Aerobic and anaerobic respiration

4.4.2.1 · Bioenergetics · revision notes

Respiration is the exothermic reaction that transfers energy in every living cell, with oxygen (aerobic) or without it (anaerobic). Expect word equations, comparisons of aerobic and anaerobic respiration, fermentation by yeast, and data questions such as the carbon dioxide made by yeast or the temperature of germinating seeds.

Key facts

- Aerobic: glucose + oxygen → carbon dioxide + water
- Anaerobic in muscles: glucose → lactic acid
- Fermentation = anaerobic respiration in yeast (bread and alcoholic drinks)
- Energy is used for: building larger molecules, movement, keeping warm
- Grade 6+ only $C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O$
- Anaerobic in plant cells and yeast: glucose → ethanol + carbon dioxide
- Respiration is exothermic and happens continuously in all living cells
- Anaerobic: incomplete oxidation of glucose, so much less energy is transferred

Notes

What respiration is

- Cellular respiration is an **exothermic** reaction (it transfers energy to the surroundings) that happens **continuously** in all living cells. It transfers the energy needed for all living processes.
- Respiration is a chemical reaction in cells. It is not the same as breathing, which moves air into and out of the lungs.
- Organisms need this energy for: chemical reactions that build larger molecules (such as proteins), movement (muscle contraction) and keeping warm.
- Respiration can be **aerobic** (using oxygen) or **anaerobic** (without oxygen).

Aerobic respiration

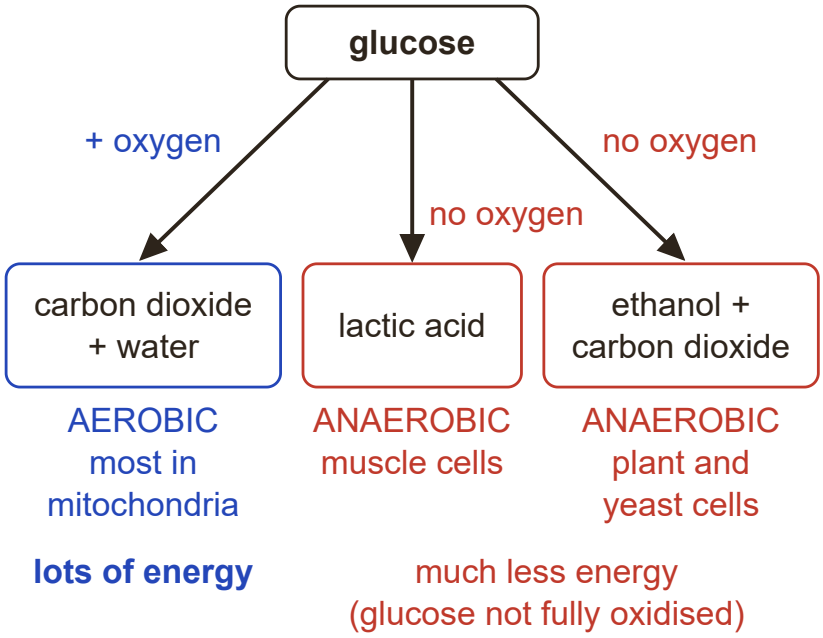
- Word equation: **glucose + oxygen → carbon dioxide + water**.
- Formulae to recognise: $C_6H_{12}O_6$, O_2, CO_2 and H_2O.
- Balanced symbol equation: $C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O$. Grade 6+ only
- Most aerobic respiration happens in the **mitochondria**. Glucose is completely oxidised, so a lot of energy is transferred.

Anaerobic respiration

- Anaerobic respiration happens when there is not enough oxygen.
- In muscle cells: **glucose → lactic acid**.
- In plant cells and yeast cells: **glucose → ethanol + carbon dioxide**.
- The oxidation of glucose is **incomplete**, so much less energy is transferred than in aerobic respiration.
- Anaerobic respiration in yeast is called **fermentation**. It is used to make bread (carbon dioxide bubbles make the dough rise) and alcoholic drinks such as beer and wine (ethanol).

Comparing the two

- Oxygen: aerobic respiration needs it; anaerobic respiration does not.
- Products: aerobic makes carbon dioxide and water; anaerobic makes lactic acid (muscles) or ethanol and carbon dioxide (plants and yeast).
- Energy: aerobic respiration transfers much more energy from each glucose molecule.
- Both use glucose and both are exothermic.



The three ways a cell can respire glucose.

How to answer each type of question

Recall: complete a respiration equation

1 to 3 marks | Grade 3

1. Check which type of respiration and which organism the question is about.
2. Muscles: lactic acid only. Yeast and plants: ethanol and carbon dioxide.
3. Aerobic, in any organism: carbon dioxide and water.

Example. (a) Complete the word equation for anaerobic respiration in yeast.
glucose → ..... + ...
(b) Name the product of anaerobic respiration in human muscle cells.

Model answer.

(a) ethanol (1); carbon dioxide (1), in either order
(b) lactic acid (1)

Explain the use of yeast, with a rate calculation

2 to 3 marks per part | Grade 5

1. Name the process: anaerobic respiration (fermentation) by yeast.
2. Name the product that matters: carbon dioxide for bread, ethanol for drinks.
3. For a rate, divide the amount of product by the time and give the unit.

Example. (a) A baker mixes yeast with flour, sugar and water and leaves the dough in a warm place. Explain why the dough rises.
(b) In an experiment, some yeast produced 18 cm^3 of carbon dioxide in 6 minutes. Calculate the mean rate of carbon dioxide production.

Model answer.

(a) The yeast respires anaerobically / ferments the sugar (1), producing carbon dioxide (1).
Bubbles of carbon dioxide are trapped in the dough, so it expands (1).
(b) 18 ÷ 6 (1) = 3 cm^3 per minute (1)

Compare aerobic and anaerobic respiration

3 to 4 marks | Grade 6

1. Make each point a direct comparison, using 'whereas' or 'but'.
2. Cover oxygen, products and the amount of energy transferred.
3. A similarity (both use glucose) can also count if the question says 'compare'.

Example. Compare aerobic respiration with anaerobic respiration in human muscle cells. [3 marks]

Model answer. Aerobic respiration uses oxygen, whereas anaerobic respiration does not (1). Aerobic respiration produces carbon dioxide and water, whereas anaerobic respiration produces lactic acid (1). Aerobic respiration transfers much more energy from each glucose molecule than anaerobic respiration (1).

Explain why anaerobic respiration transfers less energy 2 marks **Grade 7**

1. Use the key phrase: the oxidation of glucose is incomplete.
2. Say where the rest of the energy is: still stored in the lactic acid (or ethanol).

Example. Muscle cells transfer much less energy from each glucose molecule when they respire anaerobically.
Explain why.

Model answer. Without oxygen, glucose is only partly oxidised / the oxidation of glucose is incomplete (1), so much of the energy is still stored in the lactic acid produced (1).

Don't lose marks

- Saying respiration 'makes' or 'produces' energy. Energy is transferred (released), never made.
- Confusing respiration with breathing. Respiration is a chemical reaction inside cells.
- Writing that anaerobic respiration in muscles produces carbon dioxide. It produces lactic acid only.
- Saying anaerobic respiration releases no energy. It transfers much less energy than aerobic respiration, but not none.
- Saying plants only photosynthesise. All living plant cells respire all the time.

More tips

Memory tricks

- Aerobic has 'aer' as in air (oxygen). 'An-' means without, so anaerobic means without oxygen.
- Aerobic respiration is photosynthesis backwards: glucose + oxygen → carbon dioxide + water.
- Legs make lactic acid; yeast makes the bread and beer products: carbon dioxide (bread rises) and ethanol (beer).
- Three uses of the energy: build, move, keep warm.

Exam technique

- In 'compare' questions, write paired statements: 'aerobic needs oxygen, whereas anaerobic does not'. Two separate descriptions may not score.
- Always match anaerobic products to the organism: muscles (lactic acid) or plant cells and yeast (ethanol and carbon dioxide).
- Use the scientific terms: 'transfers energy', 'incomplete oxidation of glucose', 'fermentation' and 'ethanol'.
- Give word equations unless formulae are asked for; if you use formulae, check O_2, CO_2, H_2O and $C_6H_{12}O_6$.

What each grade needs

What you need to be able to do, from the first marks up to the top grade.

Grade 3 **State why organisms need energy**
For chemical reactions that build larger molecules, for movement and for keeping warm.

Grade 3

Write the word equation for aerobic respiration

glucose + oxygen → carbon dioxide + water.

Grade 4

Write the anaerobic equations for muscles and yeast

In muscles: glucose → lactic acid. In plant cells and yeast: glucose → ethanol + carbon dioxide.

Grade 5

Describe respiration as a continuous exothermic reaction

It happens all the time in living cells and transfers energy to the surroundings, supplying the energy for living processes.

Grade 5

Describe fermentation and its uses

Anaerobic respiration in yeast makes ethanol and carbon dioxide, which are used to make alcoholic drinks and bread.

Grade 6

Compare aerobic and anaerobic respiration

Compare the need for oxygen, the products and the amount of energy transferred.

Grade 7

Explain why anaerobic respiration transfers less energy

The oxidation of glucose is incomplete, so much of the energy stays in the lactic acid or ethanol.

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