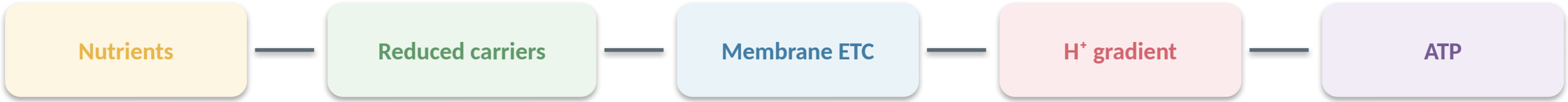
Oxidative phosphorylation



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Why cells transfer electrons

Electron transfer links nutrient oxidation to ATP synthesis.



Biological idea

Energy from nutrients is captured stepwise. Reduced carriers deliver electrons to a membrane system that converts electron-transfer energy into ATP production.

Oxidation and reduction — a biological view

Redox reactions always occur as a pair.

OXIDATION

Loss of electrons
A reduced molecule donates electrons and becomes more oxidized.

REDUCTION

Gain of electrons
An oxidized molecule accepts electrons and becomes more reduced.

OIL RIG

Oxidation Is Loss ● Reduction Is Gain

Electron transfer requires both an electron donor and an electron acceptor.

Electron donor and electron acceptor

Cells move electrons in a controlled sequence.

Electron donor

Gives electrons
Becomes oxidized
Example: NADH donates electrons to the respiratory chain.

e⁻

Electron acceptor

Receives electrons
Becomes reduced
In aerobic respiration, O_2 is the final electron acceptor.

$NADH \rightarrow NAD^+ + electrons$

$O_2 + electrons + H^+ \rightarrow H_2O$

NAD^+ / NADH — a major soluble electron carrier

NAD^+ accepts reducing equivalents; NADH carries them onward.



Oxidized form

NAD^+ can accept electrons generated during nutrient oxidation.

Reduced form

NADH carries high-energy electrons to the respiratory chain.

Cellular role

Links metabolic oxidation to membrane electron transport and ATP production.

FAD / $FADH_2$ — a second reduced electron carrier

FAD-linked electrons enter the respiratory chain through a different route.



Reduced carrier

$FADH_2$ carries electrons generated in FAD-dependent oxidation reactions.

Key difference

NADH donates electrons to Complex I; FAD-linked electrons enter through Complex II and then pass to coenzyme Q.

Both carriers feed electrons into the same membrane electron-transfer network.

Electron carriers at a glance

Different carriers perform different jobs in the chain.

NADH

Soluble reduced carrier
Donates electrons to Complex I.

$FADH_2$

Reduced flavin carrier
Feeds electrons through Complex II.

Coenzyme Q

Mobile lipid-soluble carrier
Collects electrons from I and II.

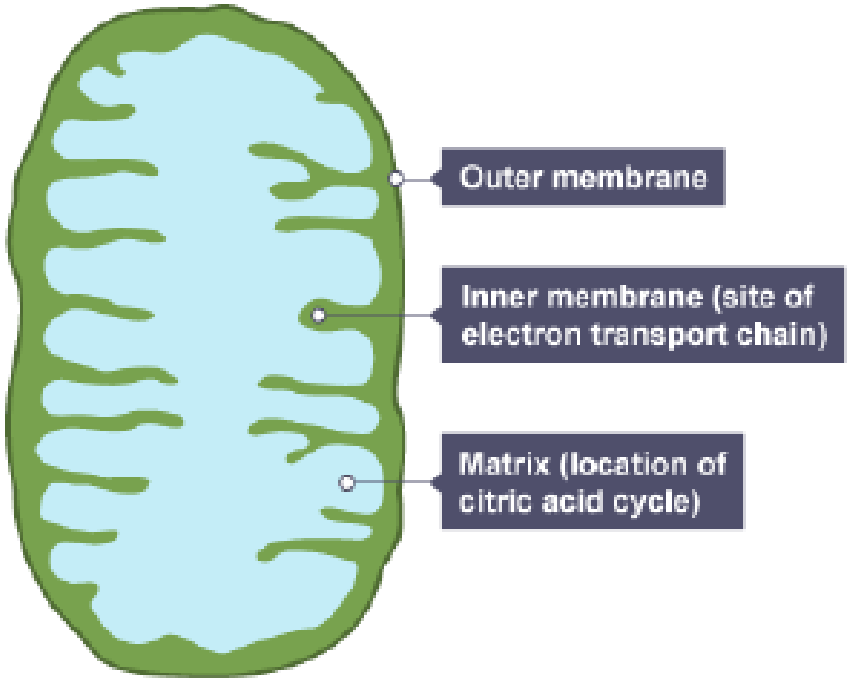
Cytochrome c

Small mobile protein carrier
Transfers electrons from III to IV.

The respiratory chain is not one protein — it is an ordered network of membrane complexes and mobile carriers.

Mitochondrial structure makes energy conversion possible

The inner membrane separates two compartments needed for oxidative phosphorylation.



Matrix

Contains many metabolic enzymes. NADH and FAD-linked reducing equivalents are generated here by nutrient oxidation.

Inner mitochondrial membrane

Contains the respiratory electron transport chain and ATP synthase.

Intermembrane space

Protons accumulate here when Complexes I, III and IV pump H^+ out of the matrix.

Peter Mitchell and the chemiosmotic idea

Electron transfer and ATP synthesis are coupled through a transmembrane proton gradient.

1961–1966

Peter Mitchell proposed that electron transport moves H^+ across the inner mitochondrial membrane.
The resulting proton gradient is then used to synthesize ATP.



Electron transfer — **H^+ pumping** — **Proton gradient** — **ATP synthesis**

Chemiosmosis = using a membrane proton gradient to drive ATP synthesis.

Oxidative phosphorylation — the overview

Reduced carriers are oxidized; oxygen is reduced; ATP is synthesized.

1. **NADH and $FADH_2$ deliver electrons**
   Reduced electron carriers are oxidized as they donate electrons.

2. **Electrons pass through the respiratory chain**
   Electron transfer releases usable free energy in a controlled sequence.

3. **Complexes pump H^+**
   Energy from electron flow moves protons from the matrix to the intermembrane space.

4. **O_2 accepts electrons**
   At the end of the chain, oxygen is reduced and water is formed.

5. **ATP synthase uses the gradient**
   H^+ returns to the matrix through ATP synthase, driving ATP production.