GLEN TUTORIALS

Grade 9 IGCSE Biology — Comprehensive Exam Solutions & Notes

BOARD: IGCSE | GRADE: 9 | SUBJECT: BIOLOGY | CHAPTER: PLANT NUTRITION

CORE VOCABULARY & KEY TERMS

- **Photosynthesis:** The fundamental biological process by which plants synthesize carbohydrates (glucose) from inorganic raw materials (CO_2 and H_2O) using light energy absorbed by chlorophyll.
- **Destarching:** The practice of keeping a plant in continuous darkness for 24–48 hours to deplete stored starch via respiration prior to testing.
- **Limiting Factor:** An environmental condition present in shortest supply that directly restricts the maximum rate of a physiological process.
- **Chlorophyll:** Green pigment located inside chloroplasts that traps light energy and converts it into chemical energy.

SECTION A: EXAM-STYLE MULTIPLE CHOICE QUESTIONS

Question 1: What are the raw materials required for photosynthesis?

A) carbon dioxide and oxygen
B) oxygen and glucose
C) glucose and water
D) water and carbon dioxide

Correct Answer: D) water and carbon dioxide

REMEMBER

The chemical reactants (raw materials) entering photosynthesis are **carbon dioxide** and **water**. Glucose is the primary carbohydrate product, and oxygen is released as a metabolic by-product.

Question 2: A student investigated the necessity of light for photosynthesis. He covered a leaf with black paper to prevent light reaching it. What is an appropriate control for his experiment?

A) a leaf that has been destarched
B) a leaf that is not covered with black paper
C) a leaf that is partly white and partly green
D) a leaf that has no carbon dioxide provided

Correct Answer: B) a leaf that is not covered with black paper

EXAM TIP

An experimental **control** keeps all variables identical except for the independent variable under test. Comparing an uncovered leaf (exposed to light) against a covered leaf isolates **light presence** as the single factor responsible for starch production.

Question 3: Which ions does a plant require to make amino acids from glucose?

A) calcium
B) iron
C) magnesium
D) nitrate

Correct Answer: D) nitrate

REMEMBER — PLANT MINERAL REQUIREMENTS

- **Nitrate ions (NO_3^-):** Essential to supply nitrogen for combining with glucose to form **amino acids** and **proteins**. Deficiency causes stunted growth and yellow older leaves.
- **Magnesium ions (Mg^{2+}):** Required for the synthesis of **chlorophyll**. Deficiency causes chlorosis (yellowing between leaf veins).

Question 4: In photosynthesis, how many glucose molecules can be made from 30 carbon dioxide molecules and 30 water molecules?

A) 5
B) 6
C) 30
D) 60

Correct Answer: A) 5

Detailed Calculation:
The balanced chemical equation for photosynthesis is:

$$6CO_2 + 6H_2O \rightarrow C_6H_{12}O_6 + 6O_2$$

This reaction ratio dictates that **6 molecules of CO_2** and **6 molecules of H_2O** combine to synthesize **1 molecule of glucose**.
$Number\ of\ glucose\ molecules = 30 / 6 = 5$.

Question 5: The graph shows how two variables affect the rate of photosynthesis in a plant. At which value of carbon dioxide concentration is carbon dioxide not a limiting factor?

Correct Answer: D (Point where the curve plateaus)

Explanation: A factor ceases to be a **limiting factor** when an increase in its concentration no longer yields an increase in the rate of photosynthesis (the curve flattens into a plateau). At point **D**, the rate has leveled off completely; at this stage, **light intensity** or **temperature** acts as the limiting factor.

SECTION B: LEAF STRUCTURE & FUNCTION SOLUTIONS

Question 6: Leaf Section Diagram Analysis

1. **(i) Name the tissue labelled C.**
   Answer: Palisade mesophyll layer.
2. **(ii) Outline how this tissue is adapted for its function.**
   Answer:
   - **High Chloroplast Density:** Packed densely with chloroplasts positioned near the upper leaf surface to capture maximum light energy.
   - **Columnar & Closely Packed Arrangement:** Cells are elongated vertically, allowing light to travel through the tissue with minimal barrier reflection.
   - **Large Internal Surface Area:** Facilitates rapid absorption and diffusion of carbon dioxide.
3. **(b) Give the letters of two cells or tissues that do not contain chloroplasts.**
   Answer: A (Waxy cuticle) / **B** (Upper epidermal cells) AND **E** (Xylem) / **F** (Phloem).
4. **(c) Describe the function of the cell labelled H.**
   Answer: Label **H** represents a **guard cell**. Guard cells control the opening and closing of the **stoma (G)** to regulate gas exchange (CO_2 uptake and O_2 release) and reduce excessive water loss via transpiration.
5. **(d) Use the letters on the diagram to describe how water reaches a chloroplast in the leaf.**
   Answer: Water enters through the **xylem tissue (E)** in the vascular bundle, passes into surrounding mesophyll cells (such as **D** or **C**) down a water potential gradient by **osmosis**, and diffuses into the chloroplasts.

Question 7: Distribution of Chloroplasts in Leaf Cells

1. **Explain why palisade mesophyll cells have so many chloroplasts.**
   Answer: They are located at the top of the leaf directly beneath the upper epidermis where light intensity is highest. Having a high concentration of chloroplasts maximizes light absorption for **photosynthesis**.
2. **Which cell could be a cell in the upper epidermis? Explain your answer.**
   Answer: Cell A. Upper epidermal cells are transparent and lack chloroplasts (count = 0) to allow light to pass unhindered through to the underlying palisade mesophyll layer.
3. **Guard cells contain chloroplasts, but not as many as spongy mesophyll cells. Which cell could be a guard cell?**
   Answer: Cell B (contains ~15 chloroplasts, which is fewer than spongy mesophyll **C** at ~67, but greater than upper epidermis **A** at 0).
4. **Chloroplasts contain chlorophyll. Describe the function of chlorophyll in photosynthesis.**
   Answer: Chlorophyll **absorbs light energy** (primarily red and blue wavelengths) and converts it into chemical energy required to drive the synthesis of glucose from carbon dioxide and water.

Question 8: Carbohydrate Synthesis and Fate

1. **Describe how plants synthesise carbohydrates.**
   Answer: Plants absorb water from the soil through roots via osmosis and take in carbon dioxide from the air through stomata via diffusion. Chlorophyll inside chloroplasts absorbs light energy, which powers the conversion of CO_2 and H_2O into **glucose** and oxygen.
2. **Outline two subsequent uses of the carbohydrates made in photosynthesis.**
   Answer:
   1. **Respiration:** Broken down during cellular respiration to release energy (ATP) for cellular work and active transport.
   2. **Storage as Starch:** Converted into insoluble **starch** for energy storage in leaves, stems, or storage roots without affecting osmotic balance.
   3. **Structural Component (Cellulose):** Converted to cellulose to form rigid cell walls.

SECTION C: EXPERIMENTAL GRAPHS & DATA INTERPRETATION

Question 9: Temperature and Photosynthesis Graph Analysis

1. **Use the graph to describe the effect of increasing temperature on the rate of photosynthesis in normal air.**
   Answer:
   - **0°C to 25°C:** As temperature increases, the rate of photosynthesis increases continuously from 0 up to a peak value of **8.0 arbitrary units (a.u.)** at **25°C**.
   - **At 25°C:** The rate reaches its **optimum temperature**.
   - **25°C to 43°C:** Above 25°C, the rate drops sharply, reaching 0 a.u. at approximately **43°C**.
2. **Explain the differences between the two curves between 0°C and 25°C. Use the term *limiting factor* in your explanation.**
   Answer: In normal air, the rate is lower because carbon dioxide concentration acts as a **limiting factor**. Supplying CO_2-enriched air removes this constraint, enabling enzymes to operate faster and increasing the peak rate from 8.0 to 9.6 a.u.
3. **Suggest why the optimum temperature of 25°C is the same for both curves.**
   Answer: The optimum temperature is determined by the tertiary structure of the **enzymes** driving photosynthesis. Increasing CO_2 concentration does not change enzyme structure or thermal stability.
4. **Explain the shape of the curves above 25°C.**
   Answer: Excessively high temperatures disrupt the hydrogen and ionic bonds in photosynthetic enzymes, causing active sites to change shape and become **denatured**. Substrates can no longer bind, halting photosynthesis.

Question 10: Syringe & Sodium Hydrogencarbonate Investigation

1. **Identify the independent variable and the dependent variable in this investigation.**
   Answer:
   - **Independent Variable:** Concentration / percentage of sodium hydrogencarbonate solution.
   - **Dependent Variable:** Distance moved by the meniscus / liquid in 30 minutes (mm).
2. **Explain why the five syringes were placed in bright sunshine.**
   Answer: To ensure light intensity is high and constant across all setups so that light does not become a **limiting factor**.
3. **Data Table & Results Plotting:**

Percentage concentration of sodium hydrogencarbonate (%)	0	0.1	0.2	0.3	0.4
Distance moved by meniscus after 30 mins (mm)	5	8	12	14	17

4. **Is carbon dioxide a limiting factor at any concentration used? Explain.**
   Answer: Yes, across all concentrations tested. As concentration increases from 0% to 0.4%, the distance moved increases continuously from 5 mm to 17 mm, proving CO_2 availability directly limits the rate.
5. **Sources of Error & Improvements:**
   - **Error 1:** Fluctuations in water temperature due to heat from sunlight.
     Improvement: Place syringes in a thermostatically controlled water bath.
   - **Error 2:** Inaccurate meniscus reading or small gas leakage.
     Improvement: Use a capillary tube with a calibrated syringe scale and take repeated measurements to compute a mean.

SECTION D: PRACTICAL INVESTIGATIONS & EXPERIMENTAL PROTOCOLS

Practical Set 1: Light & Starch Investigations

1. **Why is destarching a necessary step?**
   Answer: Destarching removes existing starch stores so that any starch detected after the experiment is guaranteed to have been synthesized during the testing phase under specific experimental conditions.
2. **Why must the leaf remain attached to the plant for 24 hours?**
   Answer: To keep the leaf alive, providing it continuous water and minerals through xylem transport while photosynthesizing under experimental conditions.
3. **Conclusion:**
   Answer: Light is necessary for photosynthesis. Uncovered leaf regions turn blue-black with iodine (starch present), while regions covered by black paper remain yellow-brown (no starch produced).

Practical Set 2: Rate of Photosynthesis in Aquatic Plants

1. **Why use an aquatic plant (e.g., Elodea / Cabomba)?**
   Answer: Aquatic plants release oxygen gas as visible underwater bubbles, allowing easy quantification of photosynthesis rates.
2. **Effect of Light Intensity:**
   Answer: As light intensity increases (lamp closer), the rate of photosynthesis increases linearly until another factor limits the rate.
3. **Function of a Heat Shield / Water Jacket:**
   Answer: Lamps emit heat in addition to light. A heat shield absorbs thermal energy, ensuring temperature remains constant so that light intensity is isolated as the only variable.
4. **Gas Volume Collection vs Bubble Counting:**
   Answer: Measuring total oxygen volume using a calibrated capillary tube/syringe is far more accurate than counting bubbles, as bubble volumes vary.

Practical Set 3: Hydrogencarbonate Indicator Analysis

HYDROGENCARBONATE INDICATOR COLOUR CODE

- **Purple / Magenta:** Low CO_2 levels (Photosynthesis > Respiration)
- **Red:** Normal atmospheric CO_2 concentration (Equilibrium / Compensation Point)
- **Yellow:** High CO_2 levels (Respiration > Photosynthesis or Darkness)

Explanation of Results:
In bright light, plants photosynthesize faster than they respire, consuming more CO_2 than they produce, turning the indicator **purple**. In darkness, photosynthesis ceases while respiration continues, accumulating CO_2 and turning the indicator **yellow**.