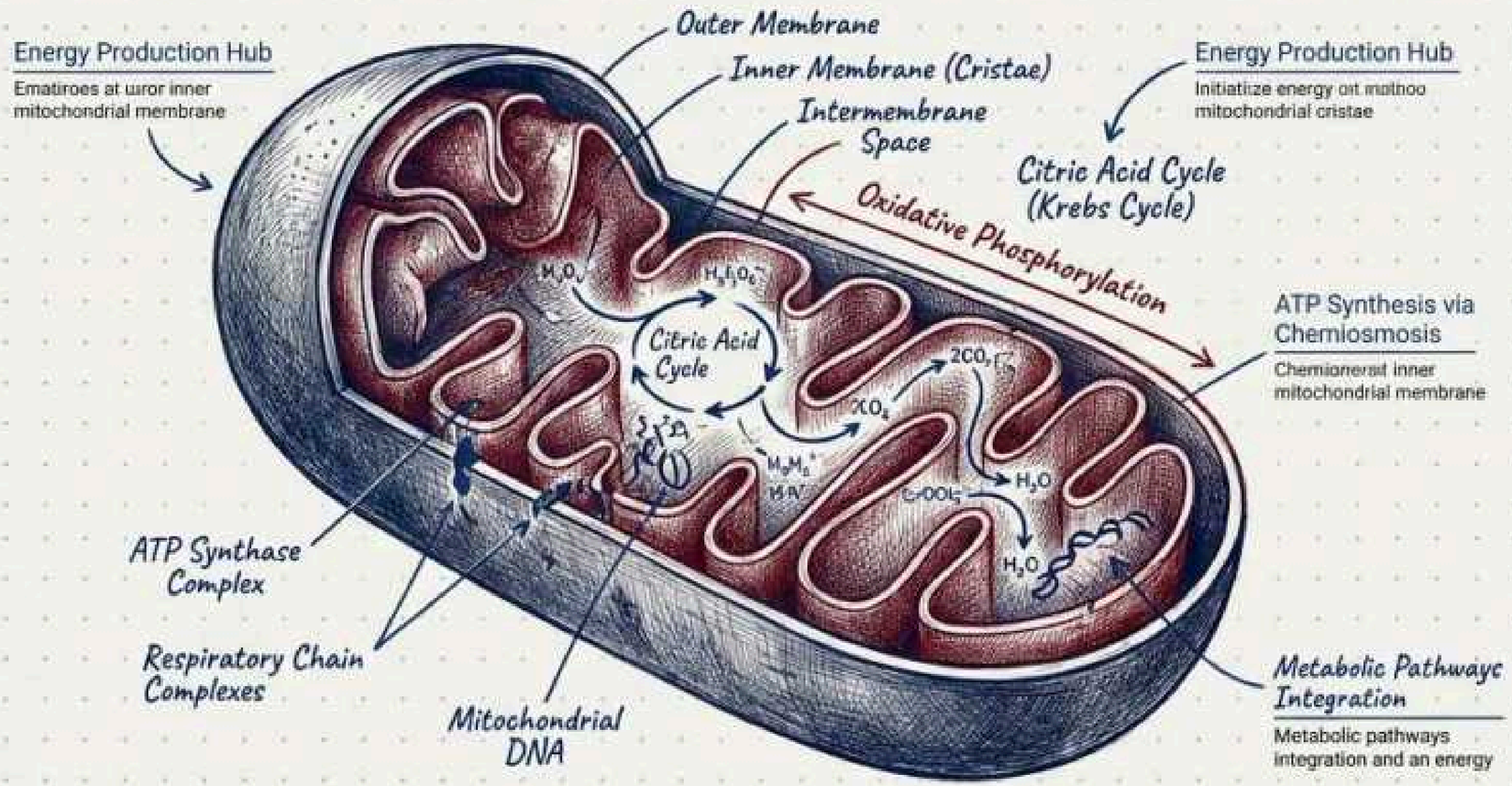
Lecture 3: Mitochondria

The Citric Acid Cycle and Oxidative Phosphorylation



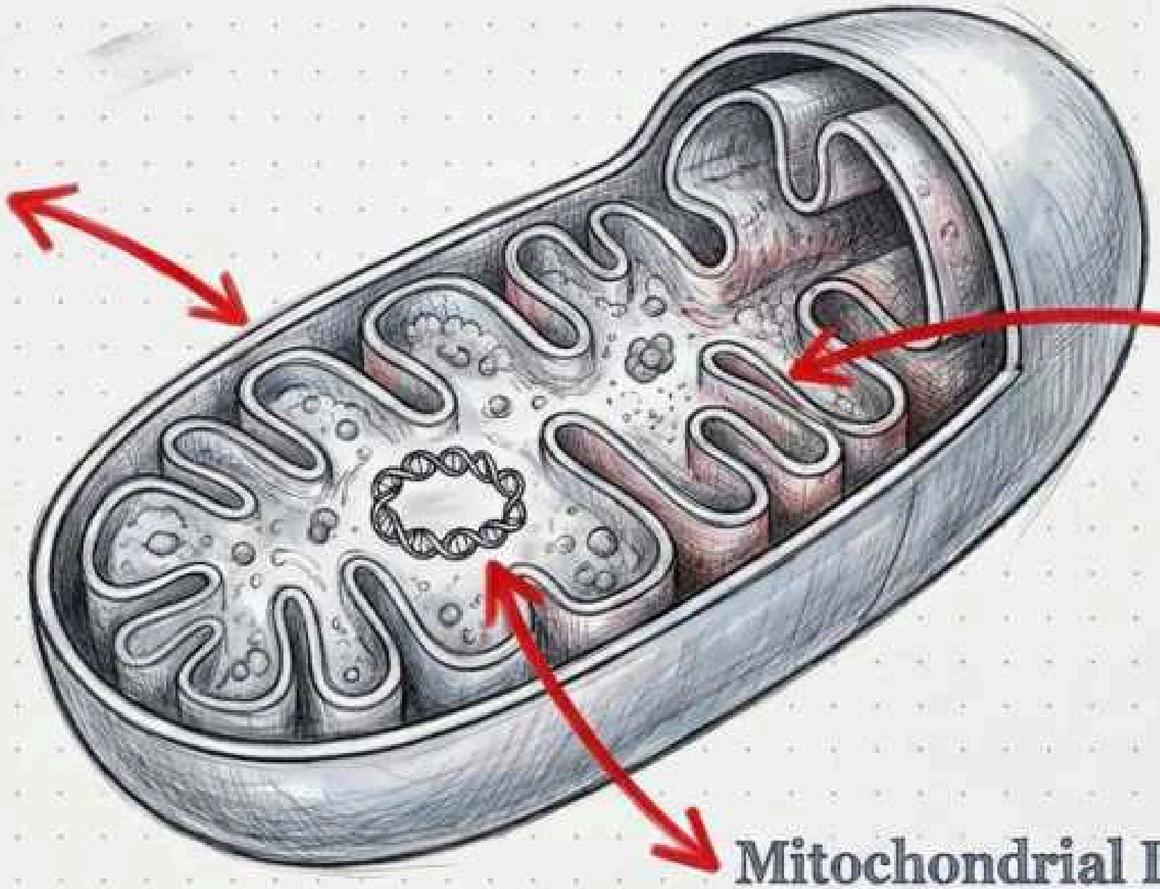
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Cellular Power Stations

¶ 3.1

Outer Membrane:

Smooth external boundary.

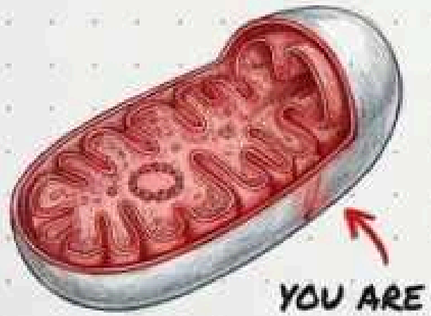


Inner Membrane & Cristae:

Deeply folded structures called cristae create a massive surface area where most ATP is generated.

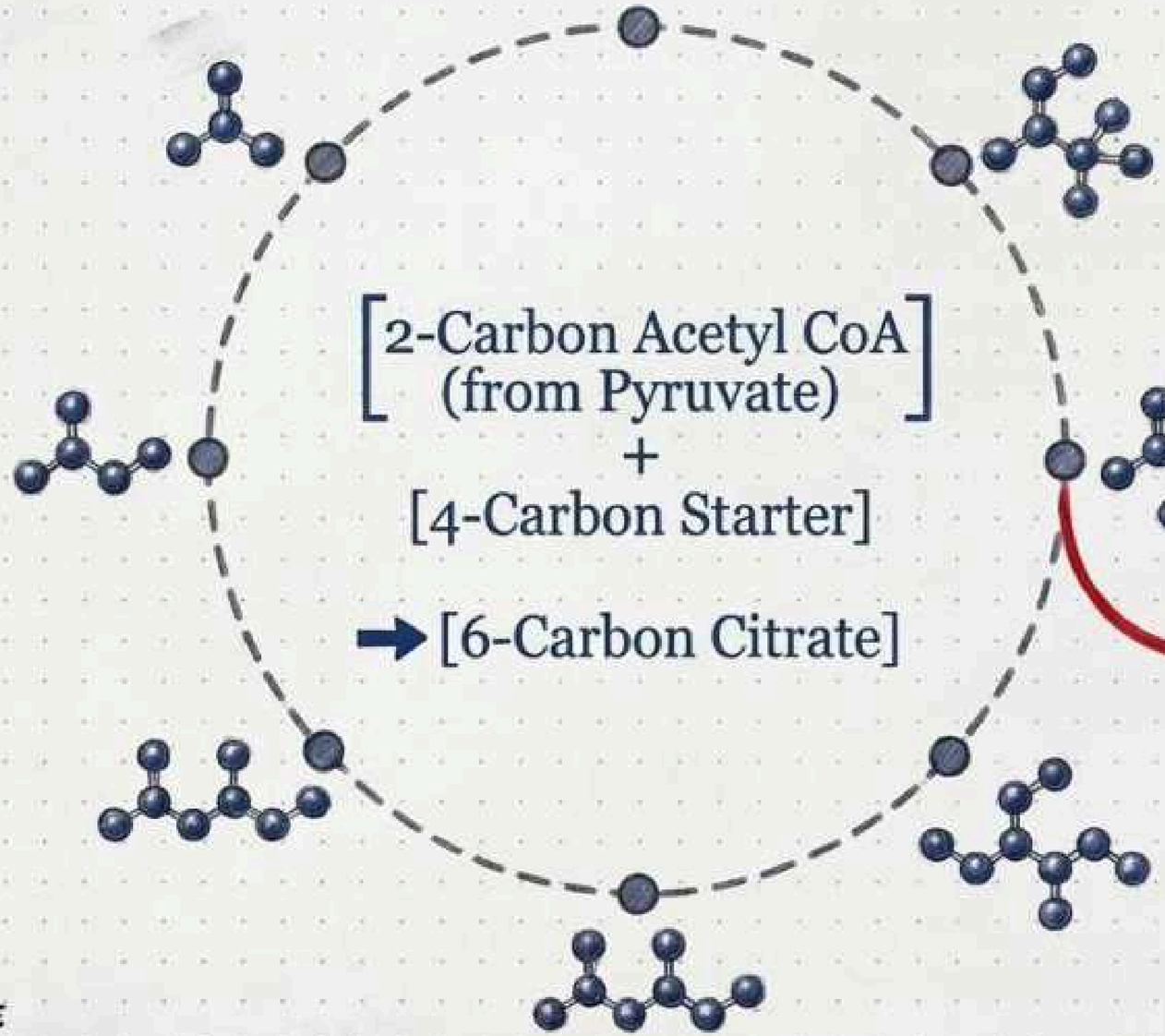
Mitochondrial DNA:

A tiny circular loop of DNA.
A biological reminder that mitochondria descended from ancient endosymbiotic bacteria living inside other cells.



Stage 1: The Citric Acid Cycle (Krebs Cycle)

¶ 3.2



In a ring of eight steps, the 6-Carbon Citrate is dismantled to regenerate the 4-Carbon starter, ready for the next turn.

- 2 CO_2
(Released as waste).



YOU ARE HERE

The Hub and the Batteries

Fats & Amino Acids

Krebs cycle

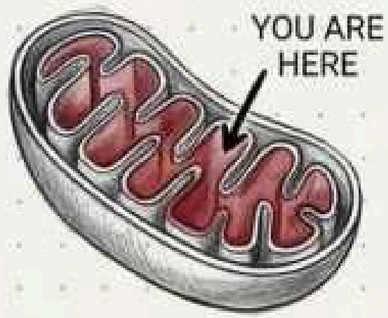
NADH

$FADH_2$

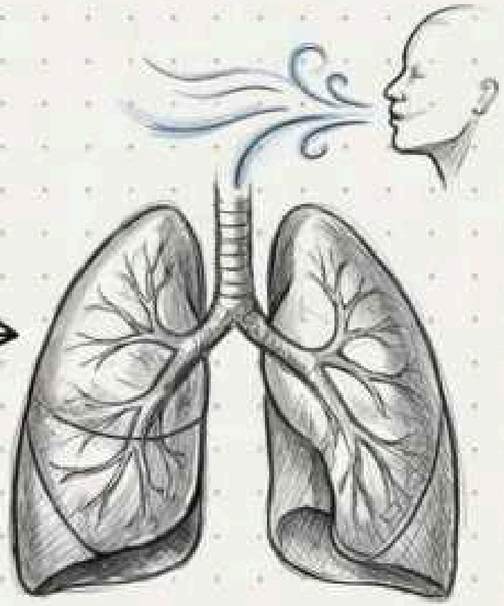
The Main Product: A set of loaded electron carriers: NADH and $FADH_2$.

Function: Think of these as charged batteries carrying high-energy electrons stripped from the fuel.

Direct Output: The cycle itself makes only a little ATP directly. Some molecules are drawn off to build other substances.

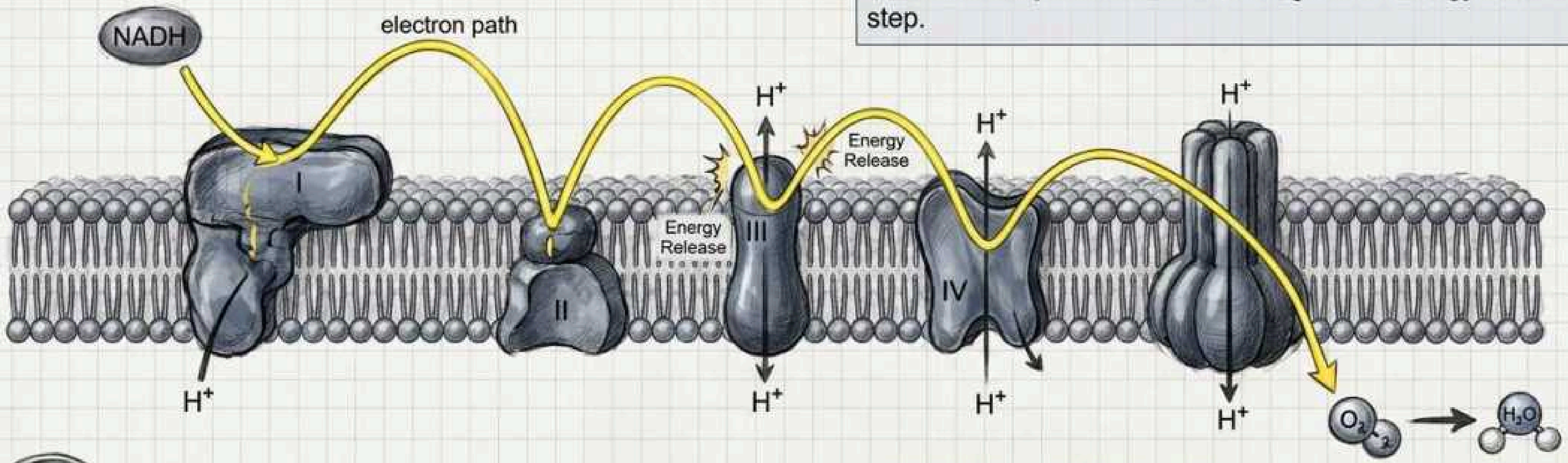


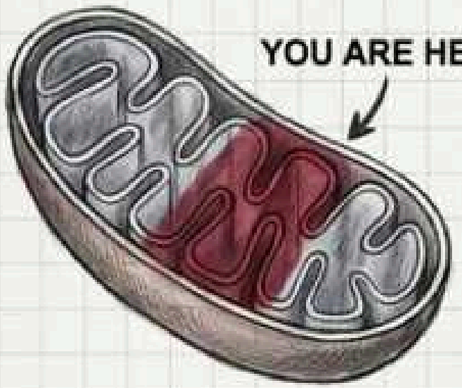
The carbon dioxide you breathe out comes largely from this cycle.



Stage 2: The Electron Transport Chain (ETC)

The Mechanism: Loaded carriers hand their high-energy electrons to the first protein complex. The electrons pass from one complex to the next, losing a little energy at each step.



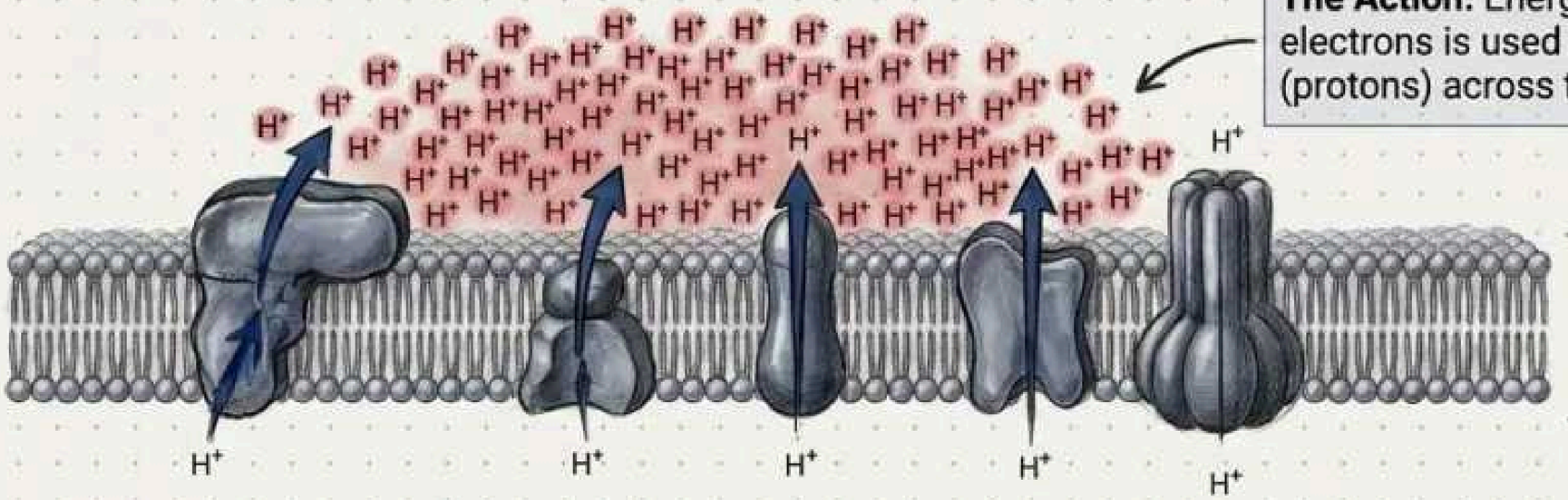


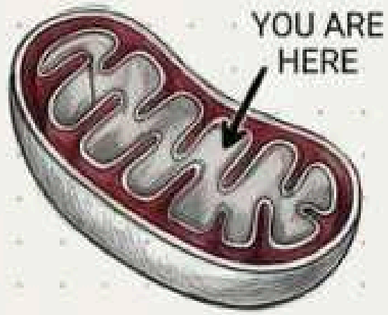
The Final Acceptor: Oxygen. It catches the electrons at the end of the chain and combines with hydrogen to form water.

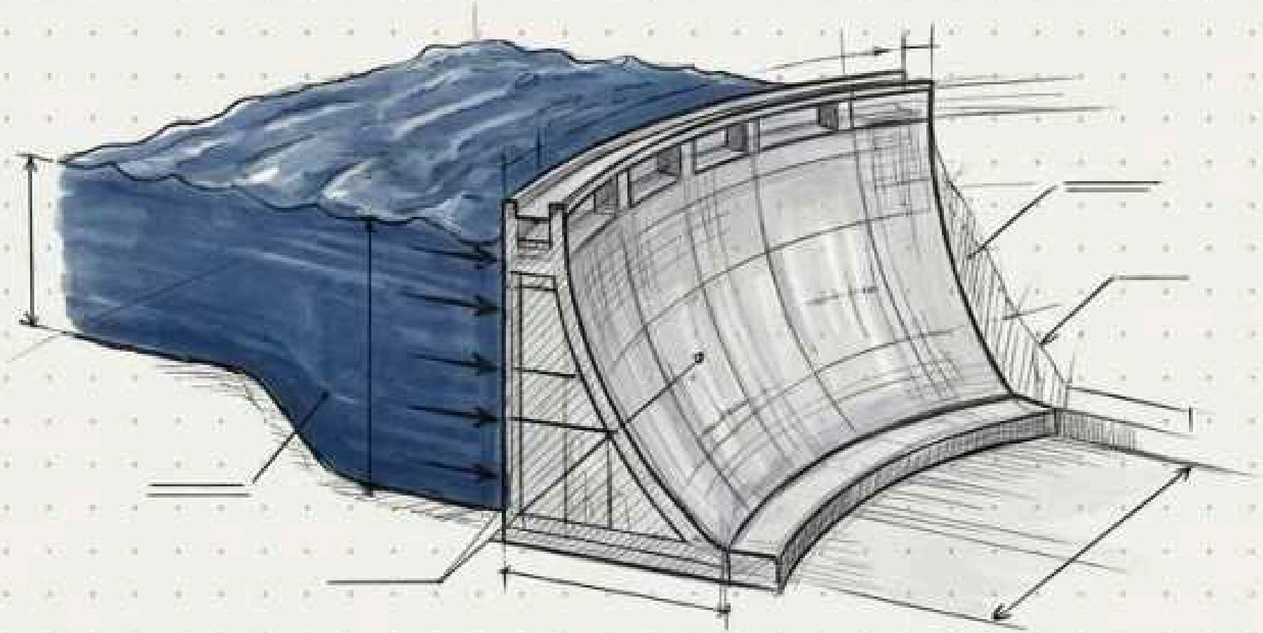
Key Insight: This is why we need to breathe: oxygen is the final acceptor of the electrons from our food.

Pumping the Gradient

The Action: Energy released by the moving electrons is used to pump hydrogen ions (protons) across the inner membrane.





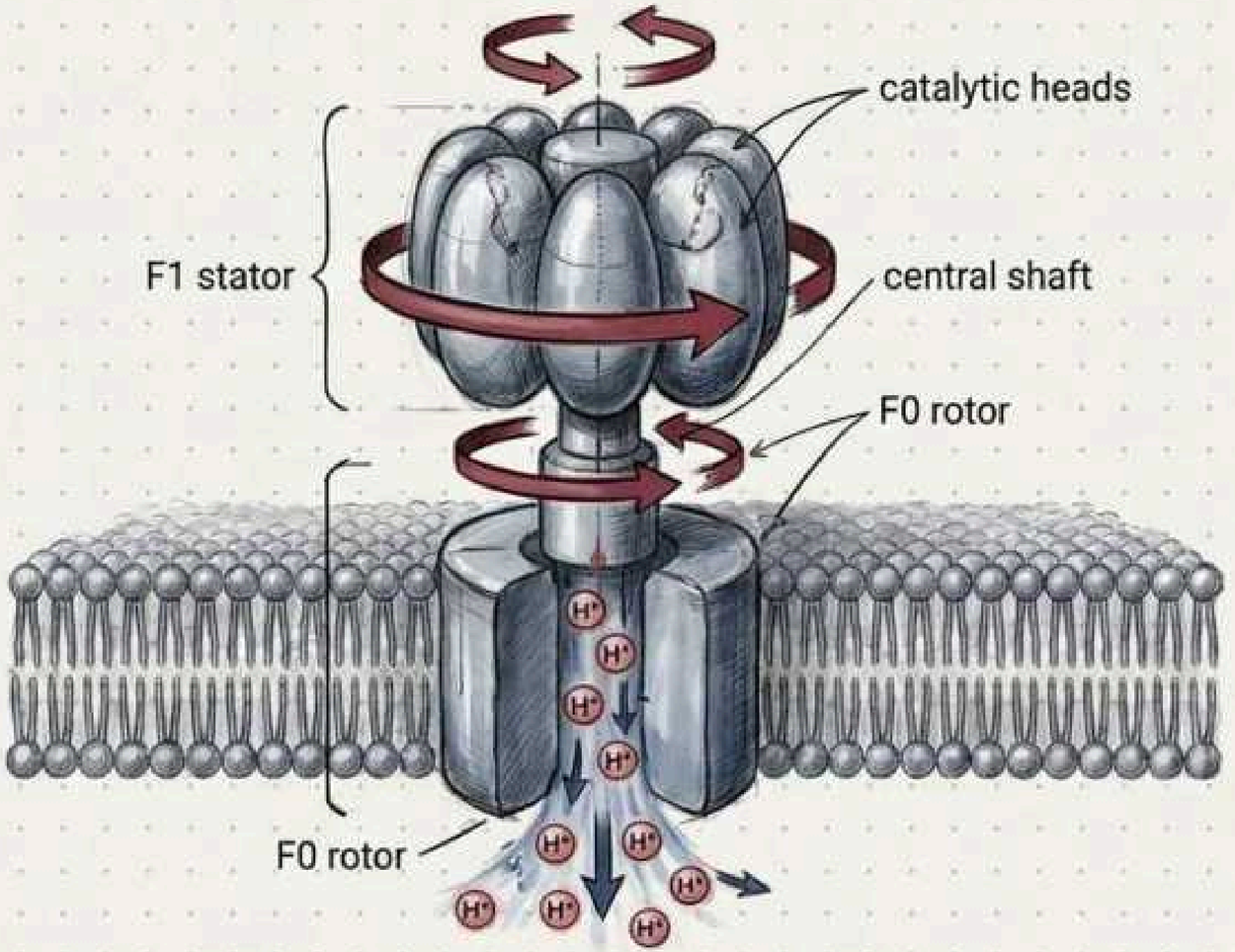


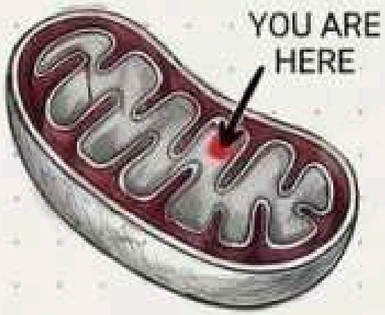
The Result: This builds a massive concentration difference and an electrical charge across the membrane.

Stored Energy: The membrane does not let protons leak back easily. Just like water piling up behind a dam, the energy is held ready for use.

ATP Synthase and Chemiosmosis

The Turbine: Protons flow back through a remarkable enzyme called ATP synthase. Part of the enzyme physically rotates as protons pass through.

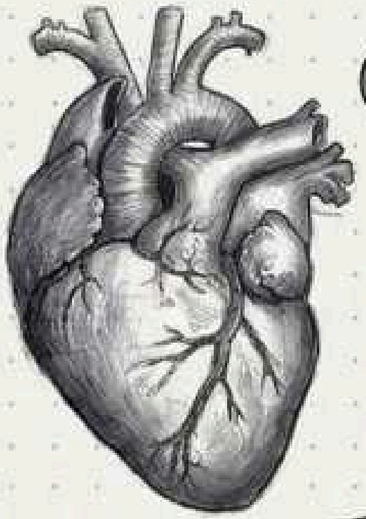




Rotation + ADP + Phosphate ➡ ATP

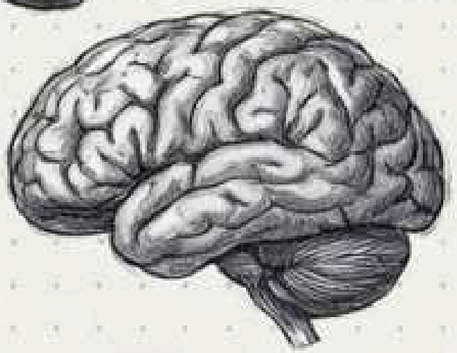
The Chemiosmotic Theory: This entire process—linking electron transport to ATP production through a proton gradient—is called Oxidative Phosphorylation.

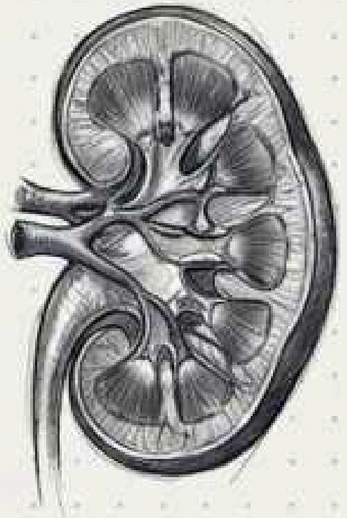
The Energy Yield



Glycolysis Alone = 2 ATP per glucose

Citric Acid Cycle + Oxidative Phosphorylation =





~30 ATP per glucose

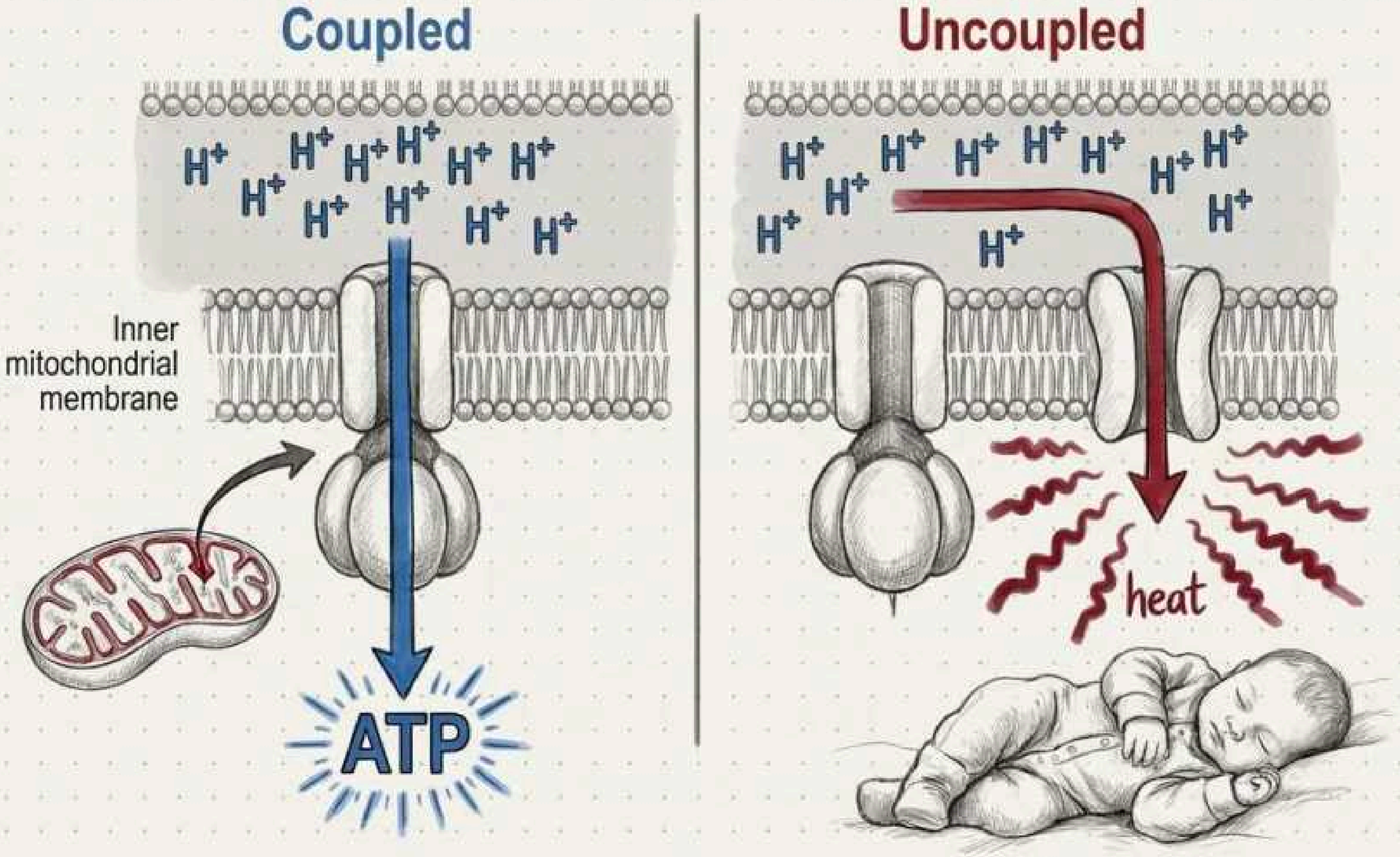
Physiological Impact: The complete burning of one glucose molecule yields many times more energy. Tissues that work hard and continuously (heart, brain, kidneys) are packed with mitochondria and depend entirely on a constant supply of oxygen to maintain this yield.

System Failure: Blocking the Pathway

Because this process is so central, blocking it is deadly.

Cyanide	Carbon Monoxide (CO)
• **Target:** Binds to the final complex of the Electron Transport Chain.	• **Target:** Binds tightly to haemoglobin in the blood.
• **Mechanism:** Stops electrons from reaching oxygen.	• **Mechanism:** Prevents oxygen from being transported in the first place.
• **Outcome:** Cells cannot use oxygen even when plenty is present. Tissues with high energy needs fail quickly.	• **Outcome:** Less oxygen is delivered to the tissues, starving the mitochondria entirely.

Uncoupling and Thermogenesis



The Leak:

Some substances uncouple the process, letting protons leak back across the membrane without passing through ATP synthase.

The Result:

Energy is released as heat instead of being captured as ATP.

Biological Application:

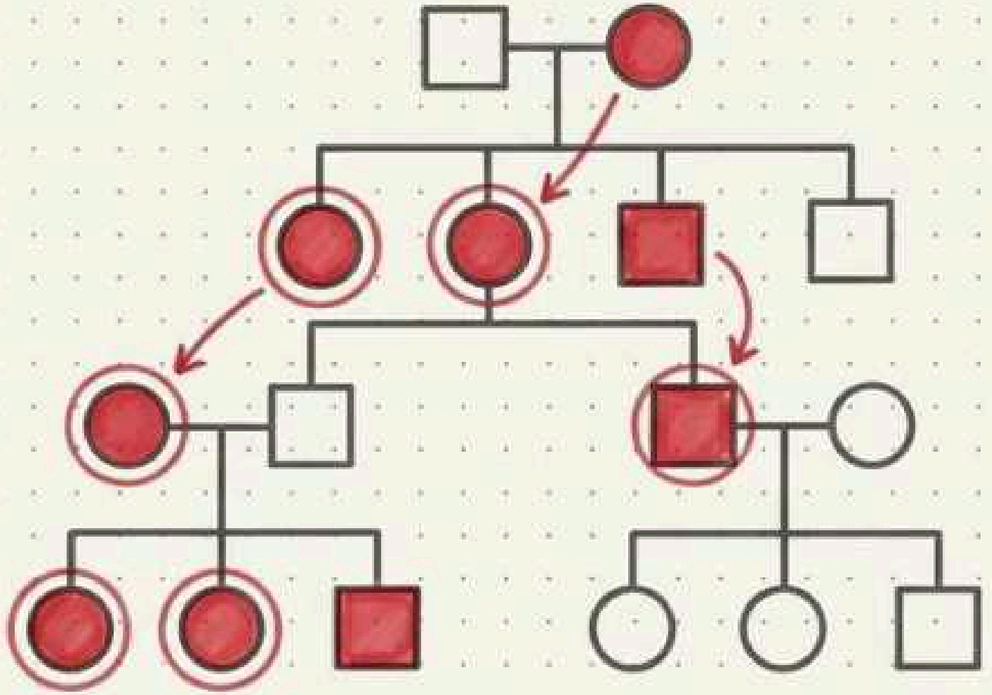
Deliberately used in brown fat (a special tissue in infants, and some adults) to generate heat and keep the body warm.

Warning:

Chemical uncoupling can cause a dangerous, fatal rise in body temperature.

Mitochondrial Genetics & Disease





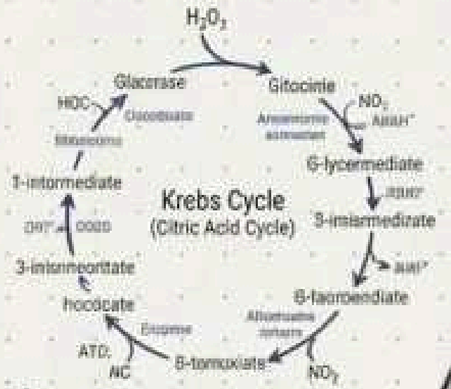
The Pathology: Rare inherited disorders caused by faults in mitochondrial DNA (or supporting nuclear genes) primarily affect energy-hungry tissues like muscle and brain.

Maternal Inheritance: Because a baby's mitochondria come almost entirely from the mother's egg, disorders of mitochondrial DNA are passed strictly down the maternal line.

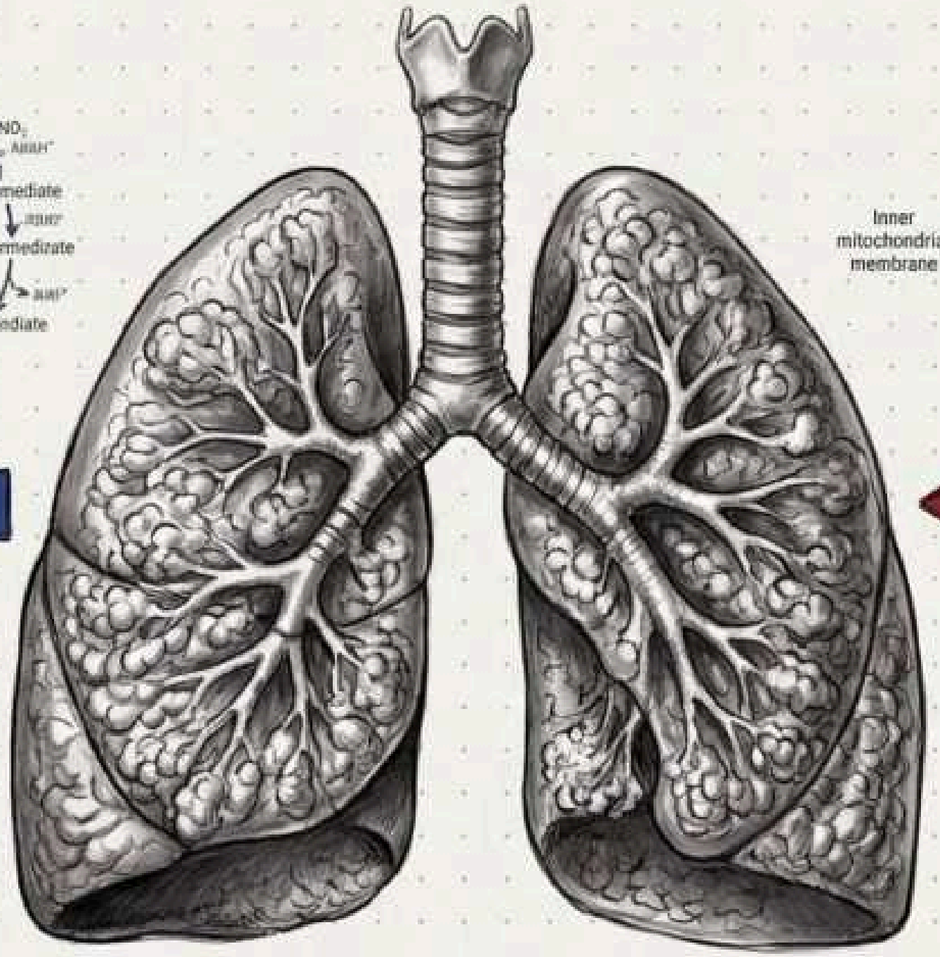
Note: The Genetics course (Medicine 503 B) returns to these patterns.

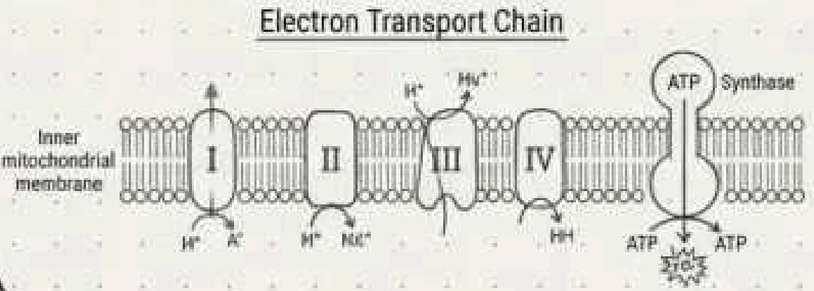
The Respiration Synthesis

¶ 3.11



CO_2



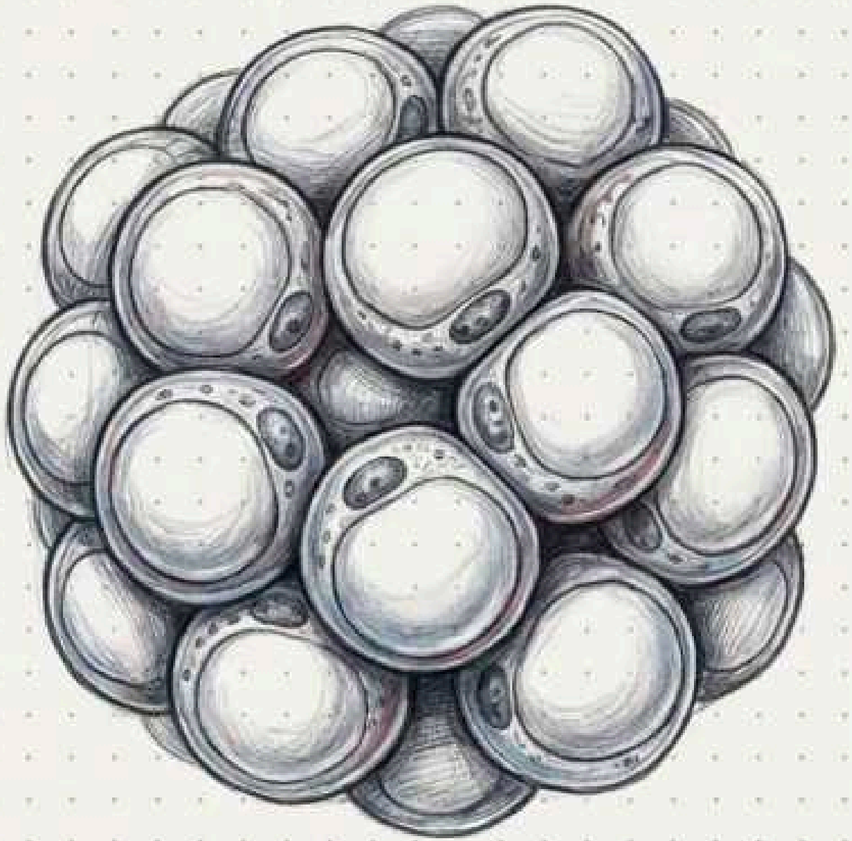


O_2

Why we breathe out Carbon Dioxide:
The Citric Acid cycle inside our mitochondria constantly strips carbon from our fuel to extract high-energy electrons, releasing the remaining carbon as CO_2 waste.

Why we breathe in Oxygen:
The Electron Transport Chain absolutely requires O_2 to sit at the end of the line and act as the final catcher for those energy-depleted electrons. Without O_2, the entire chain backs up and halts.

Looking Ahead



Next Module (Lecture 4): Fat as the Body's Great Energy Store.



Core Concept: We will explore how the human body dynamically switches metabolic gears between the states of feeding and fasting.