CLASS 11 BIOLOGY NCERT SOLUTIONS

NCERT Solutions for Class 11 Biology Chapter 11: Photosynthesis in Higher Plants – Free PDF Download

Chapter 11, Photosynthesis in Higher Plants, explains how green plants trap light energy and convert it into chemical energy stored in carbohydrates. It covers the photosynthetic pigments, the light reaction (the Z scheme and cyclic/non-cyclic photophosphorylation), the Calvin cycle (C3 pathway), the Hatch-Slack or ...

Contents

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Exercises

Q1. By looking at a plant externally, can you tell whether a plant is C3 or C4? Why and how?

No, it is not possible to identify a plant as C3 or C4 simply by looking at its external features. C4 plants are usually found in hot, dry, tropical regions (such as maize, sugarcane and sorghum) and are adapted to tolerate high temperatures and intense light, but these are ecological tendencies, not visible morphological markers. The actual difference between C3 and C4 plants lies at the internal, cellular level of the leaf, so external observation of shape, size or colour cannot reveal the photosynthetic pathway a plant uses.

Q2. By looking at which internal structure of a plant can you tell whether a plant is C3 or C4? Explain.

The difference can be seen by examining the internal anatomy of the leaf, specifically in a transverse section. C4 plants possess a distinctive arrangement of cells around the vascular bundles called **Kranz anatomy** ("Kranz" means wreath, describing the ring-like arrangement of cells). In Kranz anatomy, the vascular bundles are surrounded by large, thick-walled **bundle sheath cells** that are packed with agranal chloroplasts and have no intercellular spaces, while the mesophyll cells around them contain smaller granal chloroplasts. This gives C4 leaves two distinct, concentric layers of photosynthetic cells.

C3 plants lack this dimorphic chloroplast arrangement. Their bundle sheath cells, if present, do not contain chloroplasts, and the mesophyll is differentiated into palisade and spongy parenchyma with normal intercellular spaces. Thus, the presence or absence of Kranz anatomy under the microscope is the reliable way to distinguish a C4 leaf from a C3 leaf.

Q3. Even though very few cells in a C4 plant carry out the biosynthetic – Calvin pathway, yet they are highly productive. Can you discuss why?

In C4 plants, the Calvin cycle operates only in the bundle sheath cells, which form a small fraction of the leaf's total cell population, yet these plants show higher productivity than C3 plants. This is because C4 plants possess an efficient **CO2-concentrating mechanism**. Atmospheric CO2 is first fixed in the mesophyll cells by the enzyme **PEP carboxylase**, which has a very high affinity for CO2 and no oxygenase activity. This produces a four-carbon acid (oxaloacetic acid, converted to malate or aspartate) that is transported into the bundle sheath cells, where it is decarboxylated to release CO2.

This decarboxylation raises the CO2 concentration around **RuBisCO** in the bundle sheath cells to a level several times higher than atmospheric CO2. At this high concentration, RuBisCO functions almost exclusively as a carboxylase, and its wasteful oxygenase activity (which causes photorespiration) is suppressed. Because the Calvin cycle runs efficiently with minimal loss of fixed carbon to photorespiration, even a small number of Calvin-cycle-active cells can support a high overall rate of carbon fixation and biomass production.

Q4. RuBisCO is an enzyme that acts both as a carboxylase and oxygenase. Why do you think RuBisCO carries out more carboxylation in C4 plants?

RuBisCO can bind either CO2 or O2 at the same active site; which reaction it catalyses depends on the relative concentrations of CO2 and O2 available to it. In C4 plants, RuBisCO is present only in the bundle sheath cells, which are shielded from atmospheric air and instead receive a concentrated, steady supply of CO2 released from the decarboxylation of C4 acids (malate/aspartate) delivered from the mesophyll cells. This creates a locally high CO2-to-O2 ratio at the site of RuBisCO. Since a higher CO2 concentration favours the carboxylase reaction over the oxygenase reaction, RuBisCO in C4 plants predominantly fixes CO2 into the Calvin cycle rather than reacting with O2, resulting in greater carboxylation and negligible photorespiration.

Q5. Suppose there were plants that had a high concentration of chlorophyll b but lacked chlorophyll a. Would they carry out photosynthesis? Then, why do plants have chlorophyll b and other accessory pigments?

No, such a plant would not be able to carry out photosynthesis. **Chlorophyll a** is the chief pigment of photosynthesis; it forms the **reaction centres** of both photosystems (P680 in Photosystem II and P700 in Photosystem I), where the actual photochemical act — the conversion of absorbed light energy into chemical energy through electron ejection — takes place. Without chlorophyll a, this energy conversion cannot occur, no matter how much chlorophyll b is present.

Chlorophyll b and other accessory pigments (xanthophylls and carotenoids) function as **antenna pigments**. They absorb light at wavelengths that chlorophyll a absorbs poorly, broadening the range of light usable for photosynthesis, and they transfer the absorbed energy by resonance to the chlorophyll a molecules at the reaction centre. This increases the overall efficiency of light harvesting. Accessory pigments also protect chlorophyll a from photo-oxidative damage under high light intensity.

Q6. Why is the colour of a leaf kept in the dark, frequently yellow or pale green? Which pigment do you think is more stable?

When a leaf is kept in continuous darkness, chlorophyll synthesis stops and the existing chlorophyll molecules gradually degrade, since chlorophyll is a relatively unstable pigment that needs continuous light-dependent renewal. As the green chlorophyll breaks down, the more stable accessory pigments — the **carotenoids** (carotenes and xanthophylls) — remain intact and become visible, giving the leaf its yellow or pale green appearance. Therefore, carotenoids are more stable than chlorophyll.

Q7. Look at the leaves of the same plant on the shady side and compare them 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?

Leaves growing in the shade are usually darker green than leaves growing in full sunlight. In shaded conditions, light intensity is a limiting factor for photosynthesis, so the plant compensates by increasing its chlorophyll content per unit leaf area (through more and larger chloroplasts and greater thylakoid stacking) to capture the limited available light as efficiently as possible. Leaves in full sunlight receive abundant light and do not need this compensatory increase in chlorophyll; they may also develop more carotenoids and structural adaptations for photoprotection against excess light, which makes them appear comparatively lighter green.

Q8. 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?
Light is the limiting factor at point A and up to about the midpoint of B, because in this region the rate of photosynthesis rises steadily as light intensity increases.

(b) What could be the limiting factor/s in region A?
In region A, light intensity itself is the principal limiting factor, since the rate of photosynthesis increases in direct proportion to the increase in light. (Other factors such as CO2 concentration and temperature remain adequate and non-limiting in this region.)

(c) What do C and D represent on the curve?
Point C marks the stage where the curve begins to flatten — beyond this point, increasing light intensity no longer increases the rate of photosynthesis appreciably because a factor other than light (commonly CO2 concentration) has become limiting. Point D represents the plateau, the maximum rate of photosynthesis attainable under the existing conditions, where further increase in light intensity produces no further increase in the rate — light is no longer the limiting factor here.

Q9. Give a comparison between the following:

(a) C3 and C4 pathways

C3 Pathway	C4 Pathway
Primary CO2 acceptor is RuBP (ribulose-1,5-bisphosphate), a 5-carbon compound.	Primary CO2 acceptor is PEP (phosphoenolpyruvate), a 3-carbon compound.
The first stable product of CO2 fixation is 3-phosphoglyceric acid (3-PGA), a 3-carbon compound.	The first stable product is oxaloacetic acid (OAA), a 4-carbon compound.
CO2 fixation occurs only once, in the mesophyll cells, through the Calvin cycle.	CO2 fixation occurs twice — once in mesophyll cells (by PEP carboxylase) and again in bundle sheath cells (by RuBisCO, via the Calvin cycle).
Photorespiration occurs, especially at high temperature and light intensity.	Photorespiration is negligible due to the CO2-concentrating mechanism.
Found in most plants, e.g. rice, wheat, and other temperate-climate crops.	Found mainly in tropical grasses adapted to high temperature and light, e.g. maize, sugarcane, sorghum.

(b) Cyclic and non-cyclic photophosphorylation

Cyclic Photophosphorylation	Non-cyclic Photophosphorylation
Involves only Photosystem I (PS I).	Involves both Photosystem I and Photosystem II working together (the Z scheme).
The electron ejected from PS I eventually returns to the same PS I chlorophyll, following a closed/cyclic path.	Electrons flow in a one-way, non-cyclic path from water through PS II and PS I to NADP+.
Only ATP is synthesised; no NADPH is produced.	Both ATP and NADPH are synthesised.

Photolysis of water does not occur, so no oxygen is released.	Photolysis of water occurs, releasing oxygen as a by-product.

(c) Anatomy of leaf in C3 and C4 plants

C3 Leaf Anatomy	C4 Leaf Anatomy
Kranz anatomy is absent.	Kranz anatomy is present — bundle sheath cells form a distinct ring around the vascular bundle.
Bundle sheath cells, where present, lack chloroplasts (or are poorly developed).	Bundle sheath cells are large, thick-walled, and rich in agranal chloroplasts.
Only one type of chloroplast (granal) is present, in the mesophyll cells.	Chloroplasts are dimorphic — granal chloroplasts in mesophyll cells and agranal chloroplasts in bundle sheath cells.
Mesophyll is differentiated into palisade and spongy parenchyma with intercellular spaces.	Mesophyll cells are compactly arranged with few or no intercellular spaces.

Class 11 Biology Chapter 11 – Notes and Extra Questions

The official NCERT exercise for this chapter has exactly **9 questions**, and this number has not changed with the 2023 rationalisation — only the chapter number was renumbered from the older Chapter 13 to the current Chapter 11; the questions and their wording remain the same. Note that Question 9 is effectively a three-part comparison question (C3 vs C4 pathways, cyclic vs non-cyclic photophosphorylation, and C3 vs C4 leaf anatomy), so it carries proportionally more weight in exams than a single question number suggests — students should be comfortable drawing all three comparison tables from memory. While revising, focus on linking structure to function: understand why Kranz anatomy exists before memorising it, trace the path of an electron in the Z scheme to understand cyclic versus non-cyclic photophosphorylation, and be clear on the three phases of the Calvin cycle (carboxylation, reduction, and regeneration of RuBP) along with the ATP and NADPH requirement (3 ATP and 2 NADPH per CO2 fixed, i.e. 9 ATP and 6 NADPH for 3 CO2 to form one molecule of G3P).

What is the basic difference between the light reaction and the Calvin cycle (dark reaction) in photosynthesis?

The light reaction takes place in the thylakoid membranes and depends directly on light; it involves the absorption of light energy by pigments, photolysis of water, electron transport through the Z scheme, and generation of ATP and NADPH. The Calvin cycle (biosynthetic phase) occurs in the stroma and does not require light directly — it uses the ATP and NADPH produced by the light reaction to fix atmospheric CO2 into carbohydrate through carboxylation, reduction, and regeneration of RuBP.

Why do C4 plants have Kranz anatomy while C3 plants do not?

C4 plants evolved Kranz anatomy as a structural adaptation to concentrate CO2 around RuBisCO and minimise photorespiration, which is especially important in the hot, high-light, tropical environments they typically grow in. The dimorphic arrangement of mesophyll and bundle sheath cells allows CO2 to be captured efficiently in the mesophyll (by PEP carboxylase) and then released at a high concentration in the bundle sheath (near RuBisCO). C3 plants, which usually grow in more temperate, less light-intense conditions, do not need this extra CO2-concentrating structure.

What is photorespiration, and why is it considered a wasteful process?

Photorespiration occurs when RuBisCO acts as an oxygenase instead of a carboxylase, binding O_2 to RuBP instead of CO_2. This produces one molecule of 3-phosphoglycerate and one molecule of phosphoglycolate, which is metabolised through the chloroplast, peroxisome and mitochondria, releasing CO_2 without producing any ATP or NADPH. It is considered wasteful because it consumes fixed carbon and energy without any corresponding synthesis of sugar, effectively lowering the net efficiency of photosynthesis, particularly in C3 plants under hot, dry, high-light conditions.

How many ATP and NADPH molecules are needed to fix one molecule of CO_2 in the Calvin cycle?

Fixation of one molecule of CO_2 in the Calvin cycle requires 3 molecules of ATP and 2 molecules of NADPH. Since three turns of the cycle are needed to release one molecule of glyceraldehyde-3-phosphate (G3P, a net 3-carbon sugar product), fixing 3 molecules of CO_2 uses a total of 9 ATP and 6 NADPH.