Topic 4: Bioenergetics

AQA GCSE Biology 8461 · spec 4.4 · sheets 4.1–4.2

Bioenergetics: photosynthesis and respiration

- write the equations for photosynthesis and respiration, and explain where the energy comes from;
- explain how light, carbon dioxide and temperature limit the rate of photosynthesis;
- describe how plants use the glucose they make;

Bioenergetics: photosynthesis and respiration (2)

- compare aerobic and **anaerobic respiration**, and explain how the body responds to exercise;
- describe **metabolism** as the sum of all the reactions in a cell.

Photosynthesis

- **Photosynthesis** happens in the **chloroplasts** of plant cells and algae.
- Green **chlorophyll** absorbs light energy, which is used to turn carbon dioxide and water into **glucose**, with oxygen as a by-product.

$$\text{carbon dioxide} + \text{water} \xrightarrow{\text{light}} \text{glucose} + \text{oxygen}$$

Photosynthesis (2)

- Photosynthesis is an **endothermic** reaction: energy is transferred from the surroundings, as light, to the **chloroplasts**.
- **Worked example 1.** Three leaves on a plant were treated for two days: leaf A was covered with black paper, leaf B was sealed in a clear plastic bag with a chemical that absorbs carbon dioxide, and leaf C was left uncovered.

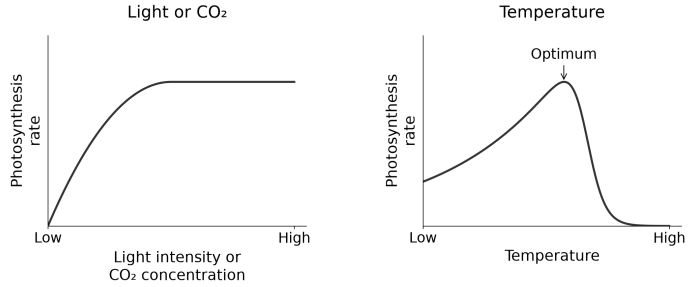
$$6CO_2 + 6H_2O \rightarrow C_6H_{12}O_6 + 6O_2$$

The rate of photosynthesis

- **light intensity** , because light supplies the energy;
- carbon dioxide concentration, because carbon dioxide is a reactant;
- temperature, because photosynthesis is controlled by enzymes;
- the amount of **chlorophyll**, because chlorophyll absorbs the light.

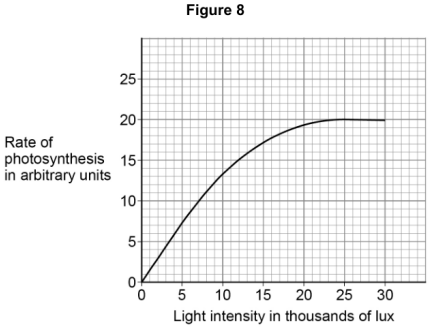
$$\text{light intensity} \propto \frac{1}{\text{distance}^2}$$

Figure: The rate of photosynthesis



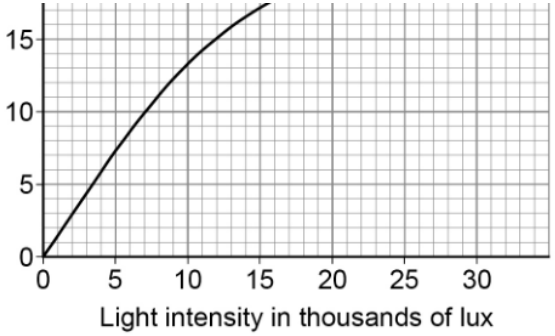
- Rate rises with **light intensity** or carbon dioxide until another factor limits it; with temperature it rises to an **optimum**, then falls as enzymes **denature**
- Read the axes and units first.

Figure: The rate of photosynthesis (2)



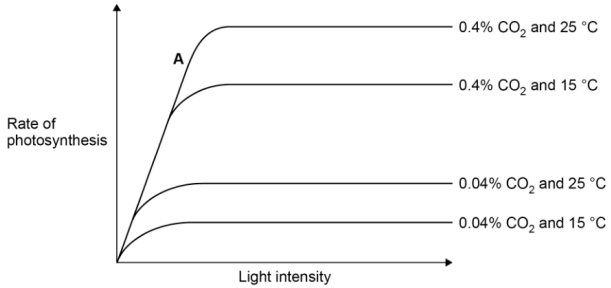
- Rate of photosynthesis against **light intensity** in thousands of lux (AQA GCSE Biology Paper 1H, June 2023, Figure 8)
- Read the axes and units first.

Figure: The rate of photosynthesis (3)



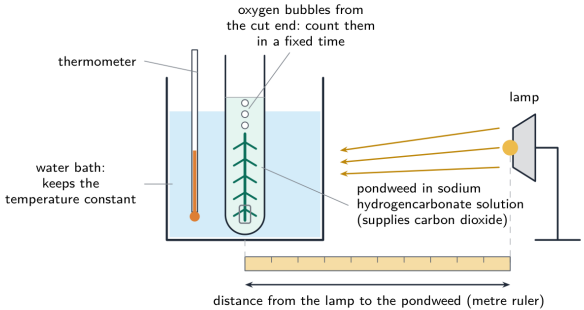
- The straight part of the same graph, enlarged
- Read the axes and units first.

Figure: The rate of photosynthesis (4)



- Rate of photosynthesis against **light intensity** at two temperatures and two carbon dioxide concentrations (AQA GCSE Biology Paper 1H, June 2024, Figure 7)
- Read the axes and units first.

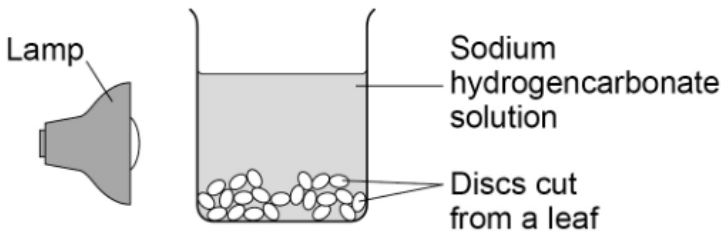
Figure: The rate of photosynthesis (5)



- Counting oxygen bubbles from **pondweed** at a measured distance from a lamp (not to scale)
- Match each part of the diagram to the text.

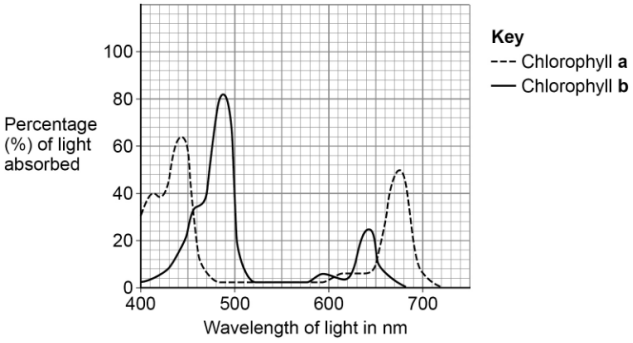
Figure: The rate of photosynthesis (6)

Figure 9



- Leaf discs in **sodium hydrogencarbonate** solution under coloured light (AQA GCSE Biology Paper 1H, June 2023, Figure 9)
- Match each part of the diagram to the text.

Figure: The rate of photosynthesis (7)



- Light absorbed by **chlorophyll** a and chlorophyll b at different wavelengths (AQA GCSE Biology Paper 1H, June 2023, Figure 10)
- Read the axes and units first.

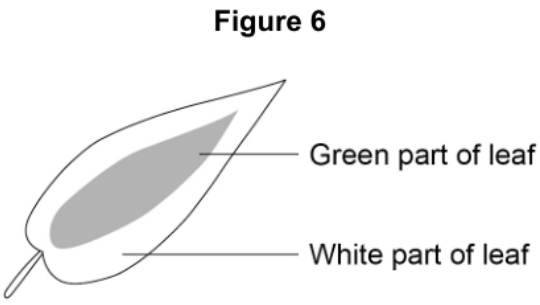
How plants use glucose

- for respiration, to release energy;
- to make **starch**, which is insoluble, for storage;
- to make fats and oils for storage, especially in seeds;

How plants use glucose (2)

- to make **cellulose** , which strengthens cell walls;
- to make **amino acids** **nitrate ions** , which are built into proteins. This also needs absorbed from the soil.

Figure: How plants use glucose



- A variegated leaf: the grey part is green and the white part has no **chlorophyll** (AQA GCSE Biology Paper 1H, June 2024, Figure 6)
- Match each part of the diagram to the text.

Respiration

- In muscles: glucose $\rightarrow$ **lactic acid** .
- In plant cells and **yeast** : glucose $\rightarrow$ **ethanol** + carbon dioxide.
- Days 0 to 5: the carbon dioxide level stays steady. The **pondweed** takes in carbon dioxide for photosynthesis as fast as both organisms release it by respiration.

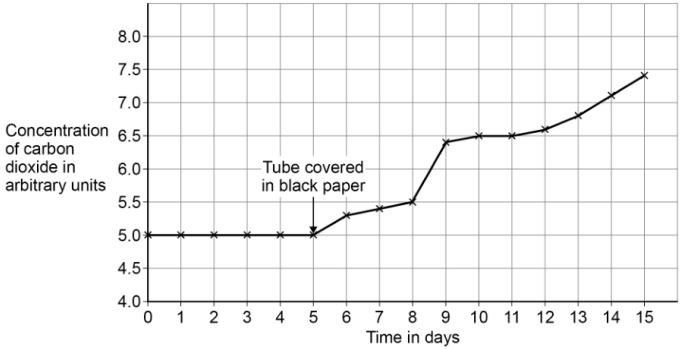
$$\text{glucose} + \text{oxygen} \rightarrow \text{carbon dioxide} + \text{water}$$

Respiration (2)

- Days 5 to 10: the level rises. In the dark there is no photosynthesis, but both organisms keep respiring.
- After day 10: the level keeps rising, because **decomposers** such as bacteria feed on the dead snail and respire.

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

Figure: Respiration

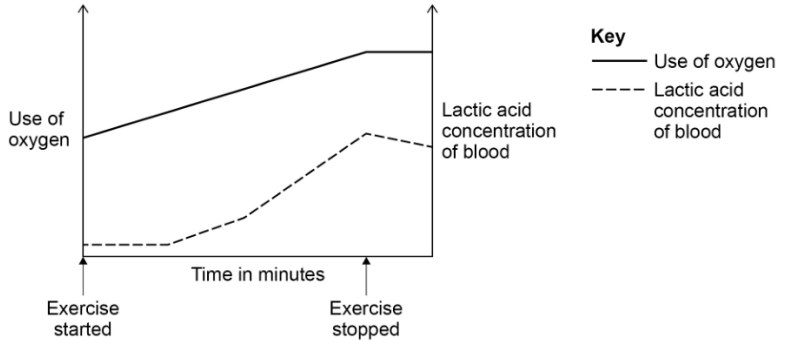


- Carbon dioxide concentration in the sealed tube over 15 days (AQA GCSE Biology Paper 1H, June 2021, Figure 7)
- Match each part of the diagram to the text.

Response to exercise

- During exercise, muscles need more energy, so they respire faster and need more oxygen and glucose.
- To supply them, the **heart rate** , the **breathing rate** and the **breath volume** all increase.
- During hard exercise the muscles may not get enough oxygen, so they respire anaerobically as well.
- **Lactic acid** builds up, and the muscles become **fatigued** : they stop contracting efficiently.

Figure: Response to exercise



- Oxygen use and blood **lactic acid** during and after exercise; each line has its own vertical scale (AQA GCSE Biology Paper 1H, June 2025, Figure 7)
- Match each part of the diagram to the text.

Metabolism

- glucose is joined into **starch**, **glycogen** (in animals) or **cellulose**;
- one molecule of **glycerol** and three **fatty acids** make a **lipid** molecule;
- glucose and **nitrate ions** make amino acids, which are joined into proteins;

Metabolism (2)

- respiration breaks down glucose;
- excess proteins are broken down to make **urea** , which is removed from the body by **excretion** in urine.

Sources for this lesson

- AQA, *GCSE Biology (8461) specification*, section 4.4 Bioenergetics, and the required practical handbook.
- J. Priestley, "Observations on different kinds of air", *Philosophical Transactions of the Royal Society* 62 (1772), pages 147 to 264.
- J. Ingenhousz, *Experiments upon Vegetables* (London, 1779).
- AQA, *GCSE Biology* Paper 1 Higher (June 2021 to June 2025), the limiting-factor, leaf-disc, variegated-leaf and exercise questions, adapted.

Common errors

- Writing light as a reactant in the photosynthesis equation; it is the energy source.
- Saying photosynthesis makes **starch** directly; it makes glucose, which is then turned into starch.
- Saying the level part of a graph is still limited by light.

Common errors (2)

- Saying plants photosynthesise instead of respiring; they do both, and respire all the time.
- Saying respiration "makes" energy; it transfers energy.
- Writing that **anaerobic respiration** in muscles makes carbon dioxide or **ethanol**.
- (HT) Saying oxygen is used in the **liver** to turn lactic acid into glucose.

Key terms

- **Photosynthesis**: an **endothermic** reaction in which light energy is used to make glucose from carbon dioxide and water.
- **Limiting factor**: the factor in shortest supply, which stops the rate increasing.
- **Respiration**: an **exothermic** reaction in cells that transfers energy from glucose.

Key terms (2)

- **Aerobic respiration**: respiration using oxygen, making carbon dioxide and water.
- **Anaerobic respiration**: respiration without oxygen, making **lactic acid** in muscles or **ethanol** and carbon dioxide in **yeast**.
- **Oxygen debt**: the extra oxygen needed after exercise to remove lactic acid.
- **Metabolism**: the sum of all the reactions in a cell or body.

Check yourself

- 1.
- Write the word equation for photosynthesis. 2.
- Give four factors that affect the rate of photosynthesis. 3.
- In RP6, why is a beaker of water placed between the lamp and the **pondweed**? 4.