

Photosynthesis in Higher Plants — Assignment 2

Class 11 Biology · Higher-difficulty challenge set + integrated problems · Answer key included · Narayan Gurukul Academy

Instructions: (1) Attempt all questions; start with the topic-wise challenge set, then attempt the integrated (multi-topic) problems.
(2) Give all answers with correct SI units. $g = 10 \text{ m/s}^2$ unless stated.
(3) A final answer key is provided at the end — try the full set before checking it.

Part A — Topic-wise challenge questions

Photosynthesis as a Physicochemical Process

1. Why is photosynthesis called a physicochemical process?
2. State the overall equation of photosynthesis.
3. Describe photosynthesis as a physicochemical process.

Light Reaction — Z-scheme

1. State the products of the light reaction.
2. What is the Z-scheme?
3. Explain the Z-scheme with reference to the two photosystems.

Dark Reaction — Calvin Cycle (C3 Pathway)

1. Why is the Calvin cycle called the C3 pathway?
2. Name the three phases of the Calvin cycle.
3. Describe the stages of the Calvin cycle.

C4 Pathway and Kranz Anatomy

1. State two advantages of the C4 pathway.
2. Distinguish between C3 and C4 plants.
3. Describe the C4 pathway and Kranz anatomy.

Photorespiration and Its Drawbacks

1. When does photorespiration occur?
2. State two drawbacks of photorespiration.
3. Explain photorespiration and its drawbacks.

Factors Affecting Photosynthesis

1. State the law of limiting factors.
2. How does CO₂ concentration affect the rate of photosynthesis?
3. Explain the factors affecting the rate of photosynthesis.

Part B — Integrated problems (multi-topic)

1. Describe the light reaction of photosynthesis, naming the photosystems and the products.
2. Describe the three phases of the Calvin cycle.
3. Explain the C4 pathway and the significance of Kranz anatomy.
4. Explain photorespiration and why it is wasteful.
5. State the law of limiting factors and explain it with an example.
6. Distinguish between C3 and C4 plants giving two examples of each.

Answer Key

Photosynthesis as a Physicochemical Process

Photosynthesis is called physicochemical because it involves both physical events (absorption of light) and chemical events (conversion of CO₂ and water into carbohydrate). Overall equation: $6\text{CO}_2 + 12\text{H}_2\text{O} \xrightarrow{\text{light/chlorophyll}} \text{C}_6\text{H}_{12}\text{O}_6 + 6\text{O}_2 + 6\text{H}_2\text{O}$. It converts light energy (physical) into chemical energy stored in glucose (chemical).

Light Reaction — Z-scheme

Products: ATP, NADPH and O₂. The Z-scheme is the pathway of electrons from water through PSII and PSI to NADP⁺, drawn as a Z. PSII (P680) absorbs light, splits water (photolysis) releasing O₂, and passes electrons through the electron transport chain to PSI (P700), which reduces NADP⁺ to NADPH; the proton gradient drives ATP synthesis (photophosphorylation).

Dark Reaction — Calvin Cycle (C3 Pathway)

It is called the C3 pathway because the first stable product is a 3-carbon compound (3-PGA). Three phases: carboxylation, reduction and regeneration. Carboxylation: RuBisCO fixes CO₂ onto RuBP to give 3-PGA. Reduction: ATP and NADPH reduce 3-PGA to glyceraldehyde-3-phosphate. Regeneration: RuBP is regenerated to continue the cycle.

C4 Pathway and Kranz Anatomy

Advantages: no photorespiration, higher productivity and efficient CO₂ use. C3 plants: first product 3-PGA, RuBisCO only, no Kranz anatomy, e.g. rice/wheat. C4 plants: first product OAA, PEP carboxylase then RuBisCO, Kranz anatomy, e.g. maize/sugarcane. In C4 plants CO₂ is fixed in mesophyll cells by PEP carboxylase into OAA (a 4-carbon acid), which is transported to bundle-sheath cells and decarboxylated to release CO₂ for the Calvin cycle — the Kranz anatomy with bundle-sheath cells around vascular bundles.

Photorespiration and Its Drawbacks

Photorespiration occurs when RuBisCO binds O₂ instead of CO₂ (favoured by high O₂ and low CO₂). Drawbacks: it consumes ATP, releases CO₂, produces no sugar and no NADPH — it is therefore wasteful. It happens because at the active site O₂ competes with CO₂, and the C2 cycle that follows yields no carbohydrate.

Factors Affecting Photosynthesis

The law of limiting factors states that the rate is limited by the factor in shortest supply. Increasing CO₂ concentration increases the rate up to a saturation point and then levels off. External factors: light, CO₂, temperature, water. Internal factors: chlorophyll content, protoplasm, leaf anatomy. The law of limiting factors: when several factors affect a process, the rate is determined by the factor nearest its minimum value.

Integrated problems

1: Physical light absorption + chemical conversion of CO₂ and water to carbohydrate; PSII (P680) and PSI (P700); products ATP, NADPH, O₂. 2: Carboxylation (RuBisCO + CO₂ → 3-PGA), reduction (ATP/NADPH), regeneration (RuBP). 3: Mesophyll fixes CO₂ into OAA via PEP carboxylase; bundle-sheath cells release CO₂ for the Calvin cycle; Kranz anatomy prevents photorespiration. 4: RuBisCO binds O₂, consuming ATP without making sugar. 5: Rate limited by the factor in shortest supply, e.g. low CO₂ limiting at high light. 6: C₃ — 3-PGA first product, no Kranz anatomy (rice, wheat); C₄ — OAA first product, Kranz anatomy (maize, sugarcane).