Respiration

Respiration and the uses of energy, aerobic respiration and its equation, anaerobic respiration in humans and yeast, lactic acid and the oxygen debt.

12.1 Respiration

> **Respiration is the set of chemical reactions in all living cells that release energy from glucose.**

Respiration happens in **every living cell all the time**. It is different from breathing (gas exchange). The energy released is used in making **ATP**, a molecule that cells use as an immediate source of energy (the details are not needed).

Uses of energy in living organisms

- **muscle contraction** for movement;
- **protein synthesis** (building proteins from amino acids);
- **cell division**;
- **active transport** of molecules and ions across membranes;
- **growth**;
- passing **electrical impulses** along neurones;
- maintaining a **constant body temperature** (in mammals and birds).

Investigating respiration in yeast

Yeast respires glucose. The effect of temperature can be investigated by adding yeast to a glucose solution at different temperatures in a water bath and measuring the rate at which **carbon dioxide** is made (counting the bubbles, or measuring the gas collected in a given time, or the time for hydrogencarbonate indicator to change colour). The rate rises with temperature up to an optimum of about $35–40\,^{\circ}\mathrm{C}$ (the enzymes work faster), and then falls when the enzymes are **denatured**.

12.2 Aerobic respiration

> **Aerobic respiration is the release of a relatively large amount of energy by the breakdown of glucose in the presence of oxygen.**

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

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

It takes place in the **mitochondria** (and the cytoplasm), and all the glucose is fully broken down. It is the opposite of photosynthesis, and the equation for aerobic respiration is the reverse of the equation for photosynthesis.

12.3 Anaerobic respiration

> **Anaerobic respiration is the release of a relatively small amount of energy by the breakdown of glucose without using oxygen.**

Less energy is released because the glucose is **only partly broken down**.

In humans (muscles):

$$\text{glucose} \rightarrow \text{lactic acid}$$

In yeast (fermentation):

$$\text{glucose} \rightarrow \text{ethanol} + \text{carbon dioxide}$$

Yeast fermentation is used to make **bread** (carbon dioxide makes the dough rise) and **alcoholic drinks** (ethanol).

	Aerobic	Anaerobic
oxygen	needed	not needed
energy released	large	small
products (humans)	carbon dioxide and water	lactic acid
products (yeast)	carbon dioxide and water	ethanol and carbon dioxide

Lactic acid and the oxygen debt

During **vigorous exercise**, the muscles need energy faster than the blood can bring oxygen to them. The muscles use **anaerobic respiration** to release extra energy, which makes **lactic acid** that builds up in the muscles and blood. The lactic acid causes **muscle fatigue** and cramp.

> **After exercise the body still takes in extra oxygen to break down the lactic acid. This is called Excess Post-exercise Oxygen Consumption (EPOC), or the oxygen debt.**

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How the oxygen debt is removed.

- The **fast heart rate continues**, so that the **blood carries the lactic acid** from the muscles to the **liver**.
- **Deeper, faster breathing continues**, to take in extra **oxygen**, which is used in the **liver** to **break down the lactic acid** (to carbon dioxide and water).

The rates return to normal when the lactic acid has been removed. A fitter person recovers faster.

> **TRY IT**
>
> Why does a person continue to breathe heavily after finishing a sprint?

The muscles made **lactic acid** by anaerobic respiration, so the body has an **oxygen debt**. Deep, fast breathing brings in extra oxygen to break down the lactic acid in the liver.

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