

Respiration

Read online at pastopic.com/cambridge/biology-0610/notes/respiration

Last checked 30 September 2026

Read first: [Enzymes](#)

© 2026 Pastopic. Free for personal study. Please share the link, not the file.

What you need to know

Respiration comes up on nearly every paper. Papers 1 and 2 ask one-mark multiple choice (which substances are used and made, which processes need energy, how an oxygen debt is removed); Papers 3 and 4 put it into longer questions about exercise, yeast or an experiment. Outcomes marked **Extended only** are tested on Papers 2 and 4 only. By the end of this topic you should be able to:

Core

1. **State what living organisms use the energy from respiration for:** muscle contraction, protein synthesis, cell division, active transport, growth, the passage of nerve impulses and keeping the body temperature constant.
2. **Investigate and describe how temperature affects respiration in yeast.**
3. **Describe aerobic respiration:** the chemical reactions in cells that use oxygen to break down nutrient molecules and release energy.
4. **State the word equation for aerobic respiration:** glucose + oxygen → carbon dioxide + water.
5. **Describe anaerobic respiration:** the chemical reactions in cells that break down nutrient molecules and release energy **without** using oxygen.
6. **State that anaerobic respiration releases much less energy** from each glucose molecule than aerobic respiration.
7. **State the word equation for anaerobic respiration in yeast:** glucose → alcohol + carbon dioxide.
8. **State the word equation for anaerobic respiration in muscles** during vigorous exercise: glucose → lactic acid.

Extended only

9. **State the balanced chemical equation for aerobic respiration:** $C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O$.
10. **State the balanced chemical equation for anaerobic respiration in yeast:**
 $C_6H_{12}O_6 \rightarrow 2C_2H_5OH + 2CO_2$.
11. **State that lactic acid builds up in the muscles and blood** during vigorous exercise, causing an **oxygen debt**.

12. **Outline how the oxygen debt is removed** after exercise: the heart rate stays high to carry lactic acid in the blood from the muscles to the liver; breathing stays deeper and faster to supply oxygen for the aerobic respiration of lactic acid; and the lactic acid is respired aerobically in the liver.

The **mitochondria** as the site of aerobic respiration belong to cell structure (Organisation of the organism), and how temperature changes enzyme activity is in Enzymes; questions on respiration use both, so this note does too. How breathing speeds up during exercise is in Gas exchange in humans; the uses of yeast in biotechnology are in Biotechnology.

Understand it

What respiration is

Every living cell needs a steady supply of energy. It gets that energy from **respiration**: a series of **chemical reactions**, each controlled by an **enzyme**, that **break down nutrient molecules** (usually **glucose**) and **release** the energy stored in them. Respiration happens in **every** living cell, in plants, animals, fungi and bacteria, day and night.

Two words cause trouble:

- **Respiration is not breathing.** Breathing (ventilation) moves air in and out of the lungs. Respiration is chemistry inside cells.
- **Energy is released, not made.** Energy cannot be created. Say respiration **releases** energy.

What the energy is used for

The syllabus lists seven uses. Learn all seven:

Use	Example
Muscle contraction	moving, the heart beating, breathing
Protein synthesis	joining amino acids into proteins such as enzymes and antibodies
Cell division	making new cells for growth and repair
Active transport	moving ions into root hair cells against a concentration gradient
Growth	making new cells and tissues
The passage of nerve impulses	messages along neurones
Keeping the body temperature constant	birds and mammals use the heat released to stay at about 37 °C

Diffusion, osmosis, transpiration and **evaporation** do **not** need energy from respiration. They are passive: particles move down a gradient on their own. Multiple-choice questions test this often.

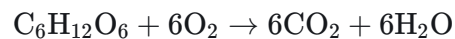
Aerobic respiration

Aerobic respiration uses **oxygen**. It breaks glucose down completely, so it releases a **lot** of energy from each glucose molecule. It happens in the **mitochondria**.



Glucose and oxygen are **used** (the reactants, on the left); carbon dioxide and water are **produced** (the products, on the right). This is photosynthesis back to front, so check which way round the arrow goes.

Extended only: the balanced chemical equation is

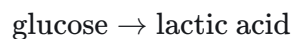


$\text{C}_6\text{H}_{12}\text{O}_6$ is glucose. Count the atoms to check it balances: on the left, 6 carbon, 12 hydrogen and $6 + 12 = 18$ oxygen; on the right, 6 carbon, $6 \times 2 = 12$ hydrogen and $12 + 6 = 18$ oxygen. So **one** glucose molecule needs **six** oxygen molecules and makes **six** carbon dioxide and **six** water molecules. Two glucose molecules make 12 of each product; three make 18.

Anaerobic respiration

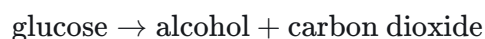
Anaerobic respiration releases energy **without oxygen**. Glucose is only partly broken down, so much of its energy stays locked in the product, and anaerobic respiration releases **much less energy per glucose molecule** than aerobic respiration. It does not happen in the mitochondria. Its products are different in different organisms.

In muscles during **vigorous exercise**, when the blood cannot bring oxygen fast enough:



That is the whole equation: **lactic acid is the only product**. No carbon dioxide, no water, no oxygen used.

In yeast (a single-celled fungus) when there is no oxygen:



The alcohol is **ethanol**; either name earns the mark. Yeast never makes lactic acid, and muscles never make alcohol.

Extended only: the balanced chemical equation for yeast is



$\text{C}_2\text{H}_5\text{OH}$ is ethanol. Atoms: left 6 C, 12 H, 6 O; right $4 + 2 = 6$ C, $2 \times 6 = 12$ H, $2 + 4 = 6$ O. So one glucose gives **two** carbon dioxide molecules anaerobically, but **six** aerobically: aerobic respiration in yeast gives $6 - 2 = 4$ more carbon dioxide molecules per glucose.

	Aerobic	Anaerobic in muscles	Anaerobic in yeast
Oxygen used?	yes	no	no
Products	carbon dioxide + water	lactic acid	alcohol (ethanol) + carbon dioxide

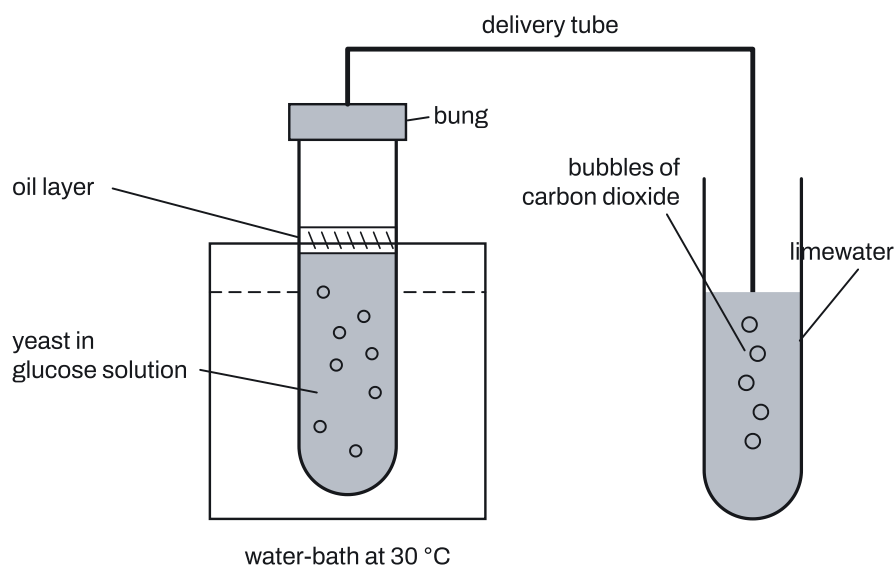
	Aerobic	Anaerobic in muscles	Anaerobic in yeast
Energy per glucose	a lot	much less	much less
Where in the cell	mitochondria	not the mitochondria	not the mitochondria

Things both kinds have in common: they are chemical reactions in cells, they are controlled by enzymes, they break down glucose (a nutrient molecule) and they release energy.

Yeast at work

We use yeast's anaerobic respiration:

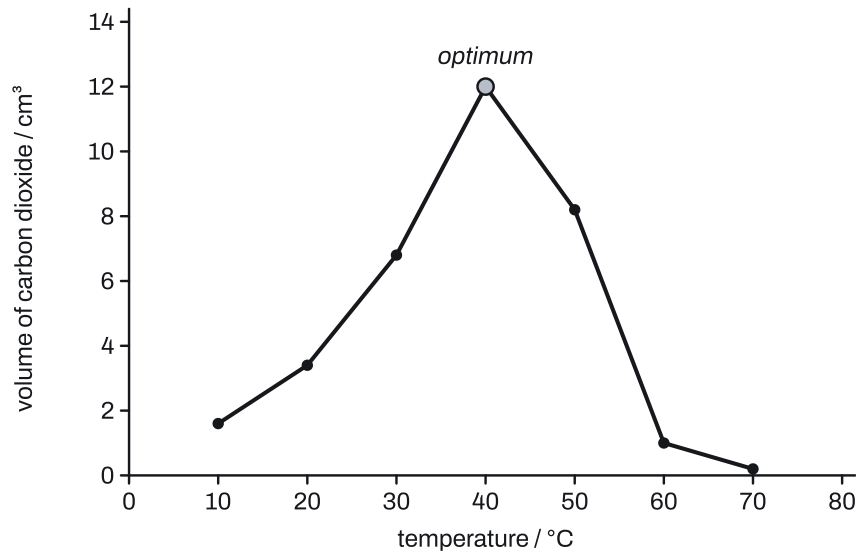
- **Bread-making:** yeast in the dough respires and makes **carbon dioxide**. The gas bubbles are trapped in the dough and make it **rise**. (The little alcohol made evaporates when the bread is baked.)
- **Biofuel:** yeast turns sugar from crops into **ethanol**, which is burned as a fuel.
- **Brewing** beer and wine: the ethanol is what is wanted.



In the laboratory, you can show yeast respiring anaerobically as above. The **oil layer** stops oxygen from the air dissolving in the solution, so the yeast has to respire anaerobically. The gas bubbles through **limewater**, which turns from clear to **cloudy**: the gas is **carbon dioxide**. A balloon over the top of the tube, instead of a delivery tube, slowly **inflates** for the same reason. With no glucose, or with boiled (dead) yeast, no gas is made.

How temperature affects respiration in yeast

Respiration is a series of enzyme-controlled reactions, so temperature affects it just as it affects an enzyme. To investigate it, put the same volume of yeast and glucose solution in water-baths at different temperatures and measure the carbon dioxide made in a fixed time: count bubbles, read a gas syringe, or time how long limewater takes to go cloudy. Keep the same mass of yeast, glucose concentration and volume, and let each tube reach the water-bath temperature first.

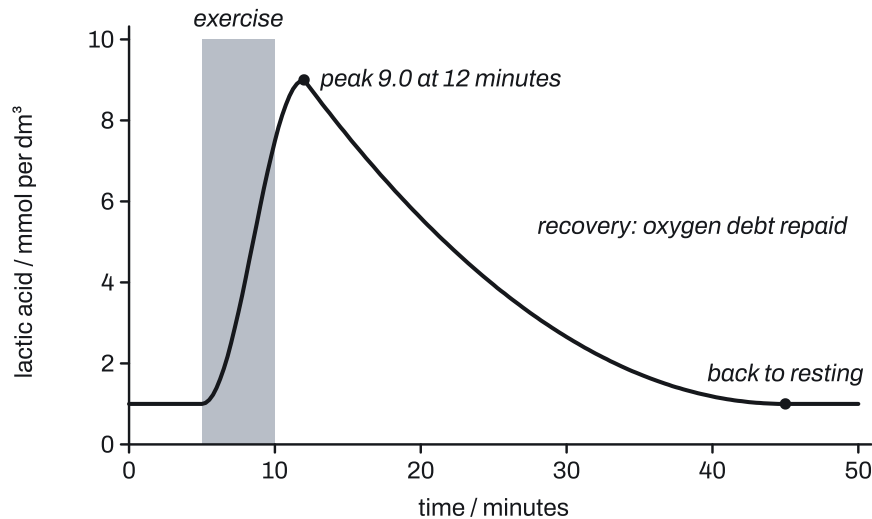


- **Up to the optimum** (here about 40 °C) the rate **increases**: molecules have more **kinetic energy**, so the enzymes and their substrate collide more often and more reactions happen each second. Between 10 °C and 30 °C the volume roughly doubles for every 10 °C.
- **Above the optimum** the rate **falls** quickly: the enzymes are **denatured**, their **active site changes shape** and no longer fits the substrate.
- **At 70 °C and above** almost no gas is made: the enzymes are denatured and the yeast is dead.

Lactic acid and the oxygen debt

During **vigorous exercise**, muscles need energy faster than aerobic respiration alone can supply it, because the heart and lungs cannot deliver oxygen fast enough. So the muscles also respire **anaerobically**, which makes **lactic acid**. Muscle cells can keep contracting, but the lactic acid builds up and can cause pain and fatigue.

Extended only: lactic acid builds up in the **muscles** and diffuses into the **blood**. Getting rid of it needs extra oxygen after the exercise is over. This extra oxygen is the **oxygen debt**: the amount of oxygen needed to remove the lactic acid made by anaerobic respiration.

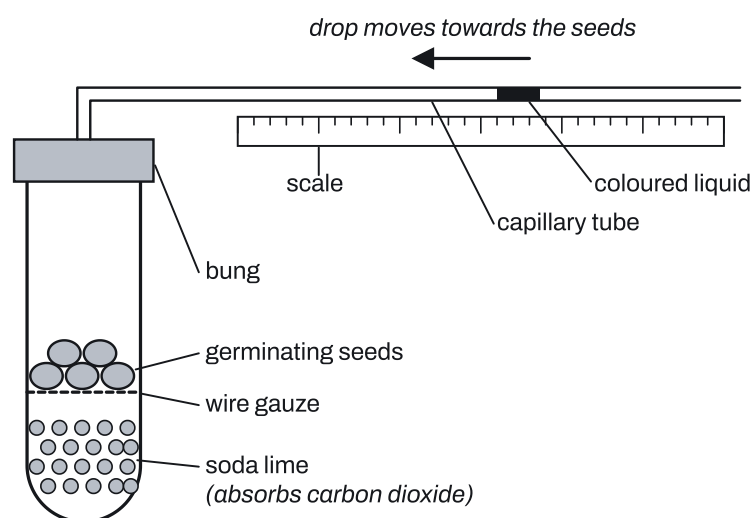


Extended only: the oxygen debt is removed in three linked steps, which is why the heart rate and breathing rate **stay high** after exercise instead of dropping straight back to resting:

1. The **heart rate stays high**, so the blood carries **lactic acid** from the **muscles** to the **liver** quickly.
2. **Breathing stays deeper and faster**, to take in the extra **oxygen**.
3. In the **liver**, the lactic acid is broken down by **aerobic respiration** (it uses oxygen).

When the lactic acid is gone, the debt is repaid and the heart rate and breathing rate return to their resting values. On the graph, lactic acid peaks just after the exercise ends (it keeps diffusing out of the muscles), then falls over about half an hour.

Measuring respiration: respirometers



A **respirometer** measures how fast small organisms (germinating seeds, woodlice, maggots) respire aerobically:

1. The organisms take in **oxygen** from the air in the tube.
2. The **carbon dioxide** they give out is **absorbed** by **soda lime** (or potassium hydroxide solution), so it cannot replace the oxygen.
3. The volume of gas in the tube **decreases**, so the drop of coloured liquid is pulled **towards the organisms**.
4. The **faster** they respire, the **further** the drop moves in a fixed time.

Keep the apparatus in a **water-bath** so the temperature stays constant. A **control** tube has the same volume of glass beads, or boiled (dead) seeds, instead of living organisms: its drop should not move.

Key facts and formulas

There is no formula list in the IGCSE Biology exam. Everything below must be learnt.

Formula	Status
Uses of energy: muscle contraction, protein synthesis, cell division, active transport, growth, passage of nerve impulses, constant body temperature	Learn it
Aerobic: glucose + oxygen → carbon dioxide + water	Learn it
Anaerobic in muscles: glucose → lactic acid	Learn it
Anaerobic in yeast: glucose → alcohol + carbon dioxide	Learn it
Anaerobic respiration releases much less energy per glucose molecule than aerobic	Learn it
Aerobic respiration takes place in the mitochondria	Learn it
Extended: $C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O$	Learn it
Extended: $C_6H_{12}O_6 \rightarrow 2C_2H_5OH + 2CO_2$	Learn it
Extended: oxygen debt removal: high heart rate carries lactic acid to the liver; deep, fast breathing supplies oxygen; lactic acid respired aerobically in the liver	Learn it
Carbon dioxide turns limewater from clear to cloudy	Learn it
Rate = $\frac{\text{amount}}{\text{time}}$ (for example mm per minute); rate = $\frac{1}{\text{time}}$ when the same amount is timed	Learn it
Percentage change = $\frac{\text{new} - \text{original}}{\text{original}} \times 100$	Learn it

How to do it

We tagged 136 questions for this topic (2021–2025, Papers 1–4; 121 different, since some multiple-choice questions appear on more than one paper). 21 of them mix types, so the counts add up to 174.

Question type	Questions
Identify reactants and products; state the word equations	48
Describe and compare aerobic and anaerobic respiration	24
Balanced chemical equations and formulae (Extended)	23
Explain lactic acid, the oxygen debt and its removal	22
State uses of energy from respiration	22
Interpret a respiration investigation	17
Uses of anaerobic respiration in yeast	7
Name the site of aerobic respiration	6
Explain the effect of temperature on respiration in yeast	5

1. Identify reactants and products; state the word equations (48 questions)

1. **Decide which kind of respiration** the question means: aerobic, anaerobic in **muscles**, or anaerobic in **yeast**. Look for clues: "oxygen", "vigorous exercise", "yeast", "bread", "no air".
2. **Write the equation** for that kind, reactants on the left of the arrow and products on the right.
3. For a **table** of "used" and "produced", or "yes" and "no", fill in each substance from the equation.

Variations you will meet:

- **Multiple choice with four equations:** reject any with glucose made from carbon dioxide and water (that is photosynthesis), any with **glycogen** instead of glucose, any muscle equation with carbon dioxide, and any yeast equation with lactic acid.
- **Written equations** are worth 2 marks: one for the left side, one for the right. Products (or reactants) can be in either order. Write **words only**; mixing words and symbols, such as "glucose + O₂", can lose the mark.
- **"The other product":** if the question gives carbon dioxide from aerobic respiration, the answer is **water**.
- **A cell diagram with arrows in and out** (oxygen in, carbon dioxide out): that is aerobic, so the other substance going in is **glucose** and the other coming out is **water**.
- **"What gas is needed for aerobic respiration?"** Oxygen (carbon dioxide and water are products; glucose is not a gas).

2. Describe and compare aerobic and anaerobic respiration (24 questions)

1. **Definitions** have three parts: **chemical reactions in cells** that **break down nutrient molecules** to **release energy**, then **using oxygen** (aerobic) or **without using oxygen** (anaerobic).

2. **Comparisons** use the table in "Anaerobic respiration": oxygen, products, energy per glucose, and where in the cell. Write both sides ("anaerobic releases **less** energy **than** aerobic").

Variations you will meet:

- **Sentence matching or ticks:** correct statements about either kind: "is a chemical reaction", "breaks down nutrient molecules", "involves enzymes", "releases energy", "happens in all living cells". Wrong ones: "requires oxygen" (for anaerobic), "produces lactic acid" (for yeast), "takes place in ribosomes", "absorbs energy", "only in animals".
- **Cloze passages:** the missing words are usually **breaks down**, **oxygen**, **less**, **molecule** and **lactic acid**.
- **Energy values from a table:** subtract to find how much more aerobic releases, or divide to say how many times as much.
- **Extended written comparison** (3 marks): anaerobic uses no oxygen; releases less energy per glucose; makes lactic acid instead of carbon dioxide and water; doesn't happen in the mitochondria; both use glucose.

3. Balanced chemical equations and formulae (23 questions, Extended)

1. **Learn both equations exactly**, with the numbers: $C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O$ and $C_6H_{12}O_6 \rightarrow 2C_2H_5OH + 2CO_2$.
2. Written equations are worth 2 marks: the first for the **correct formulae**, the second for the **balancing**.
3. Check by counting atoms of C, H and O on each side.

Variations you will meet:

- **Pick the equation:** the yeast equation has **no oxygen** on the left and C_2H_5OH on the right; the aerobic one has $6O_2$ on the left.
- **Letters for numbers**, such as $C_6H_xO_y + 6O_2 \rightarrow 6CO_z + 6H_2O$: fill in from the equation you learnt ($x = 12, y = 6, z = 2$).
- **Formulae:** glucose is $C_6H_{12}O_6$; ethanol is C_2H_5OH .
- **Several glucose molecules:** multiply every number. n glucose molecules respired aerobically use $6n$ oxygen and make $6n$ carbon dioxide and $6n$ water; anaerobically in yeast they make $2n$ ethanol and $2n$ carbon dioxide.
- **"How many more carbon dioxide molecules** does aerobic respiration in yeast make per glucose?" $6 - 2 = 4$.

4. Explain lactic acid, the oxygen debt and its removal (22 questions)

1. **Cause:** vigorous exercise → **not enough oxygen** reaches the muscles → muscles respire **anaerobically** → **lactic acid** builds up in the **muscles and blood** → an **oxygen debt**.
2. **Removal (Extended):** **heart rate stays high** to carry lactic acid in the blood to the **liver**; **breathing stays deep and fast** to supply oxygen; lactic acid is broken down by **aerobic respiration** in the **liver**.

Variations you will meet:

- **Cloze on an exercise graph** (heart rate, breathing rate, muscle pH or lactic acid): read values from the graph, such as the time to return to the resting value after exercise (subtract the time exercise stopped) or how much a value changes (subtract). Missing words: oxygen, debt, muscles, blood, liver, aerobic, heart.
- **Muscle pH falls** during exercise because lactic acid is an **acid**; it rises again as the lactic acid is removed.
- **Putting the steps in order**: anaerobic respiration in muscles → glucose to lactic acid → lactic acid builds up (oxygen debt) → fast, deep breathing continues after exercise → oxygen used to respire lactic acid aerobically.
- **Statement questions**: "lactic acid is broken down by **anaerobic** respiration" is **false**; so are "in the kidneys" and "in the muscles". "The blood carries lactic acid to the liver" is **true**.
- **Explaining a whole exercise graph** (up to 6 marks): during exercise, more muscle contraction needs more energy, so more oxygen and glucose must be delivered and more carbon dioxide removed; not enough oxygen, so anaerobic respiration, lactic acid, oxygen debt; after exercise the rates peak then fall slowly while the debt is repaid; they reach resting values when the lactic acid is gone.
- **Core** questions give a lactic acid graph and ask you to read values, calculate a change, or say when it was highest.

5. State uses of energy from respiration (22 questions)

1. Give uses **from the syllabus list**: muscle contraction, protein synthesis, cell division, active transport, growth, passage of nerve impulses, constant body temperature.
2. Give exactly as many as asked; each is 1 mark.

Variations you will meet:

- **"Which process does not need energy from respiration?"** Diffusion, osmosis, transpiration or evaporation.
- **Plants**: active transport and cell division (growth) need energy from respiration; osmosis and transpiration don't, and photosynthesis runs on light energy.
- **Completing sentences**: "energy is needed for muscle **contraction** ... for the passage of nerve **impulses** along **neurones**".
- **Why muscle cells respire fast / have many mitochondria**: they need a lot of energy for contraction.

6. Interpret a respiration investigation (17 questions)

1. **Identify what is measured**: oxygen taken in (a respirometer drop moving), or carbon dioxide made (bubbles, a gas syringe, a balloon, limewater).
2. **Calculate** with units:
 - **rate = distance ÷ time**: a drop that moves 9 mm in 30 s moves at $9 \div 30 = 0.3$ mm per second, so 18 mm in one minute;
 - **rate = 1 ÷ time** when each tube makes the same amount of gas: 60 s to make 1 cm³ gives $1 \div 60 = 0.0167 = 0.02$ cm³ per second (2 d.p.);

- **gradient** of a volume–time graph: change in volume ÷ change in time, for example $(19 - 11) \div (15 - 10) = 1.6 \text{ cm}^3 \text{ per minute}$;
- **percentage increase** = $(\text{new} - \text{original}) \div \text{original} \times 100$: from 3.0 to 4.2 is 40%.

3. **Explain** the result using the equation: the drop moves **towards** the organisms because they take in **oxygen** and the carbon dioxide is absorbed.

Variations you will meet:

- **Why each part is there:** soda lime or potassium hydroxide **absorbs carbon dioxide**; the **water-bath keeps the temperature constant**; an **oil layer keeps oxygen out** so respiration is anaerobic.
- **Balloon on a bottle of yeast and sugar:** it inflates because the yeast makes **carbon dioxide** (glucose → alcohol + carbon dioxide). With no sugar, it stays flat.
- **Limewater** turns **cloudy** with the carbon dioxide from respiring yeast.
- **Gas stops being made** after a while: the glucose (sugar) has been **used up**.
- **The fastest interval** in a table of totals: subtract each total from the next and pick the biggest difference.
- **Which temperature** from two oxygen-uptake lines: the steeper line is the warmer temperature (up to the optimum).

7. Uses of anaerobic respiration in yeast (7 questions)

1. **Bread-making:** carbon dioxide makes the dough **rise**.
2. **Biofuel:** ethanol (alcohol) is made from sugar.
3. **Brewing** beer and wine: ethanol.

Name the gas (**carbon dioxide**) and the process (**anaerobic respiration**, also accepted as fermentation).
Saying the dough rises because of **alcohol** is wrong.

8. Name the site of aerobic respiration (6 questions)

1. **Mitochondria** (one **mitochondrion**), in animal **and** plant cells.
2. **Extended:** the function of mitochondria is **aerobic respiration**, which releases energy. Say "releases", not "produces", energy, and say **aerobic**; "respiration" alone is too vague.

Wrong answers offered: chloroplast (photosynthesis), ribosome (protein synthesis), nucleus.

9. Explain the effect of temperature on respiration in yeast (5 questions)

1. **Describe** from the data: the rate **increases** as the temperature rises to an **optimum** (quote it), then **decreases**; quote values, including where it is lowest.
2. **Manipulate** the data for a mark: "the volume doubles from 20 °C to 30 °C", or a subtraction.
3. **Explain** (Extended): below the optimum, more **kinetic energy** → more collisions between enzyme and substrate; above it, enzymes **denatured**, the **active site** changes shape and **no longer fits** the substrate, so the yeast cannot respire.

Variations you will meet:

- **Pick the graph:** a curve that rises to a peak and then falls steeply to zero.
- **No gas at 95 °C:** the enzymes are denatured (and the yeast is killed). Don't say the yeast itself is denatured.

Worked examples

The bold codes show where marks are earned, as in Cambridge mark schemes. The number is how many marks.

- **M1** method mark: for a correct method, even if the numbers slip.
- **A1** accuracy mark: for a correct answer; it needs the M mark before it.
- **B1** mark for a correct result on its own, with no method needed.

Example 1

Core. Cells in the leg muscles of a runner respire aerobically most of the time.

(a) State the word equation for aerobic respiration. **[2]**

(b) Name the part of the muscle cell where aerobic respiration takes place. **[1]**

(c) State **three** uses of the energy released by respiration in the human body, other than muscle contraction. **[3]**

(d) During a sprint finish, the muscle cells also respire anaerobically. State **two** ways in which anaerobic respiration in muscle cells differs from aerobic respiration. **[2]**

(a) glucose + oxygen **B1** → carbon dioxide + water **B1**.

(b) Mitochondria (mitochondrion) **B1**.

(c) Any three from: protein synthesis, cell division, active transport, growth, the passage of nerve impulses, keeping the body temperature constant **B1 B1 B1**.

(d) Any two: anaerobic respiration does not use oxygen **B1**; it produces lactic acid instead of carbon dioxide and water **B1**; it releases much less energy per glucose molecule **B1**.

Example 2

Core. A student investigated the effect of temperature on respiration in yeast. She put equal volumes of yeast in glucose solution into water-baths at different temperatures and measured the volume of carbon dioxide made in 10 minutes. The results are in the second diagram in "Understand it".

Temperature / °C	10	20	30	40	50	60	70
Volume of carbon dioxide / cm ³	1.6	3.4	6.8	12.0	8.2	1.0	0.2

(a) Describe the effect of temperature on the volume of carbon dioxide made. Use data in your answer. **[3]**

(b) Calculate the rate of carbon dioxide production at 40 °C, in cm³ per minute. **[1]**

(c) State **two** variables the student should keep the same. **[2]**

(d) State the word equation for the reaction that made the carbon dioxide, if the yeast had no oxygen. **[2]**

(e) Explain why very little carbon dioxide was made at 70 °C. **[2]**

(a) The volume increases as the temperature rises up to 40 °C **B1**, the optimum, where it is highest at 12.0 cm³ **B1**; above 40 °C it decreases, to only 0.2 cm³ at 70 °C **B1**. (The volume doubles from 20 °C to 30 °C, which also earns a mark as data manipulation.)

(b) $12.0 \div 10 = 1.2$ cm³ per minute **B1**.

(c) Any two: the mass (or volume) of yeast, the concentration of the glucose solution, the volume of solution, the time **B1 B1**.

(d) glucose **B1** → alcohol + carbon dioxide **B1**.

(e) The enzymes that control respiration are denatured (their active site changes shape) **B1**, so the yeast cannot respire (it is killed) **B1**.

Example 3

Core. A respirometer, like the fourth diagram in "Understand it", contained germinating pea seeds and soda lime. At 20 °C the drop of coloured liquid moved 18 mm towards the seeds in 6 minutes.

(a) Calculate the rate at which the drop moved, in mm per minute. **[1]**

(b) Predict how far the drop would move in 10 minutes at 20 °C. **[1]**

(c) Name the gas the seeds took in that made the drop move, and explain why the soda lime was needed. **[2]**

(d) At 30 °C the drop moved 27 mm in 6 minutes. Calculate the percentage increase in the distance moved. **[2]**

(e) Describe a suitable control for this investigation. **[1]**

(a) $18 \div 6 = 3$ mm per minute **B1**.

(b) $3 \times 10 = 30$ mm **B1**.

(c) Oxygen **B1**. Soda lime absorbs the carbon dioxide the seeds give out, so the volume of gas in the tube falls as oxygen is used **B1**.

(d) $\frac{27 - 18}{18} \times 100$ **M1** = 50% **A1**.

(e) The same apparatus with the same volume of boiled (dead) seeds, or glass beads, instead of germinating seeds **B1**.

Example 4

Extended. An athlete ran hard from minute 5 to minute 10. Her blood lactic acid concentration is shown in the third diagram in "Understand it": 1.0 mmol per dm³ at rest, rising to a peak of 9.0 mmol per dm³ at 12 minutes and back to 1.0 mmol per dm³ at 45 minutes.

- (a) Calculate the increase in lactic acid concentration from rest to the peak. **[1]**
- (b) State how long after the end of the run the concentration took to return to the resting value. **[1]**
- (c) Explain why lactic acid built up during the run. **[3]**
- (d) Outline how the oxygen debt was removed after the run. **[3]**
- (e) Her muscles respired 5 glucose molecules aerobically. Using the balanced chemical equation, state how many molecules of oxygen were used and how many molecules of carbon dioxide were made. **[2]**
- (a) $9.0 - 1.0 = 8.0$ mmol per dm³ **B1**.
- (b) $45 - 10 = 35$ minutes **B1**.
- (c) Her muscles needed more energy for contraction than aerobic respiration could supply, because not enough oxygen reached them **B1**. So they also respired anaerobically **B1**, turning glucose into lactic acid, which built up in the muscles and diffused into the blood, causing an oxygen debt **B1**.
- (d) Her heart rate stayed high, carrying the lactic acid in the blood from the muscles to the liver **B1**. Her breathing stayed deep and fast, supplying extra oxygen **B1**. In the liver the lactic acid was broken down by aerobic respiration **B1**.
- (e) $C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O$, so $5 \times 6 = 30$ oxygen molecules used **B1** and $5 \times 6 = 30$ carbon dioxide molecules made **B1**.

Common mistakes

- **Putting carbon dioxide in the muscle equation.** Examiners report this every year. In muscles, anaerobic respiration makes **lactic acid only**.
- **Giving lactic acid for yeast.** Yeast makes **alcohol (ethanol) and carbon dioxide**. Many candidates swap the two anaerobic equations.
- **Choosing the photosynthesis equation.** Carbon dioxide + water → glucose + oxygen is photosynthesis. In respiration, glucose and oxygen are on the **left**.
- **Leaving glucose out** of a written anaerobic equation, or writing glycogen instead of glucose.

- **Mixing words and symbols** in one equation. Write it all in words, or (Extended) all in formulae.
- **Saying respiration "produces" or "makes" energy.** It **releases** energy.
- **Forgetting enzymes.** Few candidates know that respiration is controlled by enzymes; it is often a true statement in a multiple-choice question.
- **Thinking diffusion or osmosis needs energy** from respiration. They don't.
- **Confusing respiration with breathing.** Breathing moves air; respiration happens in every cell.
- **Oxygen debt: saying the heart and breathing rates "increase" after exercise.** They **stay high** (remain raised) and then fall slowly.
- **Saying lactic acid is broken down anaerobically, or in the muscles or kidneys.** It is respired **aerobically** in the **liver**.
- **Writing "respiration" when the answer is "aerobic respiration"** (for example, the function of mitochondria). Be exact.
- **Temperature answers without enzymes.** Explain with kinetic energy and collisions below the optimum, and denatured enzymes with a changed active site above it. Don't say the yeast is denatured.
- **Bread rising because of alcohol.** It rises because of **carbon dioxide** gas.

How to get the marks

- **"State" or "name":** one word or phrase (lactic acid, mitochondria, liver, carbon dioxide). Don't give two answers; a wrong one cancels a right one.
- **Word equations:** 2 marks, one each side. Include the arrow, keep reactants left, and write words only.
- **Balanced equations (Extended):** one mark for the correct formulae, one for the balancing. Use proper subscripts: $C_6H_{12}O_6$, $6O_2$, C_2H_5OH .
- **"Describe"** a trend in data: say the pattern (increases, peaks, decreases), give the optimum, quote values **with units**, and add a simple calculation if you can.
- **"Explain"** the oxygen debt: link each step (not enough oxygen → anaerobic → lactic acid → debt; heart rate → liver; breathing → oxygen; aerobic respiration in the liver). Each linked point earns a mark.
- **"Compare":** write both sides in each sentence, using comparative words: "anaerobic releases **less** energy **than** aerobic".
- **Calculations:** show the working, give units (mm per minute, cm^3 per second) and round as the question says.
- **Uses of energy:** stick to the syllabus list; "for living" or "for the body" earns nothing.
- **Use the exact terms:** aerobic, anaerobic, glucose, lactic acid, alcohol or ethanol, oxygen debt, mitochondria, liver, enzymes, denatured, active site, limewater, soda lime.

Quick check

1. Copy and complete the table with "used", "produced" or "-" (not involved).

	Glucose	Oxygen	Carbon dioxide	Water	Lactic acid	Alcohol
Aerobic respiration						
Anaerobic in muscles						
Anaerobic in yeast						

2. Which of these need energy from respiration: diffusion, protein synthesis, osmosis, active transport, cell division, transpiration?

3. **Extended:** 4 glucose molecules are respired. How many oxygen molecules are used and how many water molecules made if it is aerobic? How many carbon dioxide molecules are made if yeast respire them anaerobically?

4. In a respirometer with woodlice, the drop moved 15 mm in 6 minutes. Calculate the rate in mm per minute and predict the distance moved in 10 minutes.

5. **Extended:** A student wrote: "After exercise, lactic acid is broken down by anaerobic respiration in the muscles, so breathing rate goes back to normal straight away." Correct the answer.

Answers

1. Aerobic: glucose used, oxygen used, carbon dioxide produced, water produced, lactic acid –, alcohol –.
Muscles: glucose used, lactic acid produced, everything else –. Yeast: glucose used, carbon dioxide produced, alcohol produced, everything else –.
2. Protein synthesis, active transport and cell division. Diffusion, osmosis and transpiration are passive.
3. Aerobic: $4 \times 6 = 24$ oxygen molecules used and $4 \times 6 = 24$ water molecules made. Anaerobic in yeast: $4 \times 2 = 8$ carbon dioxide molecules.
4. $15 \div 6 = 2.5$ mm per minute; $2.5 \times 10 = 25$ mm.
5. Lactic acid is carried in the blood to the **liver**, where it is broken down by **aerobic** respiration, using oxygen. So the breathing rate (and heart rate) **stays high** after exercise, supplying that oxygen, and falls back to normal only when the lactic acid has gone: the oxygen debt has been repaid.

Past questions to try

- 0610/33/M/J/23 Q5: substances in aerobic respiration, uses of energy, and describing yeast data at different temperatures (Core).
- 0610/32/F/M/22 Q4: a respirometer with an arthropod, rate and prediction, and uses of energy (Core).
- 0610/41/M/J/23 Q6: muscle pH and the oxygen debt, and the balanced equation for yeast (Extended).
- 0610/42/M/J/24 Q1: yeast in a sugar solution, a rate from a graph, the oil layer, and why no gas is made at 95 °C (Extended).