

AQA GCSE Combined Science: Trilogy — Biology

Topic 4

Bioenergetics

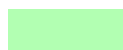
Specification 8464 · AQA

Free edition

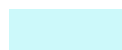
Revision notes for one topic, free to download.

These are the summary notes only. The full edition of this booklet also carries the worked examples, the required practicals and the formula sheets, with every topic in one place.

Colour Codes



Definitions



Diagrams



Notes and warnings



Mnemonics



Analogies



Common confusions



Check yourself



Sub-topic headings

This booklet is a study aid written from the published specification.
It is not affiliated with, endorsed by or approved by AQA.

**Free to download and share for personal study.
Please do not sell or republish it as your own.
For enquiries, please email pcfgyrdi@gmail.com**

Define Photosynthesis

- an endothermic reaction in which energy is transferred from the environment to the chloroplasts by light, making glucose from carbon dioxide and water.

Define Chlorophyll

- the green pigment in chloroplasts that absorbs light for photosynthesis.

Define Rate

- the amount of change divided by the time taken for that change.

Define Cellular respiration

- an exothermic reaction, occurring continuously in all living cells, that transfers energy from glucose.

Define Anaerobic respiration

- respiration without oxygen; the oxidation of glucose is incomplete so much less energy is transferred.

Define Lactic acid

- the product of anaerobic respiration in muscles.

Define Muscle fatigue

- muscles becoming tired during long periods of vigorous activity so they stop contracting efficiently.

Define Metabolism

- the sum of all the reactions in a cell or the body.

Define Endothermic reaction

- a reaction that takes in energy from the environment.

Define Exothermic reaction

- a reaction that transfers energy to the environment.

Define Limiting factor

- the factor in shortest supply, which is holding back the rate of photosynthesis.

Define Inverse square law

- light intensity is inversely proportional to the square of the distance from the source.

Define Aerobic respiration

- respiration using oxygen, which completely oxidises glucose to carbon dioxide and water.

Define Fermentation

- anaerobic respiration in yeast cells, producing ethanol and carbon dioxide.

HIGHER TIER

Define Oxygen debt

- **HT ONLY** the amount of extra oxygen the body needs after exercise to react with the accumulated lactic acid and remove it from the cells.

Define Urea

- the excretory product formed from the breakdown of excess protein.

4.1 Photosynthesis

SAY IT

Six and six makes one and six

$6\text{CO}_2 + 6\text{H}_2\text{O} \rightarrow \text{C}_6\text{H}_{12}\text{O}_6 + 6\text{O}_2$. Carbon dioxide + water → glucose + oxygen, driven by light absorbed by chlorophyll. It is **endothermic** — energy is taken in.

DON'T MIX UP

endothermic vs exothermic

Photosynthesis is endothermic — it takes energy in from light. **Respiration is exothermic** — it transfers energy out. They are opposites in every respect, which is why examiners pair them.

4.1.1 Photosynthetic reaction

Photosynthesis happens in the **chloroplasts** of plant and algal cells, using **chlorophyll** to absorb light.

4.1.2 Rate of photosynthesis

Four factors affect the rate of photosynthesis:

PICTURE IT

Photosynthesis is a kitchen running on sunlight. Carbon dioxide and water are the raw ingredients, chlorophyll is the solar panel on the roof, glucose is the meal and oxygen the steam out of the window. *Where it breaks down:* a kitchen stops when the chef leaves. A leaf photosynthesises whenever there is light, and respire all the time underneath it.

CHECK YOURSELF

Cover the grey line before you answer.

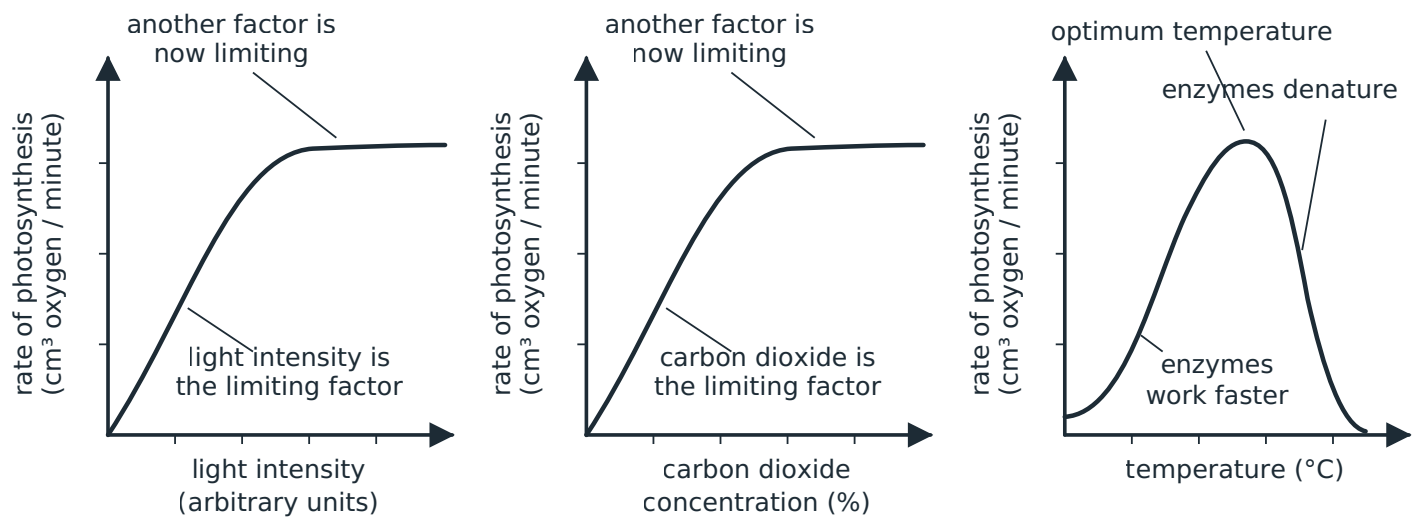
1. Write the word equation for photosynthesis.
carbon dioxide + water → glucose + oxygen (in the presence of light).
2. Where in the cell does it happen, and what absorbs the light?
In the chloroplasts; chlorophyll absorbs the light.
3. Is photosynthesis endothermic or exothermic?
Endothermic — energy is transferred from the environment into the reaction.

Factor	Effect on rate	Why
Light intensity	Rate rises as intensity rises, then levels off	Light provides the energy; above a point another factor limits the rate
Carbon dioxide concentration	Rate rises as concentration rises, then levels off	CO_2 is a raw material
Temperature	Rate rises to an optimum, then falls sharply	Enzymes work faster when warmer, but denature at high temperatures
Amount of chlorophyll	More chlorophyll, faster rate	Less chlorophyll (disease such as TMV or rose black spot) means less light absorbed

HIGHER TIER

- **HT ONLY** These factors interact and any one of them may be the factor that limits photosynthesis. On a graph, the factor that is limiting is the one that, when increased, makes the curve rise again.
- **HT ONLY** Where a graph **levels off (plateaus)**, the factor plotted on the x-axis is **no longer limiting** — something else is. **HT ONLY** **Limiting factors matter economically in greenhouses.** A grower can add **heat, light or carbon dioxide** to raise the rate, but each costs money: the extra yield must be worth more than the extra cost to stay profitable.

Limiting factors and the rate of photosynthesis



ANALOGY

Limiting factors are a sandwich production line. If you have 100 slices of bread but only 4 slices of cheese, you can only make 2 sandwiches — the cheese is limiting. Buying more bread changes nothing. Only when you add cheese does output rise, until something else (the butter, the bench space) becomes the new limit.

HIGHER TIER

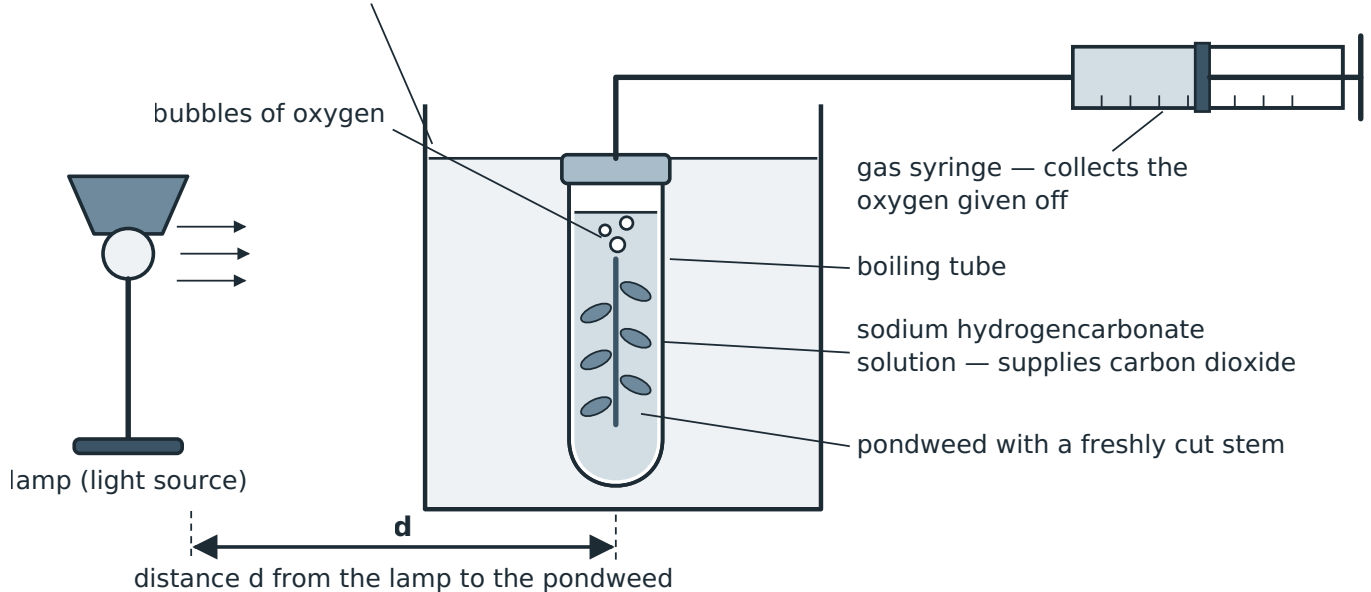
HT ONLY The inverse square law

- **HT ONLY** Light intensity is inversely proportional to the square of the distance from the light source.

Double the distance and the light intensity falls to a **quarter**; treble it and the intensity falls to a **ninth**.

Apparatus for the pondweed photosynthesis practical

large beaker of water — a heat shield: it absorbs heat from the lamp so the temperature stays constant



independent variable — distance d of the lamp from the pondweed (this changes the light intensity)

dependent variable — volume of oxygen collected in one minute (or bubbles counted per minute)

control variables — temperature (kept constant by the water bath), carbon dioxide concentration, the same piece of pondweed, the same time for each reading

SAY IT

Light, CO₂, Temperature, Chlorophyll

The four factors. The first three can each be the limiting factor; the fourth is about how much chlorophyll the plant has — reduced by disease or lack of magnesium.

CHECK YOURSELF

Cover the grey line before you answer.

1. Name the four factors affecting the rate of photosynthesis.

Light intensity, carbon dioxide concentration, temperature, and the amount of chlorophyll.

2. A graph of rate against light intensity levels off. What does that tell you?

Light is no longer the limiting factor — something else, such as temperature or carbon dioxide, now limits the rate.

3. Why might a grower add carbon dioxide to a greenhouse?

To raise the rate of photosynthesis and so the yield — but only if the extra yield is worth more than the cost.

DON'T MIX UP

reading a limiting-factor graph

Where a graph **plateaus**, the factor on the x-axis is **no longer limiting** — something else is holding the rate back. Where the line is still **rising**, the factor on the x-axis is the limiting one. Read the shape before you write.

4.1.3 Uses of glucose from photosynthesis

The glucose produced in photosynthesis may be:

- **used for respiration**, to transfer energy
- **converted into insoluble starch for storage** — insoluble so it does not affect water movement by osmosis and cannot dissolve away
- used to produce fat or oil for storage (especially in seeds)
- **used to produce cellulose, which strengthens the cell wall**
- **used to produce amino acids for protein synthesis.**

To produce proteins, plants also use nitrate ions that are absorbed from the soil.

SAY IT

Respire, Store, Build, Strengthen, Protein

The five fates of glucose: **respired** to transfer energy; converted to insoluble **starch** for storage; made into fat or oil to **store** in seeds; made into **cellulose** to strengthen cell walls; combined with nitrate ions to make **amino acids** for proteins.

DON'T MIX UP

why glucose is stored as starch

Starch is **insoluble**. That matters twice over: it cannot dissolve away, and it does not affect the water potential of the cell, so it does not drag water in by osmosis. Glucose would do both.

CHECK YOURSELF

Cover the grey line before you answer.

1. Give five uses of the glucose made in photosynthesis.
Respiration; converted to starch for storage; used to make fat or oil; used to make cellulose; used with nitrate ions to make amino acids.
2. Why is glucose stored as starch?
Starch is insoluble, so it cannot dissolve away and does not draw water in by osmosis.
3. What else does a plant need to make proteins?
Nitrate ions, absorbed from the soil.

4.2 Respiration

4.2.1 Aerobic and anaerobic respiration

- Cellular respiration is an exothermic reaction which is continuously occurring in living cells. The energy transferred supplies all the energy needed for living processes.
- Respiration can take place **aerobically (using oxygen)** or **anaerobically (without oxygen)** to transfer energy.
- Organisms need energy for:
 - chemical reactions to build larger molecules
 - movement
 - keeping warm.

WATCH OUT

Respiration does **not** "make" or "produce" energy, and it is **not** the same as breathing. Respiration is a chemical reaction inside **every** cell that **transfers** energy from glucose. Breathing (ventilation) just gets oxygen to the cells.

Comparing aerobic and anaerobic respiration

	Aerobic respiration	Anaerobic respiration
Oxygen needed?	Yes	No
Products	Carbon dioxide + water	In muscle: lactic acid. In plant and yeast cells: ethanol + carbon dioxide
Relative energy transferred	Much more (glucose is completely oxidised)	Much less (oxidation of glucose is incomplete)
Where it happens	In the mitochondria of all animal and plant cells, all the time	In the cytoplasm of muscle cells during vigorous exercise; in plant and yeast cells without oxygen

WATCH OUT

Anaerobic respiration in **muscle** does *not* make carbon dioxide — only the plant/yeast version does. Losing that mark is very common.

SAY IT

Glucose + oxygen → carbon dioxide + water

Aerobic respiration, in the mitochondria. Without oxygen, in animals: glucose → **lactic acid**. In yeast and plants: glucose → **ethanol + carbon dioxide** — which is fermentation.

PICTURE IT

Aerobic respiration is burning a log in a well-aired fire — it goes right down to ash and gets all the energy out. Anaerobic respiration is a smouldering, smoky fire: the fuel is only partly broken down, so far less energy is released and something half-burnt is left behind. *Where it breaks down:* a fire releases its energy all at once as heat. Respiration releases it in controlled steps, under enzyme control.

HIGHER TIER

4.2.2 Response to exercise

- **During exercise the human body reacts to the increased demand for energy.**
- The heart rate, breathing rate and breath volume increase during exercise to supply the muscles with more oxygenated blood. This also removes carbon dioxide faster.
- If insufficient oxygen is supplied, anaerobic respiration takes place in muscles. The incomplete oxidation of glucose causes a build up of lactic acid and creates an oxygen debt.
- **During long periods of vigorous activity muscles become fatigued and stop contracting efficiently.**
- **HT ONLY** Blood flowing through the muscles transports the lactic acid to the liver, where it is converted back into glucose.
- **HT ONLY** Oxygen debt is the amount of extra oxygen the body needs after exercise to react with the accumulated lactic acid and remove it from the cells. This is why you keep breathing hard and your heart keeps beating fast for several minutes after you stop.

DON'T MIX UP

oxygen debt vs lactic acid

Lactic acid is the substance that builds up. **Oxygen debt** is the extra oxygen needed afterwards to react with it and remove it. One is a chemical, the other an amount of oxygen owed — do not use the words interchangeably.

DON'T MIX UP

respiration vs breathing

Respiration is a chemical reaction in every cell, happening all the time. **Breathing** is ventilation — moving air in and out of the lungs. Writing "respiration" when you mean breathing is one of the most costly slips in the paper.

CHECK YOURSELF

Cover the grey line before you answer.

1. Write the word equation for aerobic respiration.
glucose + oxygen → carbon dioxide + water.
2. What are the products of anaerobic respiration in muscle, and in yeast?
Lactic acid in muscle; ethanol and carbon dioxide in yeast.
3. Give three things organisms need energy for.
Chemical reactions to build larger molecules; movement; keeping warm.

ANALOGY

Oxygen debt is a credit card. When your muscles cannot get oxygen fast enough, they borrow energy anaerobically and "put the oxygen on the card". You still get your energy now — but the debt is real, and once you stop you must keep breathing hard to pay back every bit of the oxygen you borrowed, plus interest in the form of lactic acid that has to be dealt with.

SAY IT

Heart, Breath, Volume

The three things that rise during exercise: heart **rate**, **breathing** rate and breath **volume** — all to deliver more oxygenated blood and clear carbon dioxide faster.

CHECK YOURSELF

Cover the grey line before you answer.

1. Why do heart rate and breathing rate rise during exercise?
To supply the muscles with more oxygenated blood and to remove carbon dioxide faster.
2. What causes muscle fatigue?
Long periods of vigorous activity, during which muscles become fatigued and stop contracting efficiently.
3. Where is lactic acid taken, and what happens to it?
The blood transports it to the liver, where it is converted back into glucose.

4.2.3 Metabolism

Metabolism is the sum of all the reactions in a cell or the body. The energy transferred by respiration in cells is used by the organism for the continual enzyme controlled processes of metabolism that synthesise new molecules.

Metabolism includes:

- conversion of glucose to starch, glycogen and cellulose — starch is the plant storage carbohydrate, glycogen the animal (and fungal) one, and cellulose strengthens plant cell walls
- the formation of lipid molecules from a molecule of glycerol and three molecules of fatty acids
- the use of glucose and nitrate ions to form amino acids, which in turn are used to synthesise proteins
- respiration
- breakdown of excess proteins to form urea for excretion — excess amino acids cannot be stored, so the liver breaks them down and the urea formed is removed by the kidneys.

DON'T MIX UP

glycogen **vs** glucagon

One letter apart and constantly swapped. **Glycogen** is the **storage molecule** in liver and muscle. **Glucagon** is the **hormone** that converts it back to glucose. **Glycogen** is a **general store**; **glucagon** makes the store **gone**.

WATCH OUT

Glycogen and glucagon are different things. **Glycogen** is the storage carbohydrate; **glucagon** is a hormone (Topic 5). Spell them carefully.

ANALOGY

Metabolism is a building site. Respiration is the generator that powers everything; enzymes are the workers; glucose, glycerol, fatty acids, amino acids and nitrate ions are the bricks. Building (synthesis) and demolition (breakdown, such as excess protein to urea) go on at the same time, all day, every day.

SAY IT

Starch, Glycogen, Cellulose

Three polymers from glucose: **starch** stores it in plants, **glycogen** stores it in animals and fungi, **cellulose** strengthens plant cell walls.

CHECK YOURSELF

Cover the grey line before you answer.

1. Define metabolism.

The sum of all the reactions in a cell or the body.

2. What is a lipid molecule made from?

One molecule of glycerol and three molecules of fatty acids.

3. What happens to excess amino acids?

They cannot be stored, so the liver breaks them down to form urea, which the kidneys remove.