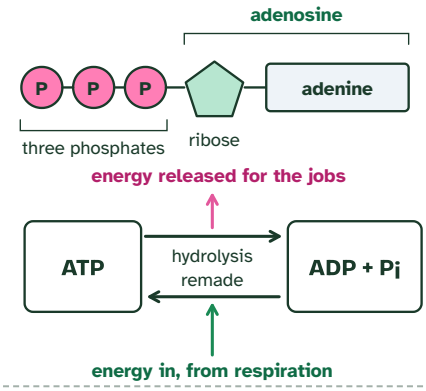
How cells make *ATP*

What to know, what to draw and what to say. Nothing else.

THE ONE IDEA

Cells release energy from carbon compounds step by step, and use it to make ATP: the one molecule every job spends.



Draw it like this. Phosphate circles, a ribose pentagon, an adenine rectangle.

C1.2.1 to 3 START HERE

ATP, the cell's *energy currency*

- **Adenosine triphosphate** is a **nucleotide** (adenine, ribose, phosphate) with two more phosphates in a chain.
- **Why it suits:** soluble, so it moves freely; **stable** until an enzyme acts; releases a **modest amount** of energy, enough for one step of a job; remade quickly.
- **Spending it:** **hydrolysis** of ATP to **ADP and phosphate** releases energy. Remaking ATP from ADP and phosphate **needs energy**, from respiration.

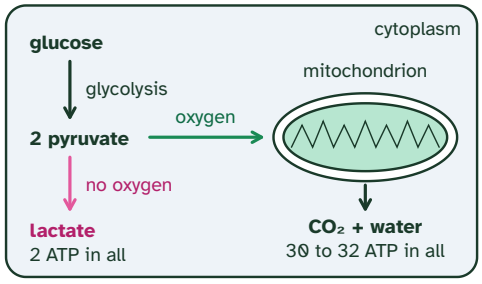
WHAT ATP PAYS FOR — *BAM*

- **B** **Building** macromolecules (anabolism)
- **A** **Active transport** pumping against the gradient
- **M** **Movement** of the cell, or of chromosomes

C1.2.4

A system for making *ATP*

- Respiration uses energy from **carbon compounds** to make ATP, in every cell, all the time.
- **Not burning:** energy is released **step by step**, each step with its own enzyme.
- **Substrates:** mainly **glucose and fatty acids**, but a wide range of carbon compounds can be used.
- **Not gas exchange:** that is gases **diffusing across a surface**, with no reaction and no energy released.



C1.2.5 HUMANS

With oxygen and *without*

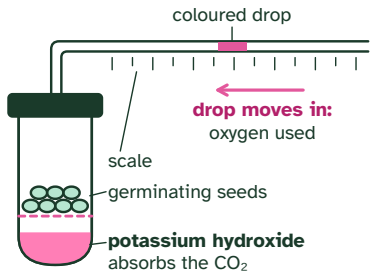
	AEROBIC	ANAEROBIC
Substrates	Glucose, fatty acids, others	Glucose only
Oxygen	**Needed**	**Not needed**
ATP yield	**About 30 to 32**	**2 per glucose**
Waste	Carbon dioxide and water	**Lactate**; no CO_2
Where	Cytoplasm, then **mitochondria**	Cytoplasm: **no mitochondria**
Equation	glucose + oxygen → carbon dioxide + water	glucose → lactate

ANAEROBIC IN HUMANS IS — *LOW*

- **L** **Lactate** the waste product
- **O** **Only 2 ATP** per glucose
- **W** **Without oxygen** in the cytoplasm

C1.2.6 SKILLS

Measuring the *rate*



- Measure **oxygen taken up**, CO_2 given out or fuel used, **per gram per minute**.
- KOH absorbs the CO_2, so the drop moves **towards** the seeds as they use O_2.
- **Control:** glass beads for seeds; take its drop's movement off.
- **Variables:** temperature, germination stage, seed mass and kind.

STEP 1 **Read** Both drops, start and end.

STEP 2 **Correct** Take off the control.

STEP 3 **Volume** $\pi r^2 \times$ distance.

STEP 4 **Rate** ÷ time ÷ mass.

C1.2.7 HIGHER LEVEL

Redox and NAD

- **Oxidation** is loss of electrons, **reduction** is gain; they happen together, as **redox**.
- A hydrogen atom is a proton and an electron, so removing hydrogen (**dehydrogenation**) **oxidises** the substrate.
- **NAD accepts the hydrogen** and is reduced: reduced NAD carries it, and its energy, to the electron transport chain.

REMEMBER — *OIL RIG*

- **O** **Oxidation** Is Loss of electrons
- **R** **Reduction** Is Gain of electrons

Inside respiration, *step by step*

C1.2.8 HIGHER LEVEL

Glycolysis: glucose to pyruvate

- In the **cytoplasm**, no oxygen: glucose becomes **two pyruvate** in about ten steps, **each catalysed by a different enzyme**. Net: **2 ATP and 2 reduced NAD**.

PENGUINS	LOVE	ORANGE	ANCHOVIES
Phosphorylation 2 ATP spent; sugar made reactive.	**Lysis** 6C split into two 3C.	**Oxidation** Hydrogen to NAD.	**ATP formation** 4 ATP made.

C1.2.9 and 10 HIGHER LEVEL

Giving *NAD* back

- Without oxygen, **pyruvate takes the hydrogen** from reduced NAD, **regenerating NAD**: glycolysis goes on.

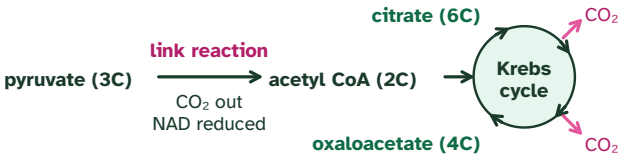
Human muscle pyruvate → lactate
Net 2 ATP. Same route as yeast; only the **last step** differs.

Yeast pyruvate → ethanol + CO_2
Baking: CO_2 raises dough. **Brewing:** ethanol is kept.

C1.2.11 and 12 HIGHER LEVEL

Link reaction and *Krebs cycle*

- **Link:** in the matrix, pyruvate is **decarboxylated and oxidised**; coenzyme A carries the **acetyl group** on, as it does from fats.
- **Krebs:** acetyl + oxaloacetate → **citrate**; **four oxidations** (dehydrogenations) and **two decarboxylations** remake oxaloacetate. A turn gives 3 reduced NAD, 1 reduced FAD, 1 ATP.



C1.2.17 HIGHER LEVEL

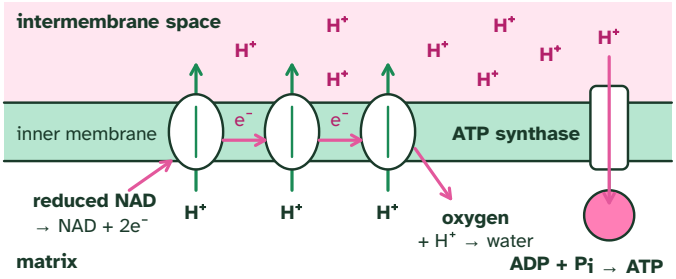
Lipid or *carbohydrate*?

	LIPID	CARBOHYDRATE
Per gram	**About 37 kJ**	**About 17 kJ**
Why	**Less O**, more H and C to oxidise	Half its mass is oxygen
Route in	As **acetyl CoA** (2C)	Through **glycolysis**
No oxygen	Cannot be used	Can be used

- Only **glycolysis works without oxygen**, and fatty acids skip it: a sprint runs on carbohydrate.

C1.2.13 to 16 HIGHER LEVEL

The chain, the gradient and *ATP synthase*



- Reduced NAD from glycolysis, the link and Krebs **gives a pair of electrons** to the first carrier, and becomes NAD again.
- Electrons pass along the carriers; the energy released **pumps protons** into the intermembrane space: a **proton gradient**.
- **Chemiosmosis:** protons flow back through **ATP synthase**, which couples their energy to **phosphorylating ADP**.
- **Oxygen**, the **terminal electron acceptor**, takes electrons and protons, making **water**, so electrons keep flowing.

WATCH OUT

Six mistakes that *cost marks*

- ✕ **ATP is not an energy store.** It is spent and remade constantly.
- ✕ **Energy is not stored in the bond.** Breaking any bond takes energy.
- ✕ **Respiration is not gas exchange.** It is chemistry inside cells; gas exchange is diffusion.
- ✕ **Humans make lactate; yeast make ethanol and CO_2.** Never the other way round.
- ✕ **The chain makes a proton gradient, not ATP.** ATP synthase makes ATP, and it is not a pump.
- ✕ **Oxygen ends up in water.** The CO_2 comes from the fuel's carbon.

COVER THE SHEET

Can you *answer these?*

1. Explain two properties that suit ATP as energy currency.
2. Distinguish respiration from gas exchange.
3. Compare aerobic and anaerobic respiration in humans.
4. Calculate a rate: 24 mm in 10 min, 1 mm bore, 2 g.
5. Explain why dehydrogenation is oxidation. HL
6. Outline the four stages of glycolysis. HL
7. Explain how yeast make dough rise. HL
8. Outline what happens to pyruvate in the matrix. HL
9. Explain how chemiosmosis makes ATP. HL
10. Explain why fat yields more energy per gram. HL

IN THE EXAM

Name the place and the carrier ("in the matrix, NAD is reduced"). Lactate and ethanol only **give NAD back**.

GO FURTHER

Animated figures, a dry lab and a marked Check are in the full guide online.