

Energy & Respiration

A-Level Biology ■ Topic 12

A-Level Biology



What we will cover

- 1 ATP – the energy currency
- 2 Substrates & RQ
- 3 The four stages
- 4 Glycolysis
- 5 Krebs & oxidative phosphorylation
- 6 Anaerobic respiration



muscles need energy



ATP – the energy currency

ATP stores energy in its terminal phosphate bond. Hydrolysis to $\text{ADP} + \text{P}_i$ releases a small, usable amount; respiration (and photosynthesis) rebuilds it. It works as a currency because it is **small and soluble**, so it moves easily around the cell, and because it is **easily made and re-made**, again and again. The energy pays for **active transport** against a gradient and for **anabolic** reactions – building large molecules such as in DNA replication and protein synthesis.

ATP is a short-term, mobile energy currency – not a store. Cells make it as they need it.

Substrates and RQ

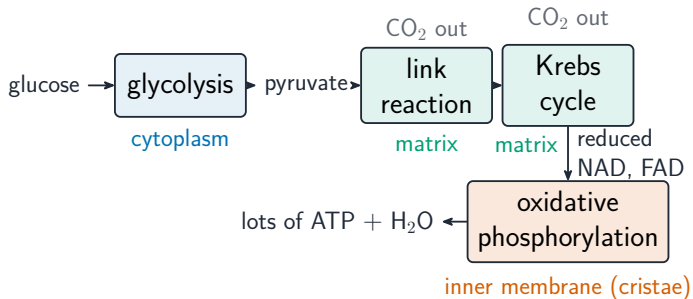
Respiratory quotient $RQ = \text{CO}_2 \text{ produced} / \text{O}_2 \text{ used}$. Carbohydrate ≈ 1.0 ; lipid ≈ 0.7 ; protein ≈ 0.9 . An RQ above 1 suggests anaerobic respiration as well.



The four stages

- **glycolysis** – in the **cytoplasm**
- **link reaction** & **Krebs cycle** – the **matrix**
- **oxidative phosphorylation** – the inner membrane

Reduced NAD & FAD carry hydrogen to the membrane.

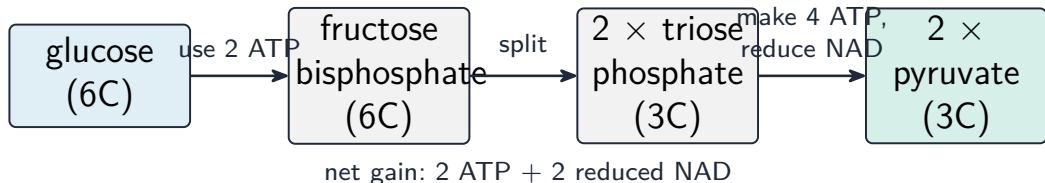


Glycolysis

Glucose (6C) is split into two **pyruvate** (3C).

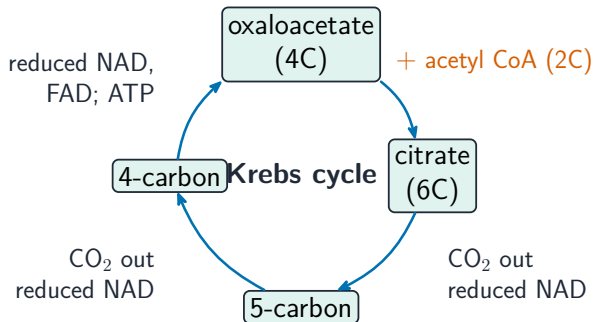
It spends 2 ATP but makes 4 – a net **2 ATP** (plus reduced NAD) – and needs **no oxygen**.

Glycolysis, in detail



Glycolysis spends 2 ATP to start but makes 4, so the net gain is 2 ATP (plus reduced NAD) – and it needs no oxygen

Krebs cycle



The link reaction makes **acetyl CoA**, which joins the cycle.
Each turn:

- **decarboxylation** – releases CO₂
- **dehydrogenation** – reduces NAD & FAD

The link reaction and the Krebs cycle

the link reaction	pyruvate enters the mitochondrion, loses a carbon dioxide , and is joined to coenzyme A A
the product	acetyl coenzyme A – two carbons, entering the cycle
the cycle starts	acetyl CoA joins oxaloacetate (4C) to form citrate (6C)
decarboxylation	removes carbon as carbon dioxide – twice per turn
dehydrogenation	removes hydrogen onto the coenzymes NAD and FAD
per turn	2 CO ₂ , 3 NADH, 1 FADH ₂ , 1 ATP – and the cycle turns twice per glucose

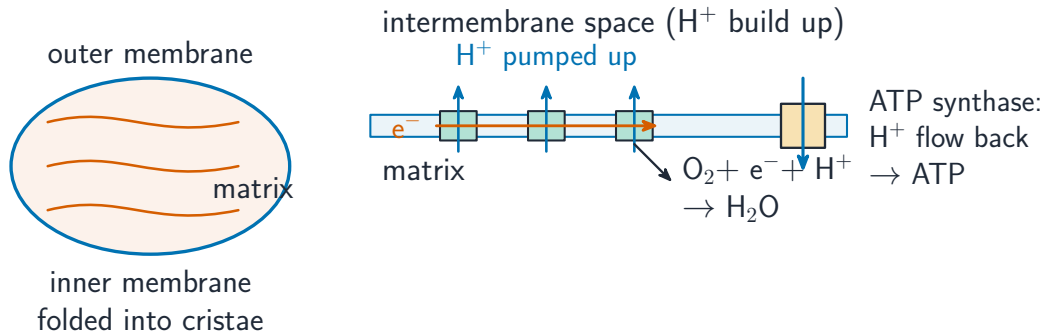
A redox **indicator** such as DCPIP or methylene blue **loses its colour** as it gains hydrogen from respiring cells. The faster it decolourises, the faster respiration is.

Oxidative phosphorylation

Makes **most** of the ATP:

- electrons pass the **electron transport chain** , pumping protons
- protons flow back through **ATP synthase** ATP (**chemiosmosis**)
- **oxygen** is the final electron acceptor → water

Oxidative phosphorylation, in detail



Electrons pump protons (H^+) into the intermembrane space; they flow back through ATP synthase to make ATP (chemiosmosis)



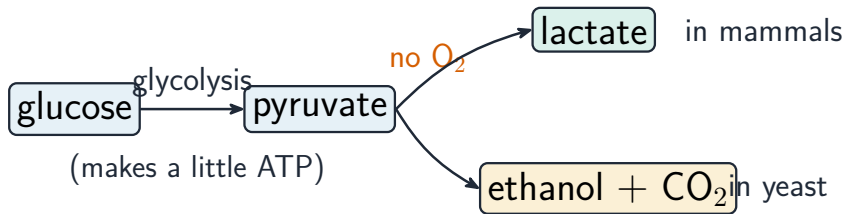
Anaerobic respiration

Without oxygen, only glycolysis runs. **Fermentation** regenerates NAD:

- mammals → **lactate**
- **yeast** → **ethanol** + CO₂

Far less ATP than aerobic respiration.

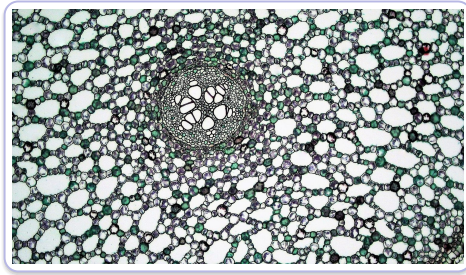
Anaerobic respiration, in detail



this regenerates NAD so glycolysis can keep running (far less ATP than aerobic)

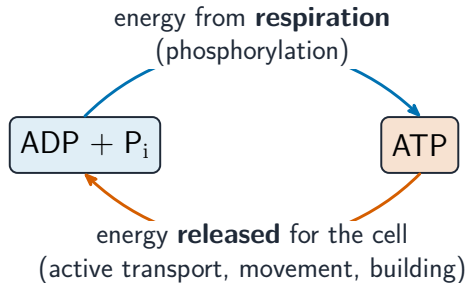
Without oxygen, only glycolysis runs.

Rice and waterlogged roots



A root of a plant that grows in water, seen in cross-section. The big white gaps are the aerenchyma – connected air channels that let oxygen diffuse all the way down to roots sitting in oxygen-poor mud

ATP – the energy currency, continued



Respiration adds a phosphate to make ATP; the cell breaks it off again to release energy

How ATP is made, and what RQ tells you

phosphorylation

direct transfer of a phosphate group to ADP – substrate-level phosphorylation

chemiosmosis

protons pumped across a membrane flow back through ATP synthase, which makes the ATP

the respiratory quotient

$$RQ = \frac{\text{CO}_2 \text{ produced}}{\text{O}_2 \text{ used}}$$

the values

carbohydrate 1.0, protein about 0.9, lipid about 0.7

why lipid is lowest

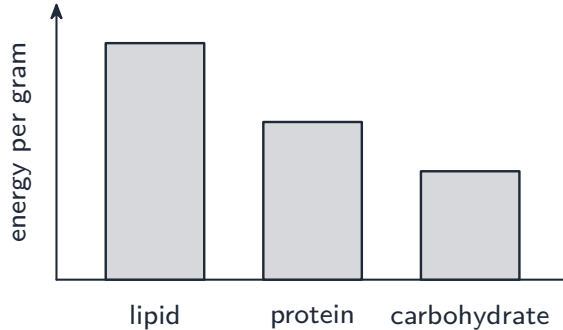
it is the most reduced substrate, so it needs the most oxygen per carbon

above 1.0

means some respiration is **anaerobic** – CO₂ released with no oxygen used

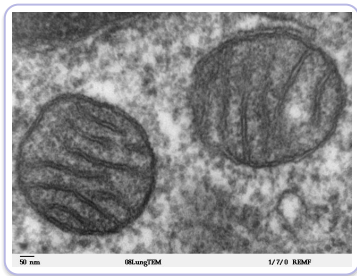
RQ identifies the **substrate** being respired. Measuring it on **germinating** seeds or **invertebrates** in a respirometer is the standard practical.

Respiratory substrates and RQ



Lipids release the most energy per gram, then proteins, then carbohydrates

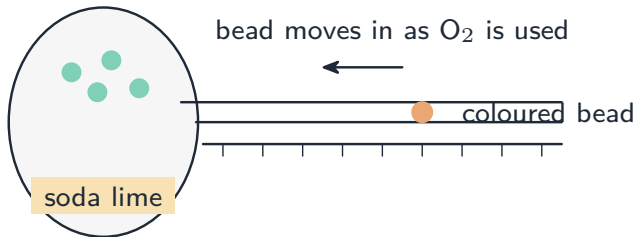
The structure of mitochondria



Two real mitochondria, photographed with an electron microscope. The dark stripes crossing the inside are the cristae – all that folding is what makes the surface for the electron transport chain so large

Respiratory substrates and RQ, continued

germinating seeds



The soda lime absorbs the CO₂ given off, so the gas volume falls only by the oxygen used – and the bead moves in by that amount

Exam tips

- State **where** each stage happens and its ATP yield: glycolysis (cytoplasm), link reaction + Krebs (matrix), oxidative phosphorylation (inner membrane, most ATP).
- Explain the roles of **NAD/FAD** (carry hydrogen to the electron transport chain) and of oxygen (the final electron acceptor).
- **RQ** = $\text{CO}_2 \text{ produced} \div \text{O}_2 \text{ used}$ (≈ 1.0 carbohydrate, 0.7 lipid); know how a respirometer measures it.
- Anaerobic respiration gives lactate (animals) or ethanol + CO_2 (yeast/plants) and far less ATP (glycolysis only).



Worked example – respiratory quotient

Find the RQ for aerobic respiration of glucose: $\text{C}_6\text{H}_{12}\text{O}_6 + 6\text{O}_2 \rightarrow 6\text{CO}_2 + 6\text{H}_2\text{O}$.

- $\text{RQ} = \frac{\text{CO}_2 \text{ produced}}{\text{O}_2 \text{ used}}$
- $= \frac{6}{6} = 1.0$
- Lipids are less oxidised, so they need **more** oxygen $\Rightarrow \text{RQ} \approx 0.7$.
- An RQ **above 1.0** means some **anaerobic** respiration is also happening.

RQ identifies the **substrate**: carbohydrate 1.0, protein ≈ 0.9 , lipid ≈ 0.7 . Above 1.0 $\Rightarrow$ extra CO_2 from anaerobic respiration.

Topic 12 – key takeaways

1

ATP

the cell's energy currency; $\text{ADP} + \text{P}_i$

2

Glycolysis

glucose to pyruvate; net 2 ATP,
no O_2

3

Krebs cycle

decarboxylation &
dehydrogenation

4

Chemiosmosis

ATP synthase makes most ATP;
 O_2 accepts e^-

Check yourself

- 1 Where in the cell does glycolysis happen?
- 2 What is the net ATP gain from glycolysis?
- 3 What is the final electron acceptor?
- 4 What does yeast make in anaerobic respiration?



Answers 1. the cytoplasm 2. 2 ATP 3. oxygen 4. ethanol and CO₂