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Biological oxidation

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Biological Oxidation

Biological oxidation is the process by which.....

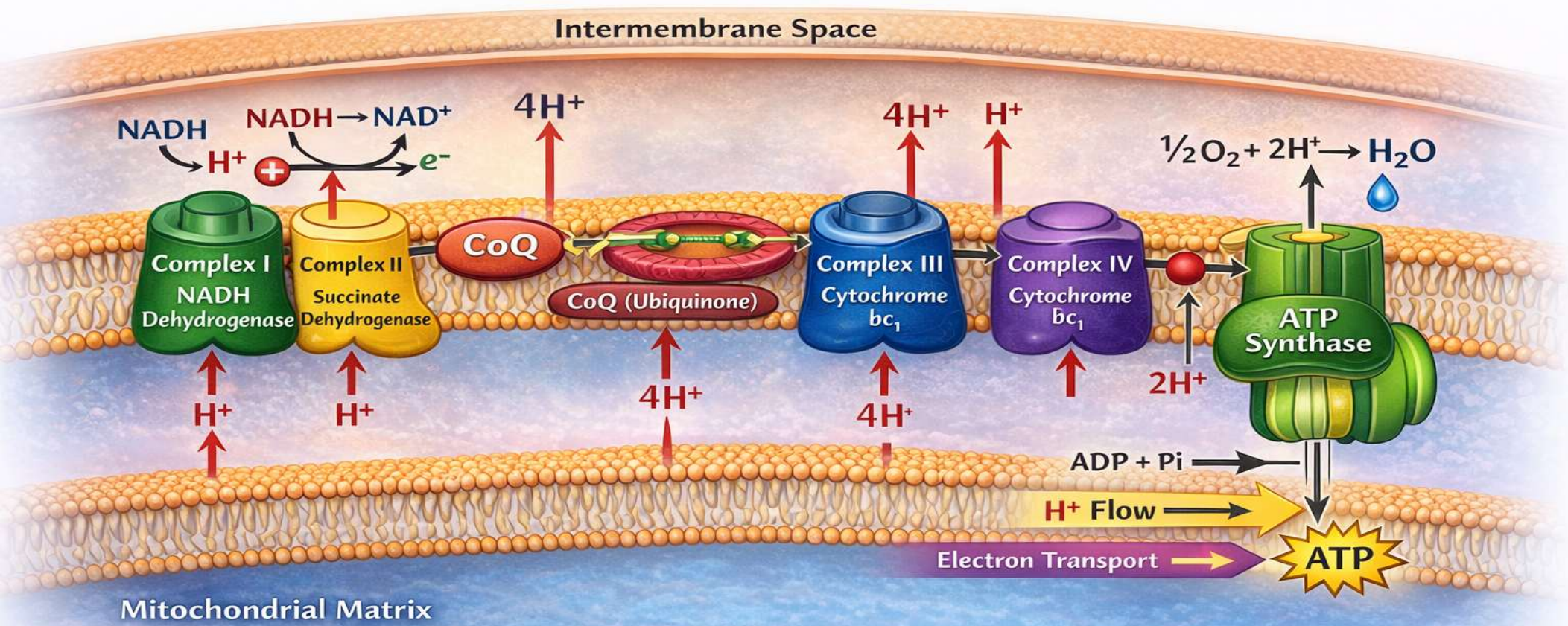
Cells break down nutrients like carbohydrates, lipids, and proteins to release and store energy as **ATP**.

Electron transport chain

The **Electron Transport Chain (ETC)** is the final and most productive stage of cellular respiration. It acts like a power plant, converting energy from the food you eat into a form your cells can use, called ATP.

Think of the ETC as a **bucket brigade** or a **relay race** where electrons are passed from one runner to the next until they reach the finish line.

Electron Transport Chain (ETC) in the Inner Mitochondrial Membrane



Complex I NADH Dehydrogenase	Complex II Succinate Dehydrogenase	Complex III Cytochrome bc_1	Complex IV Cytochrome c Oxidase	H^+ Flow \rightarrow ATP
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A. Intermembrane Space

Protons, or H⁺ ions, are **pumped** into the intermembrane space by the protein complexes, creating an electrochemical gradient across the inner mitochondrial membrane.

B. Inner Membrane

The **inner mitochondrial membrane** is where the protein complexes and electron carriers are embedded. It separates the intermembrane space from the mitochondrial matrix and is the site of ATP synthesis.

C. Matrix

The **mitochondrial matrix** is where the citric acid cycle, or Krebs cycle, occurs, producing the NADH and FADH₂ that fuel the electron transport chain. ATP is synthesized from ADP and Pi in the matrix.



1. Complex I

Complex I, or **NADH dehydrogenase**, is the first protein complex in the electron transport chain. It receives electrons from NADH, which is oxidized to NAD⁺, and pumps protons into the intermembrane space.

2. Complex II

Complex II, or **succinate dehydrogenase**, It receives electrons from FADH₂, which is oxidized to FAD. Unlike the other complexes, it does not pump protons across the membrane.

3. Coenzyme Q

Coenzyme Q, also known as ubiquinone, is a mobile electron carrier that shuttles electrons from Complexes I and II to Complex III. Coenzyme Q is a quinone that becomes ubiquinol when it accepts electrons.



4. Complex III

Complex III, or **cytochrome c reductase**, receives electrons from coenzyme Q and pumps protons across the inner mitochondrial membrane. It then transfers the electrons to cytochrome c.

5. Cytochrome C

Cytochrome c is another mobile electron carrier that transports electrons from Complex III to Complex IV. It is a small heme protein found loosely attached to the inner mitochondrial membrane.

6. Complex IV

Complex IV, or **cytochrome c oxidase**, is the final protein complex in the electron transport chain. It receives electrons from cytochrome c and transfers them to oxygen, which is reduced to water. Complex IV also pumps protons across the membrane.

7. ATP Synthase

ATP synthase is an enzyme that uses the electrochemical gradient of protons to synthesize ATP from ADP and inorganic phosphate. Protons flow back into the matrix through ATP synthase, driving the production of ATP in a process called chemiosmosis.



Inhibitors of Electron Transport Chain (ETC)

Inhibitor	Site of Action	Work (Effect)
Rotenone	Complex I	Blocks electron transfer from NADH to CoQ
Amytal	Complex I	Inhibits electron flow from NADH
Malonate	Complex II	Competitive inhibitor of succinate dehydrogenase
Antimycin A	Complex III	Blocks electron transfer to cytochrome c
Cyanide (CN ⁻)	Complex IV	Inhibits cytochrome oxidase, blocks O ₂ use
Carbon monoxide (CO)	Complex IV	Prevents oxygen binding
Sodium azide (N ₃ ⁻)	Complex IV	Stops electron transfer to oxygen

Oxidative Phosphorylation

Definition

Formation of ATP using energy released from the **Electron Transport Chain (ETC)** in presence of oxygen.

Location

Inner mitochondrial membrane

Mechanism (Simple Steps)

1. NADH & FADH₂ donate electrons to ETC.
2. Electrons pass through Complex I → II → III → IV.
3. Energy released pumps H⁺ (protons) into intermembrane space.
4. Proton gradient (electrochemical gradient) is formed.
5. H⁺ flows back through ATP synthase.
6. ADP + Pi → ATP formed.
7. Oxygen accepts electrons → H₂O formed.

Key Points

- ✓ Oxygen required
- ✓ ETC involved
- ✓ Produces maximum ATP (~26–28 ATP per glucose)

Inhibitors of Oxidative Phosphorylation (ATP Synthase Inhibitors)

Inhibitor	Site	Work
Oligomycin	ATP synthase (F ₀ unit)	Blocks proton channel → No ATP formation
DCCD	ATP synthase	Inhibits proton flow
Atractyloside	ADP/ATP translocase	Prevents ADP entry into mitochondria

Uncouplers of Oxidative Phosphorylation

Uncoupler	Work (Effect)
2,4-Dinitrophenol (DNP)	Carries H ⁺ across membrane → Destroys proton gradient
FCCP	Proton carrier → Collapses gradient
Thermogenin (UCP-1)	Produces heat in brown fat
High-dose aspirin	Acts as weak uncoupler

Substrate-Level Phosphorylation

Definition

Direct formation of ATP by transfer of phosphate from a high-energy substrate to ADP (Adenosine Diphosphate).

Location

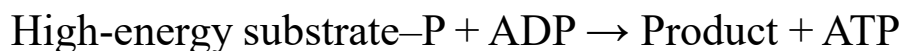
Glycolysis (cytoplasm)

Krebs cycle (mitochondria)

Mechanism (Simple Steps)

1. A high-energy phosphorylated substrate is formed.
2. An enzyme transfers its phosphate directly to ADP (or GDP).
3. ATP (or GTP) is formed immediately.

General Reaction:



Key Points

- ✓ No oxygen required
- ✓ No ETC involved
- ✓ Produces small amount of ATP

Oxidative v/s Substrate-Level Phosphorylation

Feature	Oxidative Phosphorylation	Substrate-Level Phosphorylation
Definition	ATP formed using energy from ETC	ATP formed by direct phosphate transfer
Oxygen	Required	Not required
ETC	Involved	Not involved
Location	Inner mitochondrial membrane	Cytoplasm & mitochondrial matrix
Mechanism	Proton gradient → ATP synthase	Direct enzyme-mediated transfer
ATP Yield	High (26–28 ATP/glucose)	Low (2–4 ATP total)
Example	NADH → ETC → ATP	PEP → Pyruvate

🎯 1-Line Difference (Very Important)

👉 Oxidative phosphorylation depends on oxygen and proton gradient.

👉 Substrate-level phosphorylation is direct ATP formation without oxygen.



Thank you

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