Bioenergetics & Metabolic Foundations

BCH 100 — Introductory Biochemistry · Dr. Radi

By the end of this unit, you can…

- Interpret ΔG (with ΔH, ΔS) to judge spontaneity, and explain reaction coupling
- Describe ATP as the energy currency — its bonds, the ATP/ADP cycle, and food-energy connection
- Explain cofactors, coenzymes, and the electron carriers NADH, $FADH_2$, and CoA (and their vitamin origins)
- Map the stages of catabolism and anabolism and the hormones that regulate them

Today's route

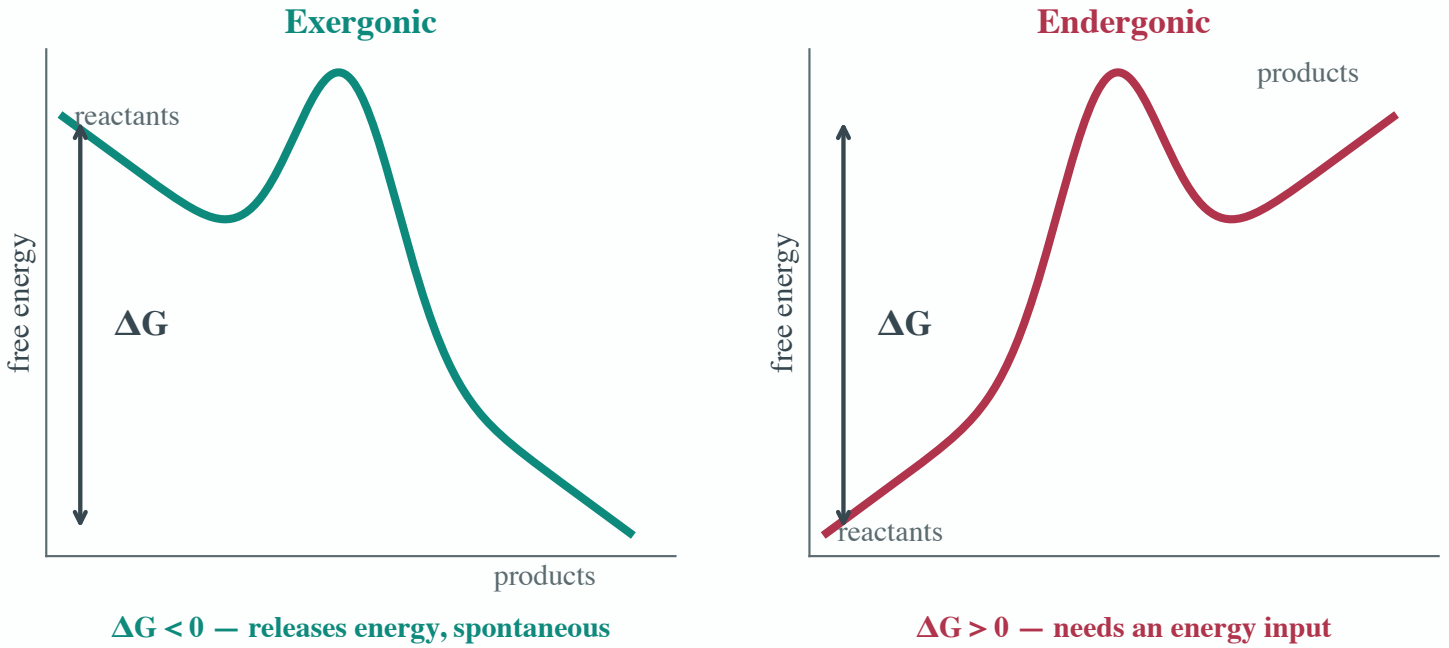
1. Bioenergetics – Free Energy & Coupling
2. ATP – The Cell's Energy Currency
3. Coenzymes, Cofactors & Electron Carriers
4. The Stages of Metabolism

1 · Bioenergetics — Free Energy & Coupling

"Use ΔG to tell which reactions run on their own — and how the cell pays for the ones that don't."

Does a reaction go? Ask ΔG

Whether a reaction runs downhill is set by its **free energy**: **ΔG = ΔH − TΔS** — the heat released (**ΔH**) minus the disorder created (**TΔS**). **ΔG < 0** is **exergonic** and goes on its own; **ΔG > 0** is **endergonic** and needs a push.



💡 ΔG says nothing about **speed** — that's the enzyme's job. It only says which way is downhill.

Coupling: let ATP pay for it

Cells run uphill reactions constantly — they just **pay for them**. Bolt an endergonic reaction onto the big **exergonic** hydrolysis of **ATP**, and because they share a step the **ΔG°′ values add up**. Uphill + a bigger downhill = **net downhill**.

glucose + Pi → glucose-6-P — **ΔG°′ = +13.8**

uphill alone ✗

ATP → ADP + Pi — **ΔG°′ = –30.5**

the driver

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glucose + ATP → glucose-6-P + ADP — **ΔG°′ = –16.7**

downhill — GO! ✓

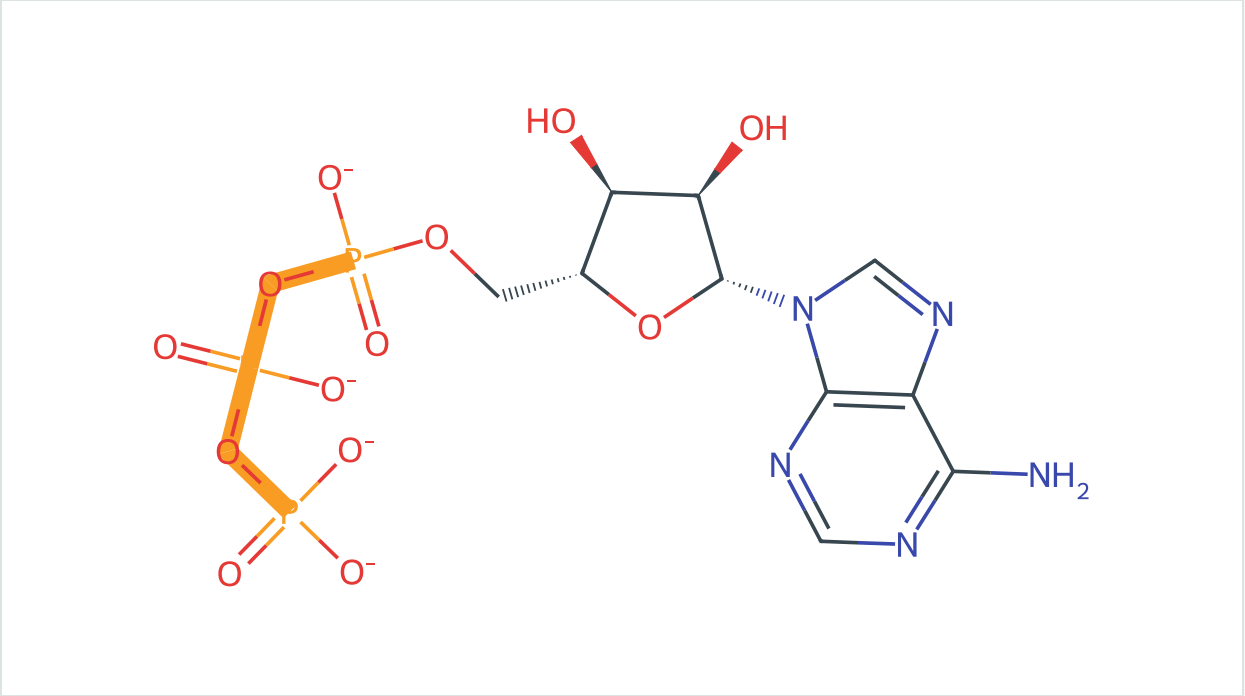
couple them and the shared ΔG°′ adds up: +13.8 – 30.5 = –16.7 kJ/mol

2 · ATP — The Cell's Energy Currency

"Meet ATP — why its phosphate bonds store energy, how the ATP/ADP cycle spends it, and where the Calories on a label go."

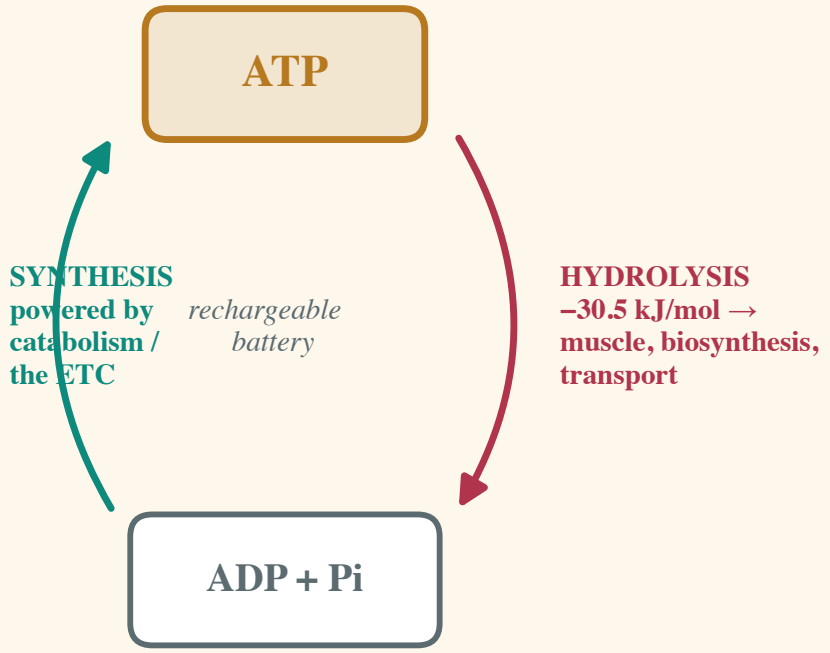
ATP: adenine, ribose, and three phosphates

ATP is adenosine with a **triphosphate** tail. The energy lives in the two **phosphoanhydride bonds** linking the phosphates — cram three negative phosphates together and they **repel**, so snapping one off releases a lot of energy.



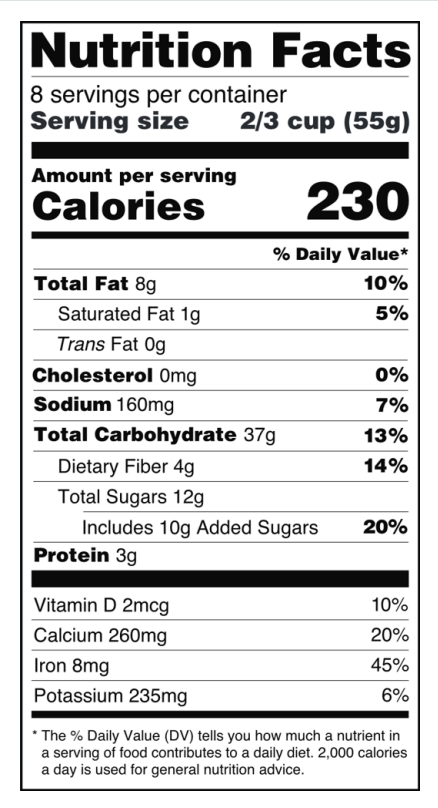
The ATP ⇌ ADP cycle

ATP is a **rechargeable battery**, not a storage tank. Hydrolyzing it to **ADP + Pi** releases **−30.5 kJ/mol** to power muscle, biosynthesis, and transport; catabolism (and the electron transport chain) **recharges** it. A cell turns over its **body weight in ATP** each day.



Where the Calories go

The **Calories** on a food label are just **fuel** — the energy your body harvests from fat, carbs, and protein and banks as **ATP**. That "230 Cal" is about **960 kJ** (1 Cal = 4.184 kJ) of chemical energy headed for the ATP cycle.



Nutrition Facts

8 servings per container

Serving size **2/3 cup (55g)**

Amount per serving

Calories **230**

	% Daily Value*
Total Fat 8g	**10%**
Saturated Fat 1g	**5%**
Trans Fat 0g	
Cholesterol 0mg	**0%**
Sodium 160mg	**7%**
Total Carbohydrate 37g	**13%**
Dietary Fiber 4g	**14%**
Total Sugars 12g	
Includes 10g Added Sugars	**20%**
Protein 3g	
Vitamin D 2mcg	10%
Calcium 260mg	20%
Iron 8mg	45%
Potassium 235mg	6%

* The % Daily Value (DV) tells you how much a nutrient in a serving of food contributes to a daily diet. 2,000 calories a day is used for general nutrition advice.

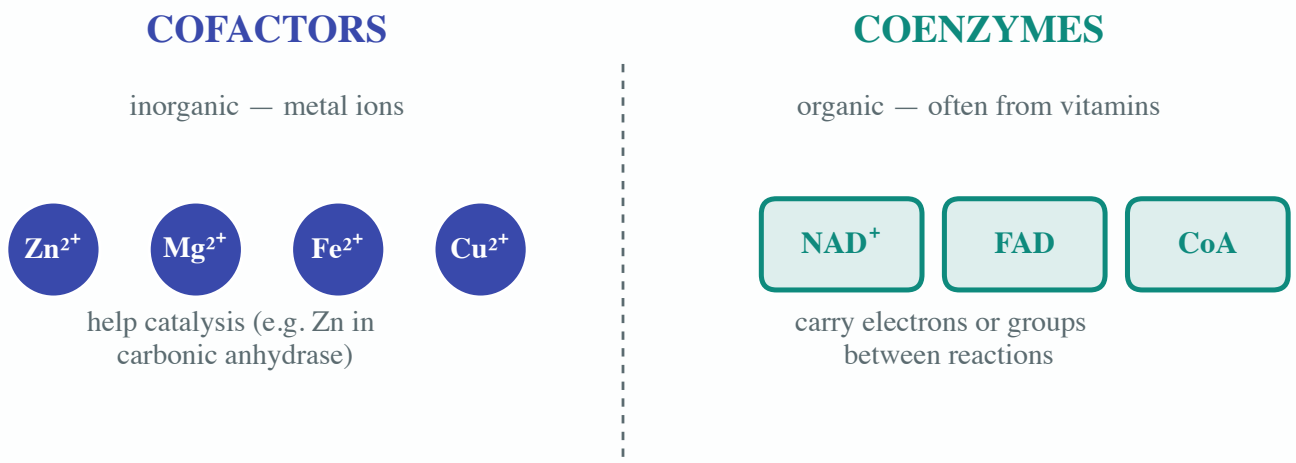
Nutrition Facts label: U.S. FDA, public domain (Wikimedia Commons)

3 · Coenzymes, Cofactors & Electron Carriers

"Meet the enzyme's helpers — metal cofactors, organic coenzymes, and the NADH / $FADH_2$ / CoA that shuttle electrons and groups."

Cofactors vs coenzymes

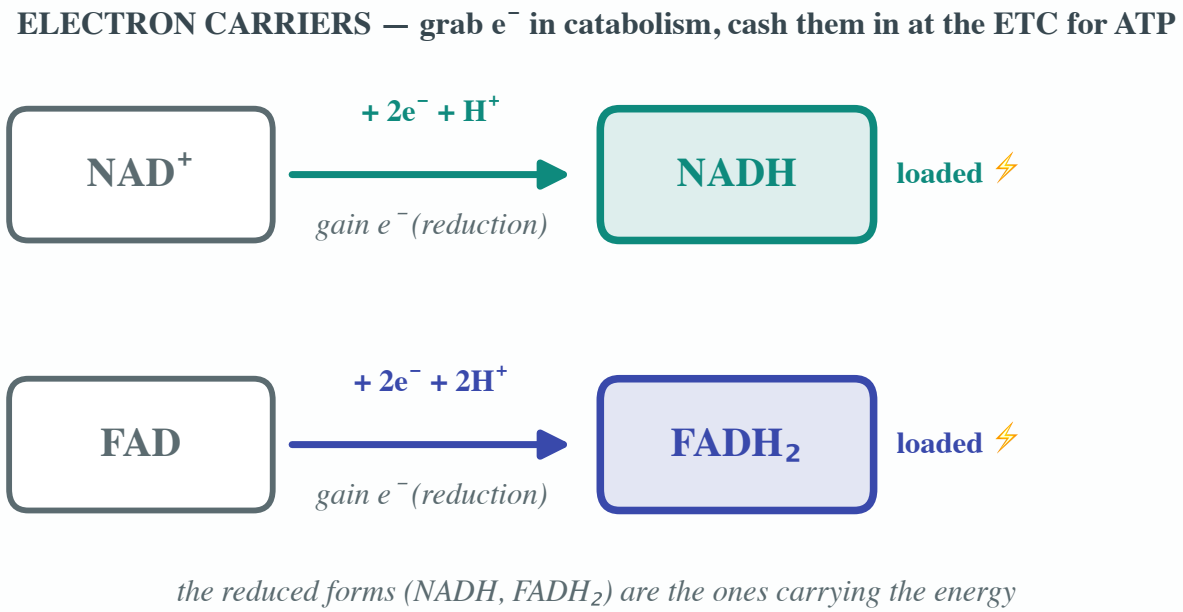
Many enzymes can't work alone — they need a non-protein **helper**. **Cofactors** are **inorganic** (metal ions like Zn^{2+}, Mg^{2+}, Fe^{2+}); **coenzymes** are small **organic** molecules, often built from **vitamins**. Both sit in the active site and make catalysis happen.



both are non-protein helpers an enzyme needs to work

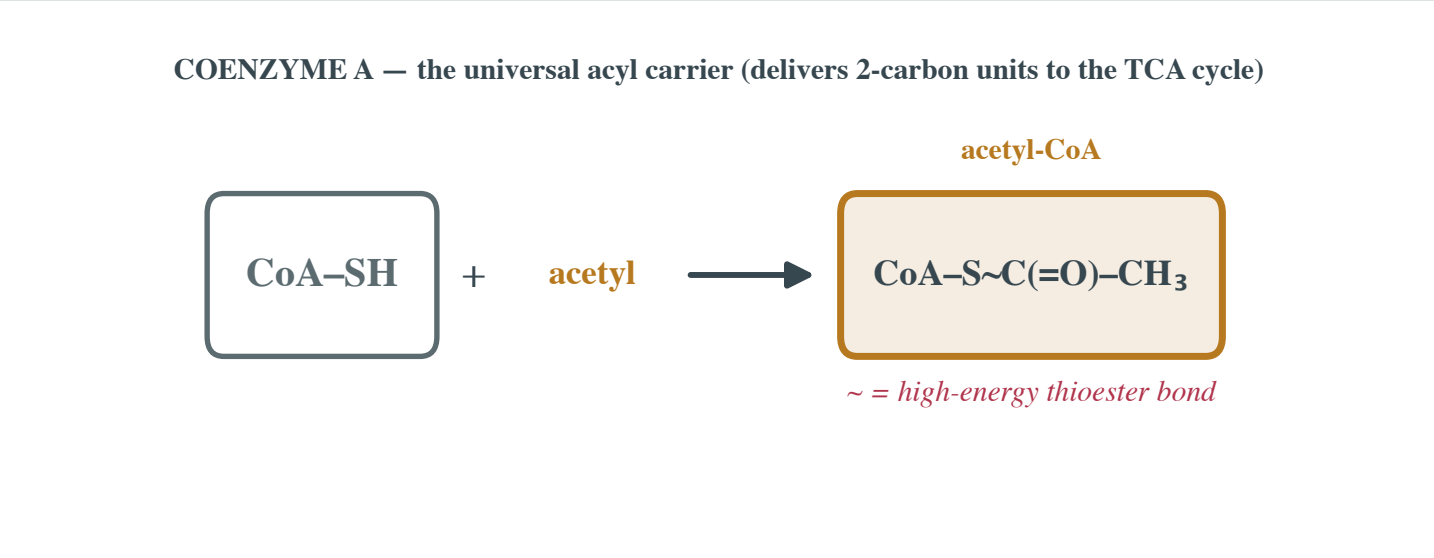
NAD^+ and FAD: the electron taxis

Catabolism strips **electrons** off fuel, and **NAD^+** and **FAD** catch them — becoming **NADH** and **$FADH_2$**. The reduced, "loaded" forms carry that energy to the **electron transport chain**, where it's cashed in to make ATP.



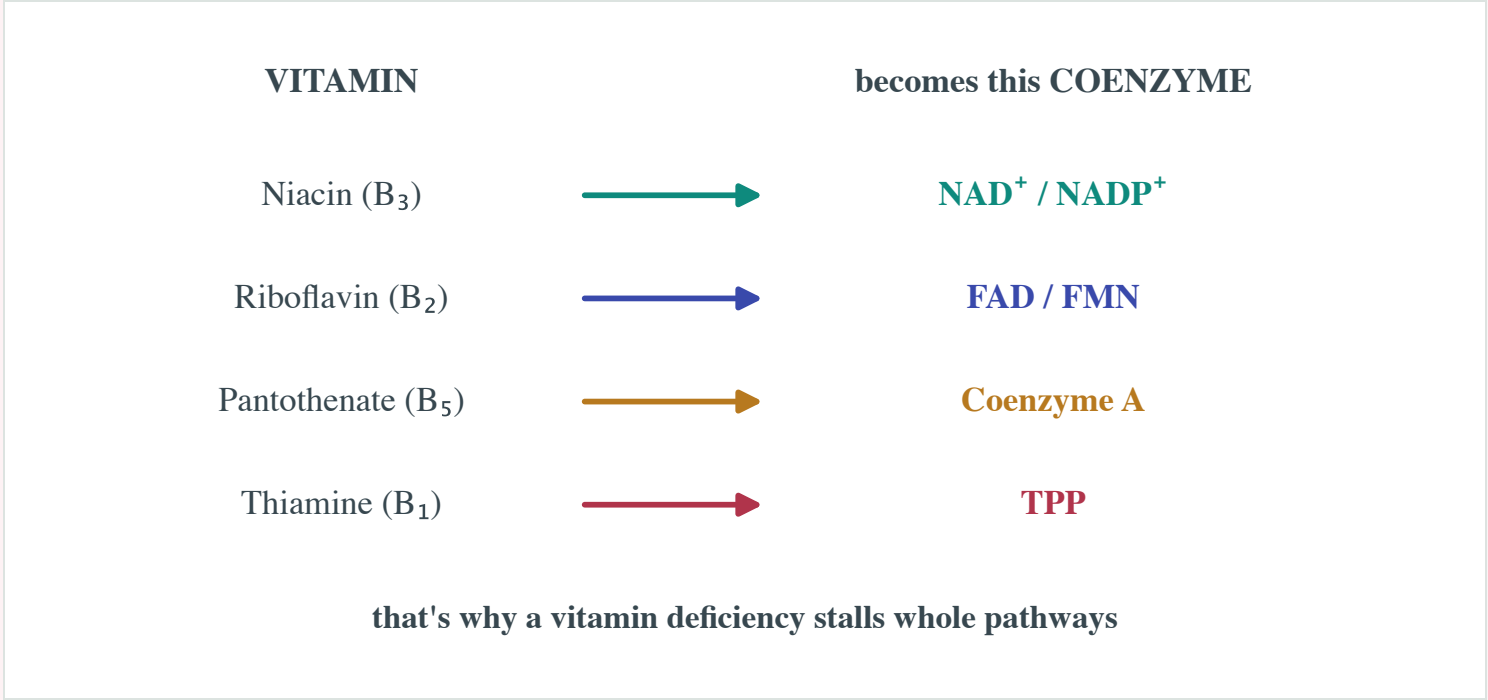
Coenzyme A: the acyl carrier

Coenzyme A carries **acyl groups** on a reactive **–SH** end. Load it with a 2-carbon acetyl group and you get **acetyl-CoA** — the high-energy **thioester** that feeds carbons into the TCA cycle.



Why you need your vitamins

Most coenzymes are **built from water-soluble vitamins** – niacin → NAD^+, riboflavin → FAD, pantothenate → CoA. That's why a **vitamin deficiency** doesn't break one reaction; it **stalls whole pathways** (think pellagra, beriberi).

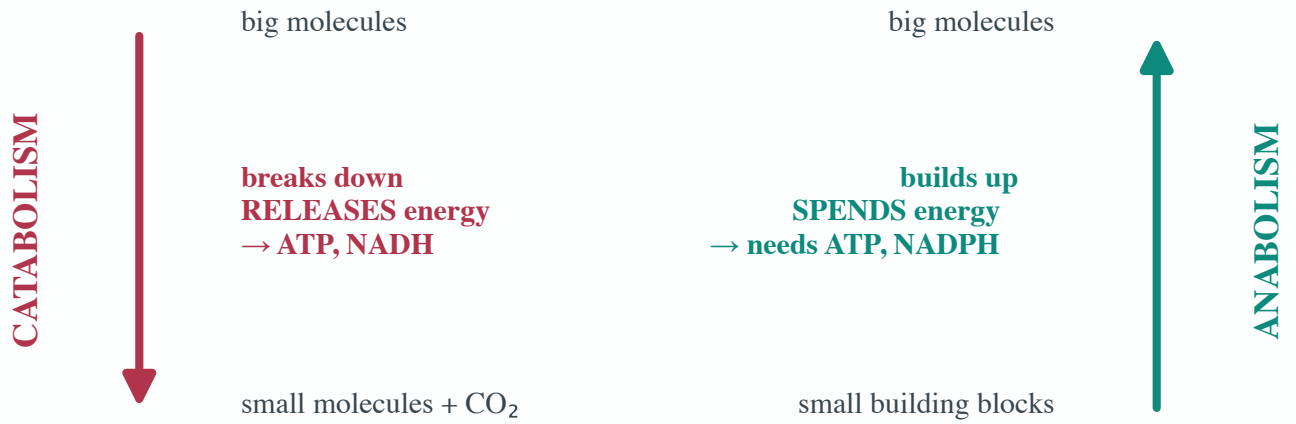


4 · The Stages of Metabolism

"Zoom out to the whole map — catabolism vs anabolism, the funnel down to acetyl-CoA, and the hormones that flip the switch."

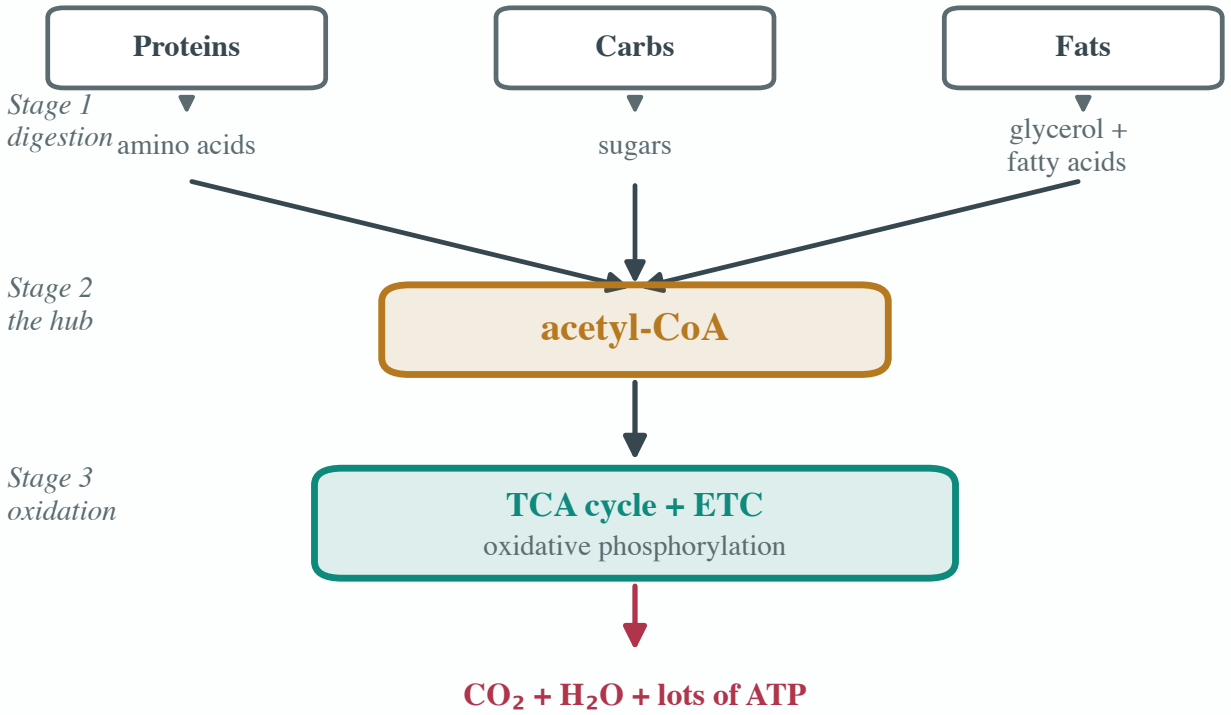
Two directions: catabolism & anabolism

Metabolism runs both ways. **Catabolism breaks big molecules down**, oxidizing them to **release energy** (making ATP and NADH). **Anabolism** runs the other way — **building** big molecules from small ones, **spending** ATP and NADPH to do it.



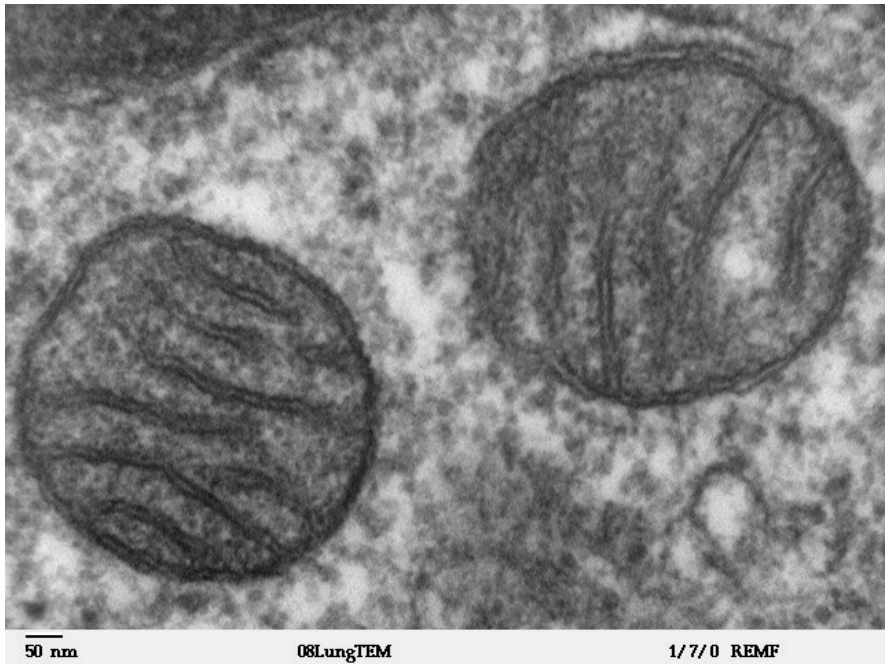
Everything funnels to acetyl-CoA

Catabolism runs in **three stages**: **(1)** digestion chops proteins, carbs, and fats into building blocks; **(2)** those converge on one hub, **acetyl-CoA**; **(3)** the **TCA cycle + electron transport chain** oxidize it fully to **CO_2 + H_2O + lots of ATP**.



Where it happens: the mitochondrion

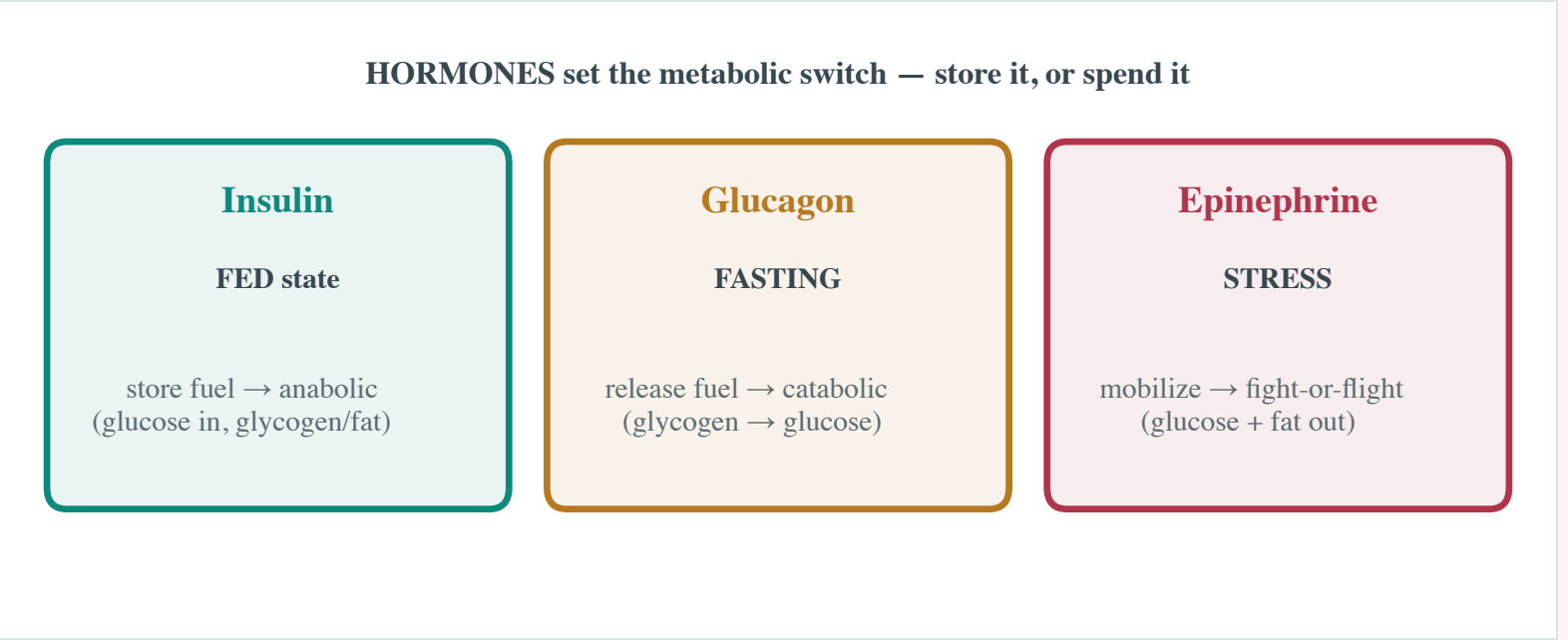
Much of this runs inside the **mitochondrion** — you can see its folded inner membrane (**cristae**) in this real electron micrograph. Those folds are studded with the **electron transport chain**, while the **matrix** they enclose runs the **TCA cycle** — together turning fuel into ATP.



TEM: Louisa Howard, public domain (Wikimedia Commons)

Hormones flip the switch

Your body decides **store or spend** with hormones. **Insulin** (fed) says **store** — anabolic. **Glucagon** (fasting) says **release** — catabolic. **Epinephrine** (stress) says **mobilize now** — the fight-or-flight surge of glucose and fat.



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- ☐ map the stages of catabolism and anabolism and the hormones that regulate them?

If any box stays empty, the practice site has a drill for it.
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