

Cell respiration

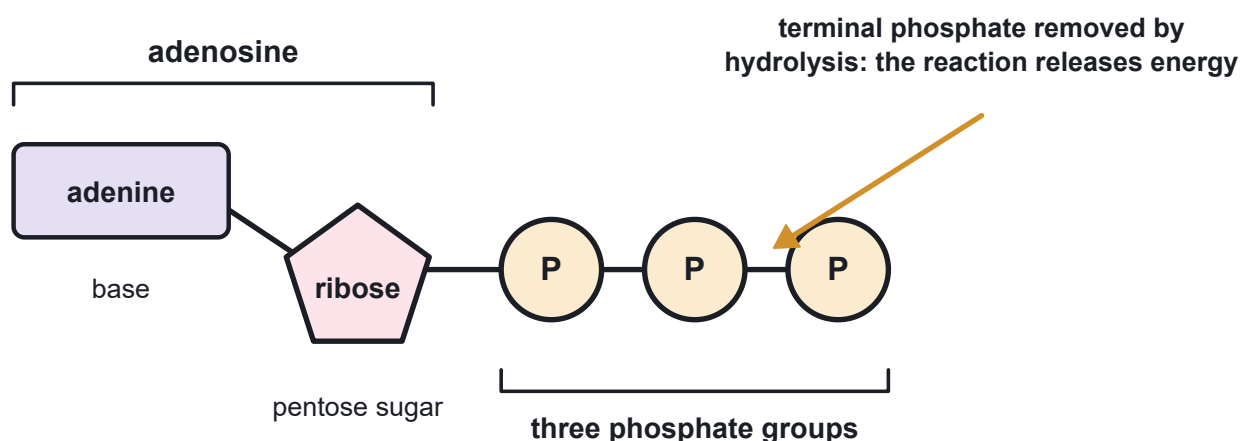
Revision notes • IB Biology C1.2: ATP, aerobic and anaerobic respiration, and measuring the rate of cell respiration.

For IB Diploma Biology SL undefined. **HL only** is additional higher level content, for HL students only.

Cell respiration Spec C1.2

ATP: the molecule that distributes energy Spec C1.2.1, C1.2.2, C1.2.3

ATP (adenosine triphosphate) is the molecule that distributes energy within cells. It is a **nucleotide**, made of the base adenine, the pentose sugar ribose and a chain of three phosphate groups.



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ATP is a nucleotide: adenine, ribose and three phosphates. Hydrolysis of the **terminal phosphate** releases energy.

Why ATP suits its role as energy currency

- It is **soluble** in water, so it moves easily to wherever energy is needed in the cell.
- It is **stable** at the pH of a cell and does not break down unless an enzyme catalyses it, so energy is not wasted.
- It **cannot pass freely through membranes**, so it stays inside the cell where it was made.
- Hydrolysis of one phosphate group releases an amount of energy that is **sufficient for many tasks** in the cell, without releasing so much that most is wasted as heat.
- It is **rapidly regenerated** from ADP and phosphate, so a small pool of ATP can be recycled many times.

Life processes that ATP supplies with energy

- **Active transport** across membranes, for example pumping ions against their concentration gradient.
- **Synthesis of macromolecules** (anabolism), such as proteins, DNA and glycogen.

- **Movement:** of the whole cell (for example muscle contraction, cilia and flagella) or of cell components such as chromosomes during cell division.

Interconversion of ATP and ADP



Energy is released by **hydrolysis of ATP** to ADP (adenosine diphosphate) and phosphate. Energy is **required to synthesise ATP** from ADP and phosphate. In cells this energy comes from cell respiration (and in photosynthetic cells also from light). Often the phosphate removed from ATP is transferred to another molecule, making it more reactive.

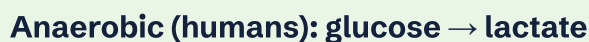
Common mistake: ATP does not store large amounts of energy long term; it distributes energy. Fats and carbohydrates are the energy stores.

Cell respiration: aerobic and anaerobic Spec C1.2.4, C1.2.5

Cell respiration is a system for producing ATP within the cell using energy released from carbon compounds. Glucose and fatty acids are the principal substrates, but a wide range of carbon (organic) compounds can be used, including amino acids.

Do not confuse it with **gas exchange**. Gas exchange is the diffusion of oxygen and carbon dioxide between an organism and its environment, for example across the alveoli. Cell respiration is a set of enzyme-catalysed reactions inside every living cell. Gas exchange supplies the oxygen that aerobic respiration uses and removes the carbon dioxide it produces.

Word equations (glucose as substrate)



Differences between anaerobic and aerobic cell respiration in humans

	Aerobic	Anaerobic
Respiratory substrates	Carbohydrates, lipids (fatty acids) and amino acids	Glucose (carbohydrate) only
Oxygen required	Yes	No
Relative ATP yield per glucose	Large (about 30 ATP; older textbooks give 36–38)	Small (2 ATP)
Waste products	Carbon dioxide and water	Lactate
Where in the cell	Starts in the cytoplasm, mostly in mitochondria	Cytoplasm only
Mitochondria needed	Yes	No

Humans use anaerobic respiration when oxygen cannot be supplied fast enough, for example in muscles during very intense exercise. It gives ATP quickly but in small amounts, and the lactate must be removed later.

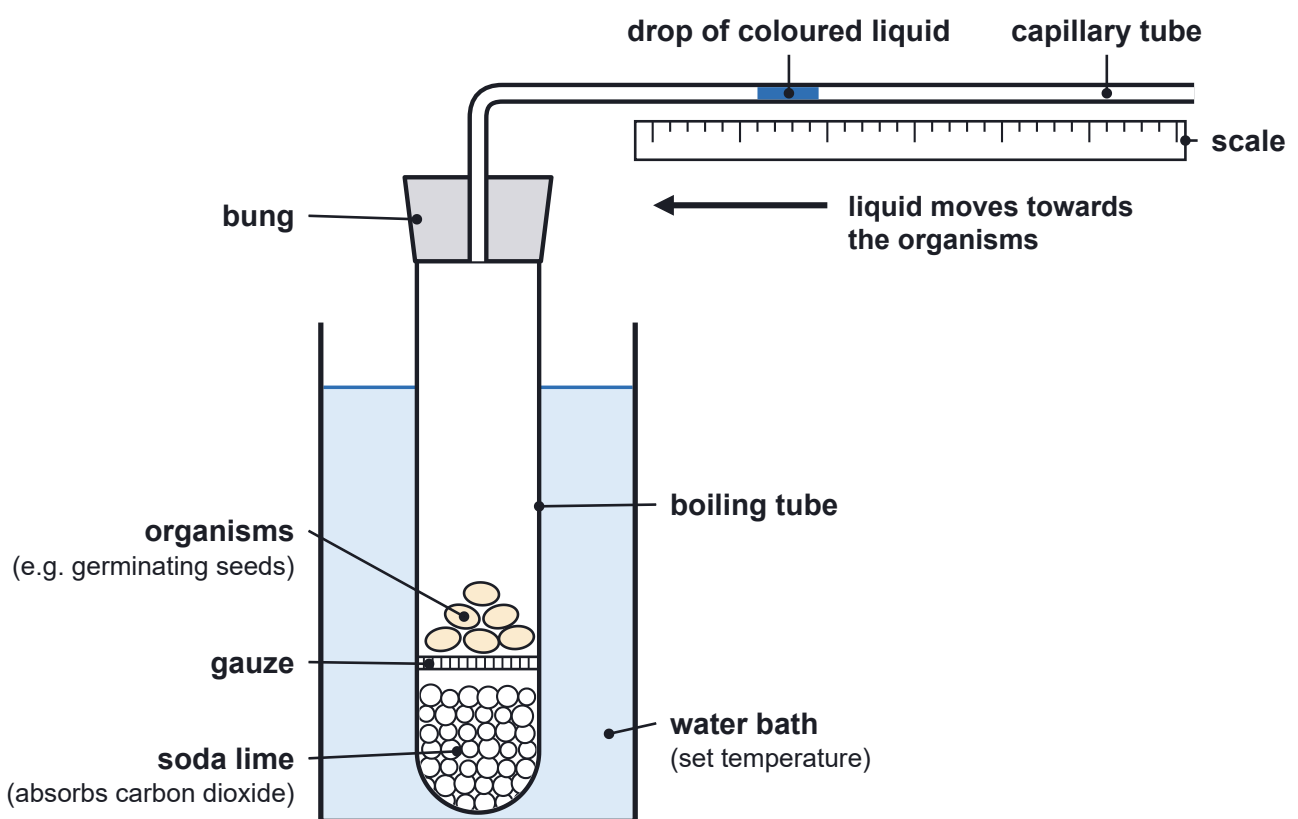
Exam tip: In 'compare' questions, write paired statements: 'aerobic respiration needs oxygen whereas anaerobic does not'. Lactate is the IB term; do not write lactic acid unless the question does.

Variables affecting the rate of cell respiration Spec C1.2.6

The rate of cell respiration is the amount of oxygen used, carbon dioxide produced or substrate used **per unit time**. To compare organisms of different sizes, divide by mass, for example mm³ of oxygen per gram per minute.

Variables that affect the rate

- **Temperature:** respiration is enzyme-catalysed, so rate rises to an optimum, then falls as enzymes denature.
- **Oxygen concentration:** low oxygen limits aerobic respiration.
- **Substrate availability:** for example glucose concentration for yeast, or stored food in germinating seeds.
- Others: type and activity of the organism, pH, and stage of development (germinating seeds respire faster than dry seeds).



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A simple respirometer. Soda lime absorbs carbon dioxide, so the **drop moves towards the organisms** as they use oxygen.

Measuring the rate

1. Place a known mass of organisms (for example germinating seeds or invertebrates) in a sealed tube with an alkali such as soda lime to absorb carbon dioxide.
2. Keep the tube in a water bath at a set temperature and let it equilibrate.
3. Record the distance the liquid drop moves in a fixed time.
4. Set up a control tube with glass beads of the same volume instead of organisms, to correct for temperature and pressure changes.
5. Repeat at different values of the independent variable (for example temperature) and calculate rates.

Rates can also be measured with oxygen or carbon dioxide sensors and a data logger, or for yeast by measuring the volume of carbon dioxide released.

Rate of respiration from a respirometer

2.5 g of germinating seeds were placed in a respirometer. The drop in the capillary tube (radius 0.50 mm) moved 30 mm in 10 minutes. Calculate the rate of oxygen uptake per gram.

1. Volume of oxygen = $\pi r^2 h = 3.14 \times 0.50^2 \times 30 = 23.6 \text{ mm}^3$.
2. Rate = $23.6 \text{ mm}^3 \div 10 \text{ min} = 2.36 \text{ mm}^3 \text{ min}^{-1}$.
3. Per gram: $2.36 \div 2.5 = 0.94 \text{ mm}^3 \text{ g}^{-1} \text{ min}^{-1}$.

Answer: $0.94 \text{ mm}^3 \text{ g}^{-1} \text{ min}^{-1}$ (to 2 significant figures).

Maths skill: Rate = amount $\div$ time. Always state units, and divide by mass when organisms or samples differ in size.

Practical skill: Use living organisms ethically: handle invertebrates gently, use gauze to keep them away from the corrosive soda lime, and return them to their habitat afterwards.

Quick check

1. What is the full name of ATP and what type of molecule is it?
2. Write the word equation for anaerobic respiration in humans.
3. Why is soda lime used in a respirometer?

Quick check answers

Cell respiration

1. Adenosine triphosphate; a nucleotide.
2. glucose → lactate
3. It absorbs carbon dioxide, so the movement of the drop measures oxygen uptake.