which is a five carbon ketose sugar. It is the most abundant enzyme on the earth. The active site on this enzyme can bind competitively to both carbon dioxide and oxygen. The relative concentration of carbon dioxide and oxygen determines which of them will bind to the enzyme. RuBisCO carries out more carboxylation in C4 plants because these plants have a mechanism that increase the concentration of carbon dioxide at the enzyme site. During the C4 pathway, when the C4 acid from the mesophyll cells is broken down in the bundle sheath cells, it releases carbon dioxide which results in the increase of intracellular concentration of carbon dioxide. So, RuBisCO functions as a carboxylase and binds with plants.

Question 5. 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: Chlorophyll-a molecules are essential for the process of photosynthesis as they act as antenna molecules. These molecules get excited by absorbing photons and emit electrons during cyclic and non-cyclic photophosphorylation. Chlorophyll a molecules form the reaction centres for both photosystems I and II. Due to these reasons, photosynthesis is absent in plants lacking chlorophyll a. Chlorophyll b, carotenoids and xanthophylls are accessory pigments. The major functions of these pigments are as follows

1. Absorption of light rays of different wavelengths and transfer of this energy to reaction centres.

2. Carotenoids and xanthophylls also protect the chlorophyll molecule from photo-oxidation.

Thus, it can be concluded that if any plant were to lack chlorophyll-a and contain a high concentration of chlorophyll-b, then this plant would not undergo photosynthesis.

Question 6. Why is the colour of a leaf kept in the dark frequently yellow, or pale green? Which pigment do you think is more stable?

Answer:

- In the dark, there is no production of chlorophyll.
- Chlorophyll present in the leaf is degraded, thus making the leaf pale green or yellow.
- Carotenoid is a more stable pigment.

Question 7. **Look at leaves of the same plant on the shady side and compare it with the leaves on the sunny side. Or, compare the potted plants kept in the sunlight with those in the shade. Which of them has leaves that are darker green ? Why?**

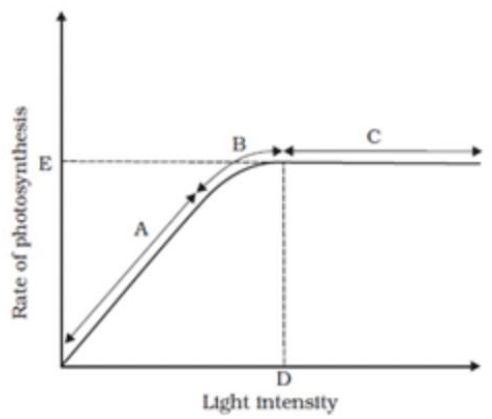
Answer: Light is a limiting factor for photosynthesis. Leaves get lesser light for photosynthesis when they are in shade. Therefore, the leaves or plants in shade perform lesser photosynthesis as compared to the leaves or plants kept in sunlight. In order to increase the rate of photosynthesis, the leaves present in shade have more chlorophyll pigments. This increases the chlorophyll content with increase in the amount of light absorbed by the leaves which increases the rate of photosynthesis. Therefore, the leaves or plants in shade are greener than the leaves for plants kept in the sun.

Question 8. **Figure shows the effect of light on the rate of photosynthesis. Based on the graph, answer the following questions:**

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

(b) What could be the limiting factor/s in region A?

(c) What do C and D represent on the curve?



Graph of light intensity on the rate of photosynthesis

Answer:

(A) Generally, light is not a limiting factor. It becomes a limiting factor for plants growing in shade or under tree canopies. In the given graph, light is a limiting factor at the point where photosynthesis is the minimum. The least value for photosynthesis is in region A. Hence, light is a limiting factor in this region.

(B) Light is a limiting factor in region A. Water, temperature, and the concentration of carbon dioxide could also be limiting factors in this region.

(C) Point D represents the optimum point and gives the light intensity at which the maximum photosynthesis is recorded. The rate of photosynthesis remains constant after this point, even though the intensity of light

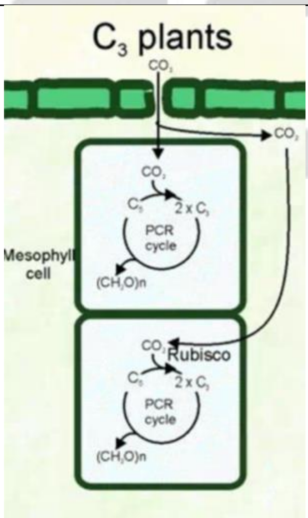
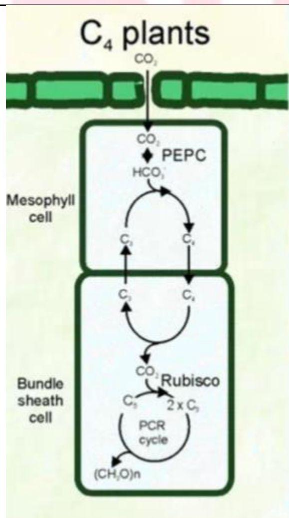
Question 9. Give a comparison between the following:

(a) C_3 and C_4 pathways

(b) Cyclic and non-cyclic photophosphorylation

(c) Anatomy of leaf in C_3 and C_4 plants

Answer:
(a) C3 and C4 pathways

C3 Pathway	C4 Pathway
The primary acceptor of CO_2 is RUBP- a six carbon compound.	The primary acceptor of CO_2 is phosphoenol pyruvate which is a three carbon compound.
The first stable compound is 3 phosphoglycerate.	The first stable product is oxaloacetic acid.
It takes place in mesophyll cells of the leaves.	It takes place in the mesophyll and bundle-sheath cells of the leaves.
It is a slower process of carbon fixation and photo-respiratory losses are high.	It is a fast process of carbon fixation and photo-respiratory losses are low.
	

(b) Cyclic and non-cyclic phosphorylations

Cyclic phosphorylation	Non-cyclic phosphorylation
Only photosystem I is involved.	Both Photosystems I and II are involved.
Water is not required.	Photolysis of water is required.
Oxygen is not evolved.	Oxygen is evolved.
NADPH is not synthesised.	NADPH is synthesised.
Used to produce additional ATP to meet energy demands.	Products can be used for the light independent reactions.

(c) Anatomy of leaf in C_3 and C_4 plants

C3 leaves	C4 leaves
Bundle sheath cells are absent.	Bundle sheath cells are present.
RuBisCo is located in the mesophyll cells.	RuBisCo is located in the bundle sheath cells.
The first stable compound produced is 3-Phosphoglycerate which is a three carbon compound.	The first stable compound produced is oxaloacetic acid which is a four carbon compound.
Photorespiration occurs.	Photorespiration does not occur.