

4 · Bioenergetics

AQA · GCSE · Biology

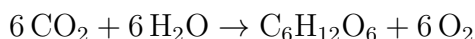
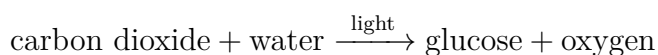
Bioenergetics: photosynthesis and respiration

Plants capture light energy; respiration transfers energy for living processes in plant and animal cells. This reference covers **AQA GCSE Biology 8461, topic 4.4 Bioenergetics**.

How the exam treats this topic:

- Paper 1 carries Bioenergetics. RP6: light intensity and the rate of photosynthesis using pondweed.
- Limiting-factor graphs with two or three factors, the **inverse square law** and greenhouse economics are **HT only**.
- Equations are word equations – know the symbol forms too (CO_2 , H_2O , O_2 , $\text{C}_6\text{H}_{12}\text{O}_6$).

Photosynthesis (4.4.1.1)

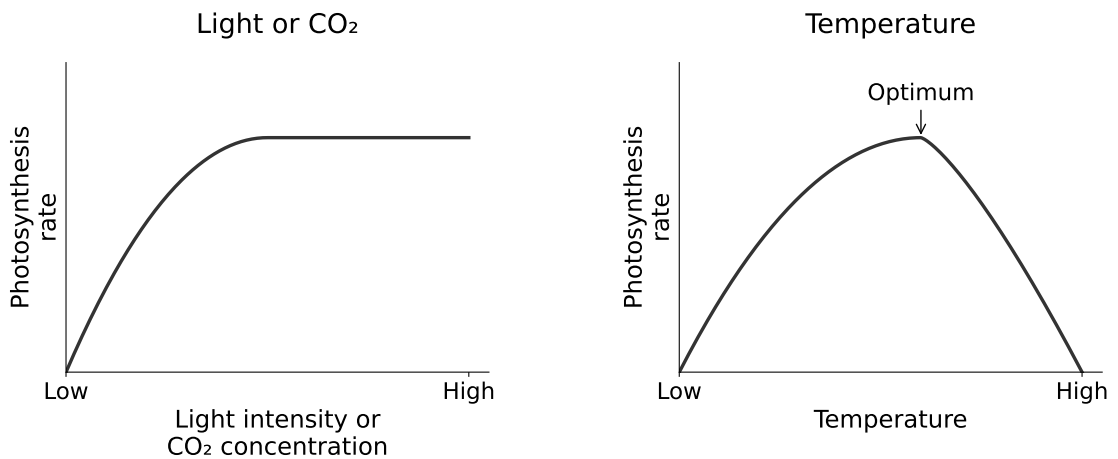


Photosynthesis is an **endothermic** reaction: energy is transferred **from the environment to the chloroplasts by light**. Chlorophyll absorbs light; carbon dioxide and water are the reactants, glucose and oxygen the products. Light is an energy input, not a chemical reactant. The coefficients balance the atoms: 6 carbon, 12 hydrogen and 18 oxygen on each side.

Worked evidence (2024 Q07.1): black paper blocks light; sealed transparent plastic prevents carbon dioxide entering; an uncovered leaf has both. In the supplied results, covered leaves have no starch and the uncovered leaf does. Explain the chain: restricted photosynthesis $\rightarrow$ no new glucose $\rightarrow$ no conversion of that glucose to starch. Do not claim photosynthesis directly makes starch.

Rate of photosynthesis and limiting factors (4.4.1.2)

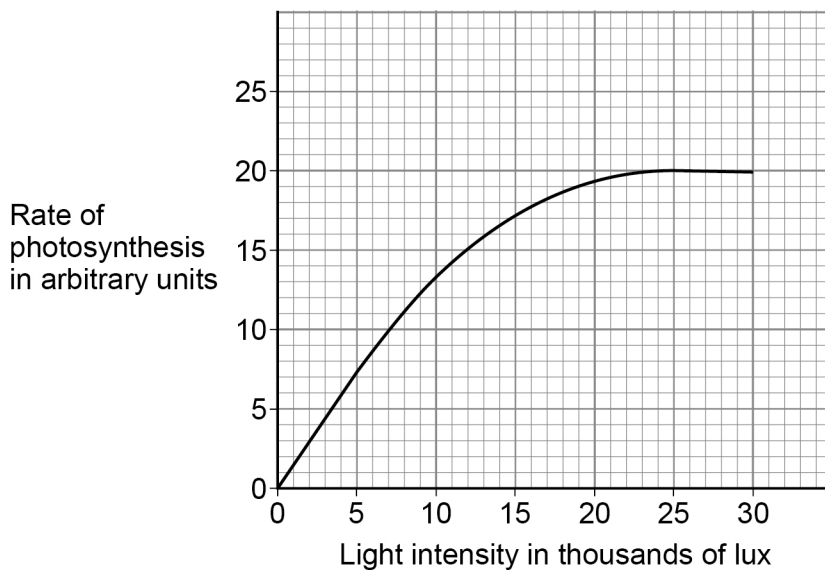
Factor	Why changing it can affect rate
light intensity	supplies energy absorbed by chlorophyll
CO_2 concentration	supplies a reactant
temperature	affects enzyme-controlled reaction rate
chlorophyll amount	affects how much light can be absorbed

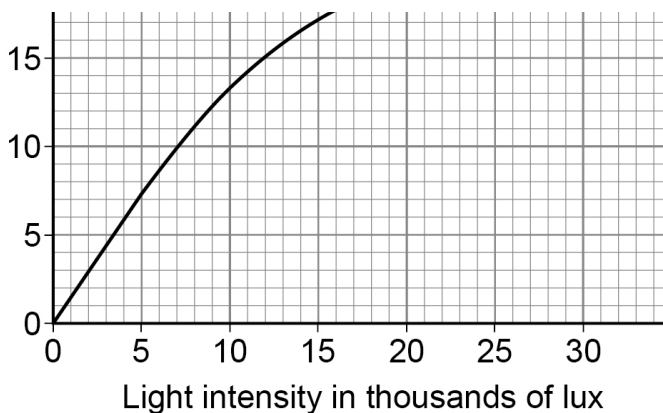


Light/CO₂ curves level off when another factor limits. The temperature curve falls above its optimum as enzymes denature; the optimum is not a universal fixed temperature.

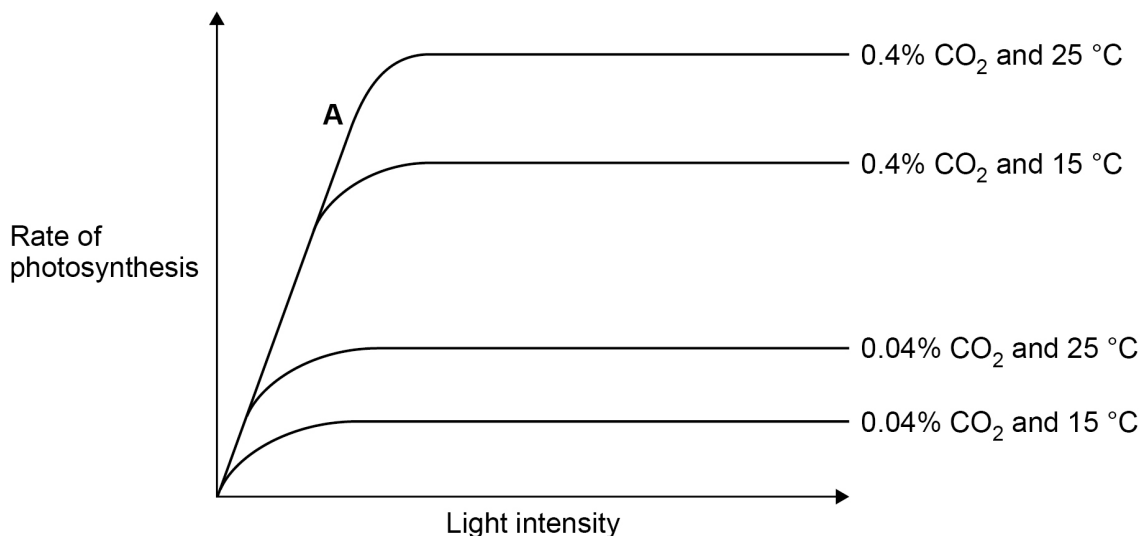
A **limiting factor** prevents the rate increasing under the current conditions; increasing that factor can increase rate. For temperature, this means an increase towards an appropriate optimum, not unlimited heating. (HT) Interacting factors require comparing curves at the same light intensity with just one other condition changed.

Figure 8





2023 Q06.2: the straight section from 0 to 5 000 lux can be represented by $y = mx + c$. The x-axis is in **thousands of lux**: a reading of 5 means 5 000 lux. A changing gradient is not one straight-line relationship; the plateau shows further light does not raise the rate under these conditions.



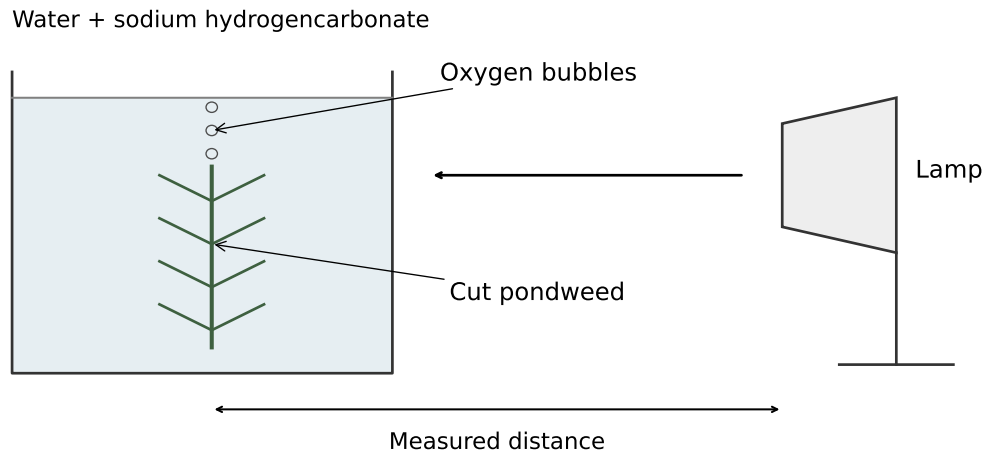
(HT) 2024 Q07.7–.8: at A, more light increases rate. Compare 15→25°C while CO₂ stays 0.4%: higher rate, through faster particle movement/enzyme activity. Compare 0.04→0.4% CO₂ at the same temperature: more reactant increases rate. On each high-light plateau, a different factor limits; light is not the limiting factor there. These comparisons do not justify an unlimited-temperature rule.

(HT) Inverse square law: light intensity is proportional to $1/\text{distance}^2$. For the same source, $I_2/I_1 = (d_1/d_2)^2$. Sheet 4.1 Q3.2: $d_2/d_1 = 45 \text{ cm}/15 \text{ cm} = 3$; $I_2/I_1 = (15 \text{ cm}/45 \text{ cm})^2 = 1/9$. The new intensity is one ninth of the old. A photosynthesis-rate prediction additionally needs light to limit in an approximately proportional region and other conditions to stay suitable; the law itself predicts intensity.

(HT) Greenhouse economics: identify the limiting factor, estimate the

yield/revenue gain, and compare it with the added cost. Lighting supplies energy; added CO₂ supplies reactant; heating towards the optimum can speed enzyme-controlled reactions. Each may fail to pay if another factor limits or the cost exceeds extra crop revenue. Heating alone is not automatically CO₂ addition.

RP6: changing light intensity



Use pondweed in sodium hydrogencarbonate solution (CO₂ supply). Set several measured lamp distances, allow adjustment at each, then count oxygen bubbles in a fixed time. Maintain temperature with a water bath and monitor with a thermometer; keep CO₂ concentration constant; keep pondweed size and timing comparable. Repeat at each distance and calculate a mean. Rate = bubble count/time, with units such as bubbles/s. Alternatively measure collected oxygen volume/time. A gas syringe or **inverted** measuring cylinder must actually collect/measure oxygen; naming apparatus alone is not a method. Unequal bubble size limits volume accuracy, and gas collection measures volume more directly. Repeats reduce random variation; they do not fix unequal bubble volumes.

2025 temperature investigation: the independent variable is temperature; the measured dependent variable is **time for ten bubbles**, not the calculated rate. Five tubes were placed in different-temperature baths and left two minutes before timing. All times below are exact original Table 4 values.

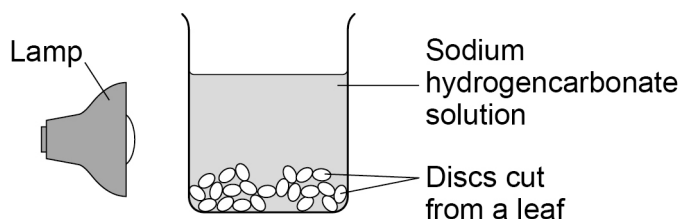
Temperature / °C	Time for 10 bubbles / s
10	84
20	43
30	27
40	25
50	33

Worked rate (2025 Q04.2, four marks): rate = bubble count/time; rate = 10 bubbles/43 s = 0.232558... bubbles/s; rate = **0.233 bubbles/s** (3 significant figures).

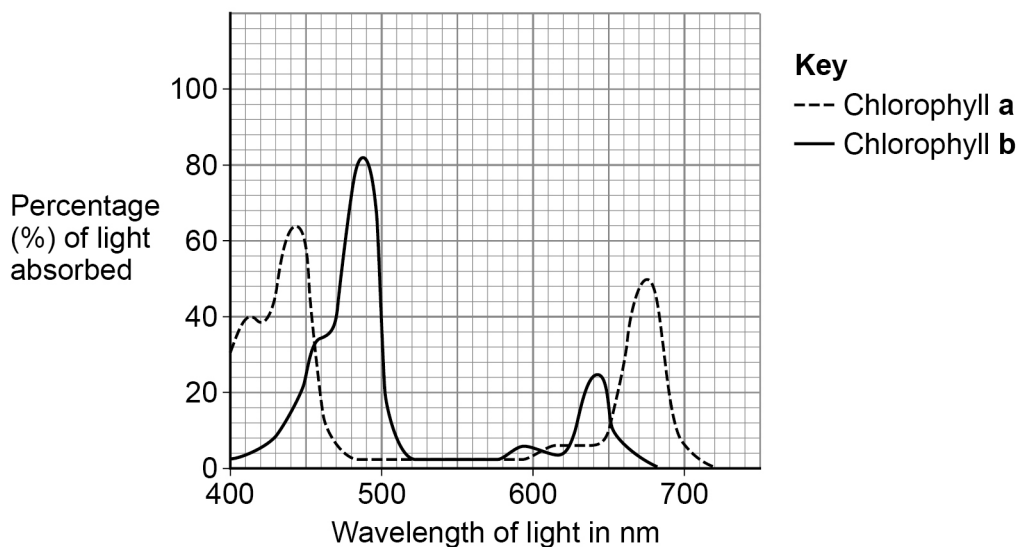
A smaller time for the same output means a higher rate. At 40°C versus 10°C, the rate is higher; particles have more kinetic energy and collide more frequently. The lower measured rate at 50°C does not change that comparison or prove an exact universal optimum.

Leaf-disc application (2023 Q06.3–.7)

Figure 9



Change light colour using coloured LEDs/bulbs or transparent filters. Independent variable: light colour/wavelength. Dependent variable: time for ten discs to reach the surface. Remove initial air so discs sink and rising gas comes from photosynthesis. Sodium hydrogencarbonate supplies CO_2 used in photosynthesis. Oxygen produced becomes trapped in/around the discs, reducing their average density so they rise. Do not claim CO_2 is the gas making them rise.



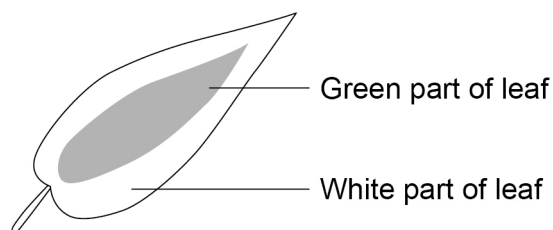
2023 Q06.8–.9: two chlorophyll types allow more wavelengths to be used, not all wavelengths. Original Table 6 ranges: violet 380–435, blue 450–499, green 500–570, yellow 571–590, red 620–720 nm. Table 5 times for ten discs: blue 115 s, green 831 s, red 397 s. Near 490 nm (blue), chlorophyll b absorbs about 80%; green wavelengths are absorbed very little. Thus blue discs rise sooner because photosynthesis/oxygen production is faster; green discs take longer. Use spectral absorption data and colour ranges, not times alone, in the four-mark explanation.

Uses of glucose (4.4.1.3)

Glucose from photosynthesis is used for:

- **respiration**;
- converted to **insoluble starch** for storage (it does not dissolve to form a concentrated cell solution);
- **fat or oil** for storage;
- **cellulose** for cell walls;
- **amino acids** for protein – this also needs **nitrate ions from the soil**.

Figure 6

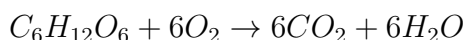


Worked evidence (2024 Q07.2–.3): after the supplied 48-hour light treatment, predict starch in the green region and no starch in the white region. Green tissue has chlorophyll and absorbs light for photosynthesis; glucose made there can form starch. White tissue lacks chlorophyll. A positive iodine test is blue-black; a negative result remains yellow/orange/brown. This is a prediction for the supplied investigation, not a guarantee that every green leaf always contains starch.

Respiration (4.4.2.1)

Respiration is an **exothermic** reaction occurring **continuously in living cells**, transferring energy for movement, keeping warm and reactions that build larger molecules. Plants respire in light and darkness. Breathing moves air; cellular respiration is a chemical process. Energy is transferred or released, not created.

Aerobic word equation: glucose + oxygen → carbon dioxide + water.



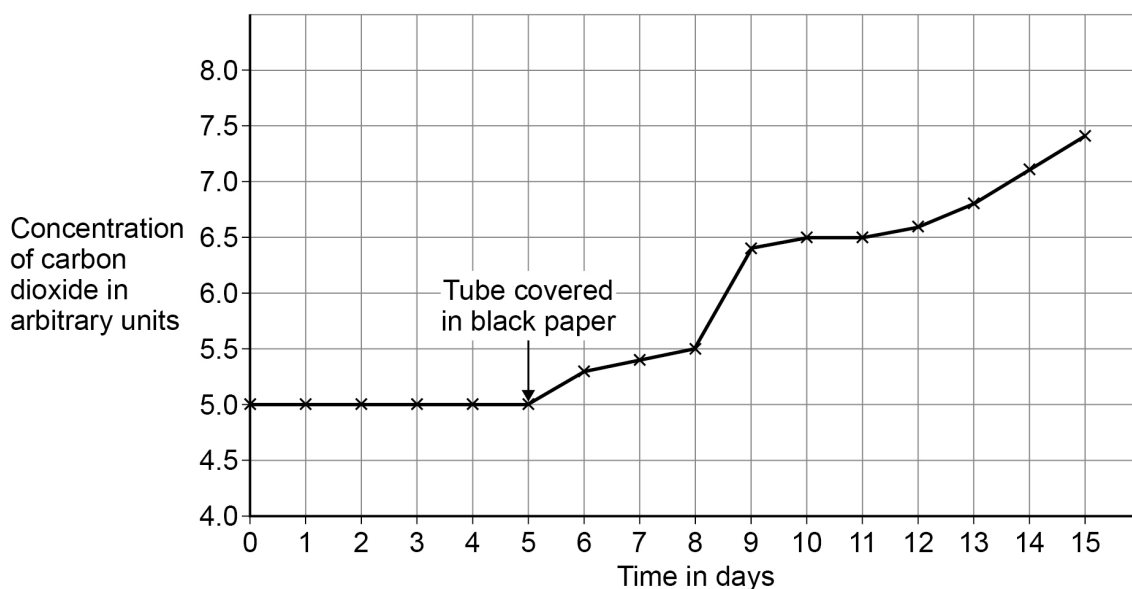
Both sides have 6 carbon, 12 hydrogen and 18 oxygen atoms. In human cells, mitochondria are the main site of aerobic respiration; its stages occur in the cytoplasm and mitochondria. Anaerobic respiration occurs in the cytoplasm.

Pathway	Products from glucose	Energy per glucose
Aerobic, using oxygen	Carbon dioxide + water	Much more transferred
Anaerobic, human muscle	Lactic acid	Much less transferred
Anaerobic, plant / yeast	Ethanol + carbon dioxide	Much less transferred

Anaerobic word equations: **muscle:** glucose $\rightarrow$ lactic acid; **plant/yeast:** glucose $\rightarrow$ ethanol + carbon dioxide. Anaerobic respiration incompletely oxidises glucose, so transfers less energy per glucose molecule; it still transfers energy.

Anaerobic respiration in yeast is **fermentation**. With little oxygen in dough, yeast uses sugar and releases ethanol and carbon dioxide; trapped gas bubbles make the dough rise. Ethanol is also important in alcoholic drinks. Yeast can respire aerobically when oxygen is available; excessive heat does not keep improving fermentation.

Worked evidence: two processes at once (2021 Q04.6–.8). A tube contains pondweed and a snail, with a carbon dioxide probe. It is well lit until day 5, then completely covered with black paper. The snail dies on day 10. The local file is catalogued November 2021; the original paper is printed Jun21.

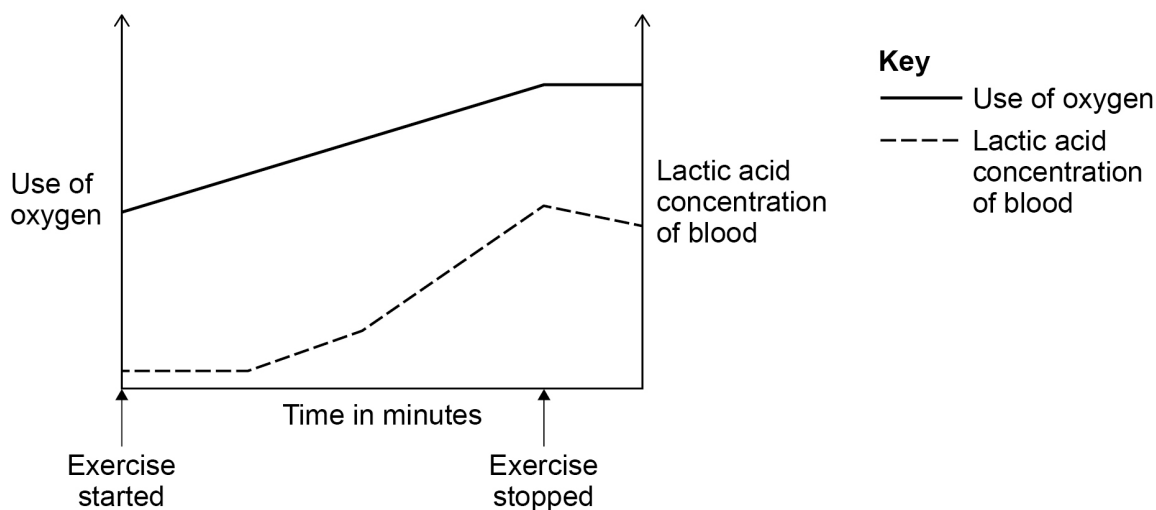


- **Days 0–5:** pondweed takes in carbon dioxide for photosynthesis; both pondweed and snail respire, releasing it. Uptake balances release, so concentration stays constant. A flat line does not mean both processes stopped.
- **Days 5–10:** darkness prevents photosynthesis, while both organisms continue respiring. Carbon dioxide accumulates.
- **After day 10:** decomposers such as bacteria break down the dead snail. These living microorganisms respire and release carbon dioxide; the dead snail is not continuing to respire.

Response to exercise (4.4.2.2)

Heart rate, breathing rate and breath volume **increase** during exercise to supply muscles with more oxygenated blood for aerobic respiration. Breathing rate counts breaths per minute; breath volume is air moved per breath. If oxygen supply cannot meet demand, **anaerobic respiration contributes alongside aerobic respiration**, and **lactic acid** accumulates. In the AQA GCSE model, this causes muscle fatigue and less efficient contractions.

(HT) Blood transports lactic acid to the **liver**, which converts it back into glucose. Separately, **oxygen debt** is the extra oxygen needed after exercise to react with and remove accumulated lactic acid. Do not describe extra oxygen as a reactant in the conversion back to glucose in the liver: the 2025 Q05.7 scheme ignores that claim.



Worked recovery explanation [2]: lactic acid has accumulated / an oxygen debt exists (1); extra oxygen is needed to react with and remove it (1). The solid and dashed lines use different, unnumbered vertical axes: compare changes within each curve, not their absolute heights against each other.

Explaining two effects [4] (2023 Q04.1): pair each effect with a reason. Muscles become fatigued (1) because lactic acid builds up (1). Heavy/deep breathing continues after exercise (1) because extra oxygen is needed to remove accumulated lactic acid / repay oxygen debt (1).

Worked investigation plan (2023 Q04.2 [6]): use the same suitable athletes for at least two exercise types. Before each trial, allow recovery to resting heart rate and measure that baseline. Exercise for the same duration; measure heart rate promptly afterwards with the same method and delay. Keep relevant conditions such as prior activity and caffeine intake similar. Calculate each athlete's increase, then compare mean increases for each exercise type. Randomise exercise order to reduce order effects. A logical method giving a valid comparison earns the higher levels; six disconnected facts do not guarantee six marks.

Teacher data, beats per minute: exercise A changes are 40, 50 and 30; B changes are 60, 70 and 50. $\text{Change} = \text{after-exercise heart rate} - \text{resting heart rate}$. $\text{Mean change} = \text{sum of changes} \div \text{number of athletes}$. Mean change for A = $(40 + 50 + 30) \div 3 = \mathbf{40 \text{ beats per minute}}$. Mean change for B = $(60 + 70 + 50) \div 3 = \mathbf{60 \text{ beats per minute}}$. B gives a mean increase **20 beats per minute** greater in this sample. These are authored examples, not original exam results.

Connect to circulation (2025 Q05.8 [2]): more red blood cells provide more haemoglobin to carry oxygen (1); this supports more aerobic respiration and energy transfer in muscles (1). **Supplied exam application (2023 Q04.3 [2]):** increased muscle mass can allow more/stronger contractions (1), improving speed, strength or stamina (1). The original question states anabolic steroids are banned in competitive sport; the task is to explain its supplied relationship.

Metabolism (4.4.2.3)

Metabolism is the sum of all reactions in a cell or body. Energy transferred by respiration supports continual enzyme-controlled processes that build new molecules. Recognise building and breakdown reactions:

- glucose $\rightarrow$ **starch, glycogen or cellulose**;
- **one glycerol + three fatty acids** $\rightarrow$ a lipid molecule;
- in plants, glucose + **nitrate ions** $\rightarrow$ amino acids $\rightarrow$ **proteins**;
- **respiration**, which breaks down glucose and transfers energy;
- breakdown of **excess proteins** to form **urea** for excretion.

Urea is not a protein building block. Protein synthesis and formation of urea are not a direct reversible pair. Sugars, amino acids, fatty acids and glycerol supply different materials for synthesis and breakdown.

Checklist before you call this topic done

- Write the photosynthesis word and symbol equations; say endothermic + light $\rightarrow$ chloroplasts.
- Explain the four rate factors; read flattening single-factor graphs; (HT) inverse square law and greenhouse economics.
- Describe RP6 with its controls and the rate calculation.
- List five uses of glucose (with nitrate for protein).
- Compare aerobic with both anaerobic equations; name fermentation's two products and uses.
- Exercise: three increases; lactic acid and oxygen debt; (HT) the liver's role.
- Define metabolism with its five strands.