Oxidative Phosphorylation

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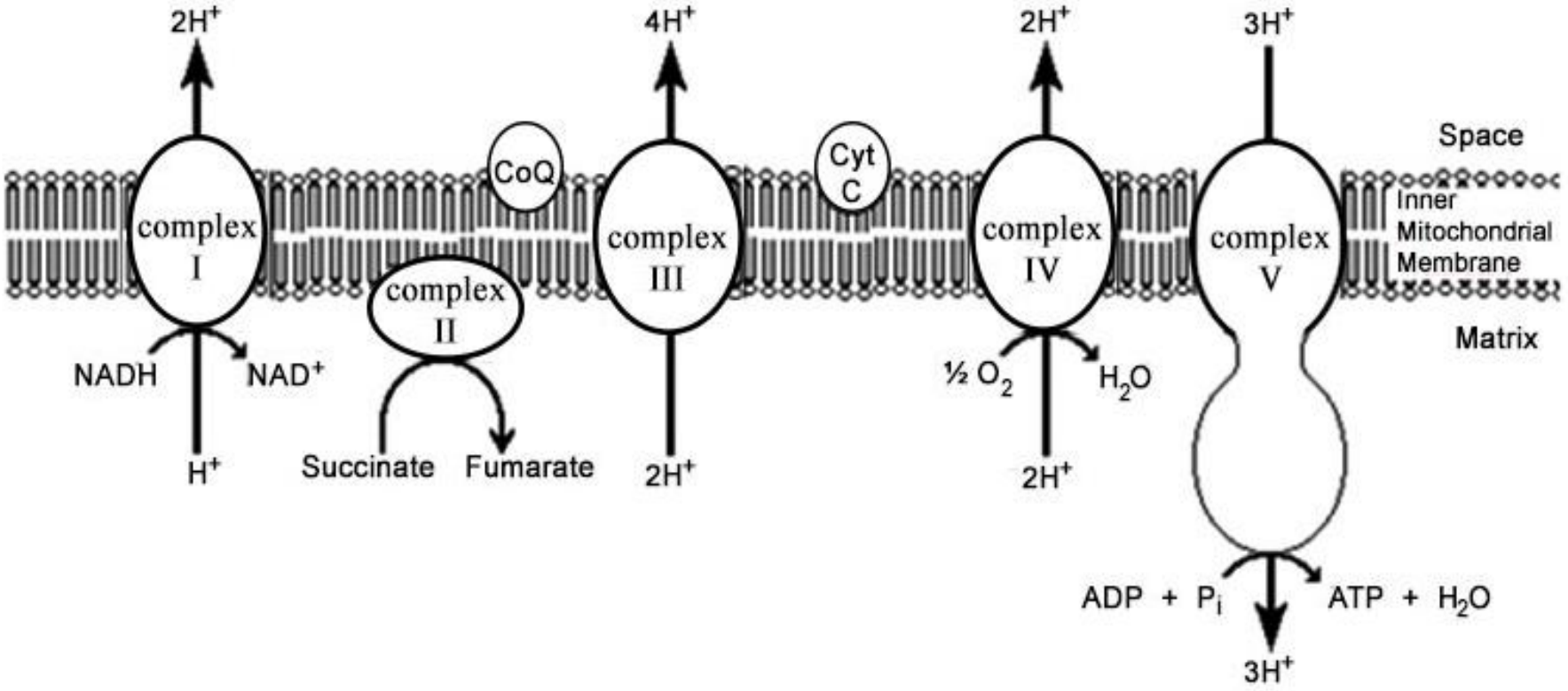
Oxidative phosphorylation

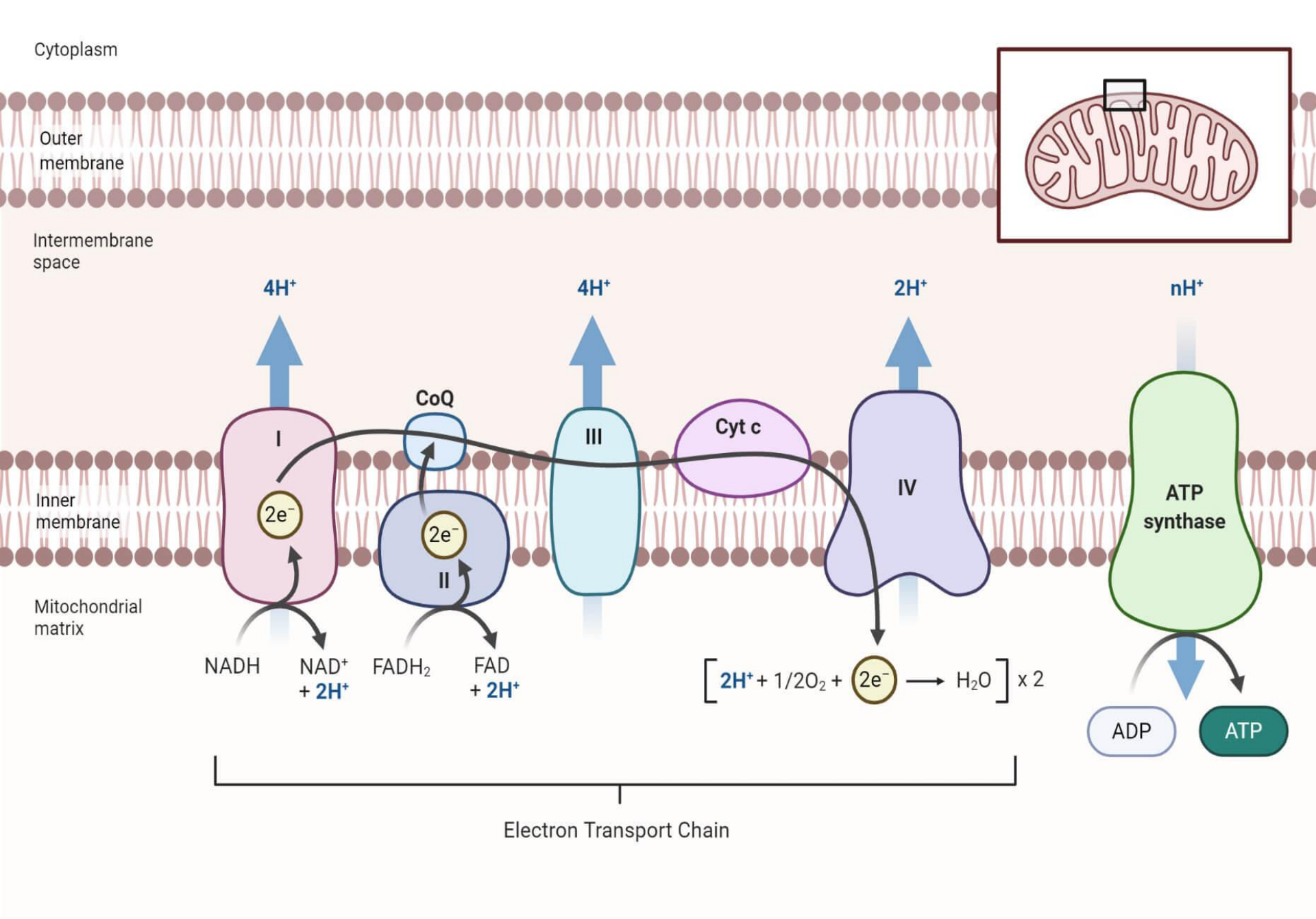
- Oxidative phosphorylation is the process by which energy from electron transport chain is used to make ATP, and is the culmination of energy yielding metabolism in aerobic organisms. Oxidative phosphorylation involves the reduction of O_2 to H_2O with electrons donated by NADH and $FADH_2$, and equally occurs in light or darkness.

Electron Transport Chain

- The electron transport chain or system in mitochondria consists of four multiprotein complexes (called by Roman numerals I to IV) which are localised in the inner mitochondrial membrane and also ubiquinone (UQ or coenzyme Q) and cytochrome-c which are not tightly bound to membrane protein but act as mobile carriers between the complexes

ELECTRON TRANSPORT CHAIN



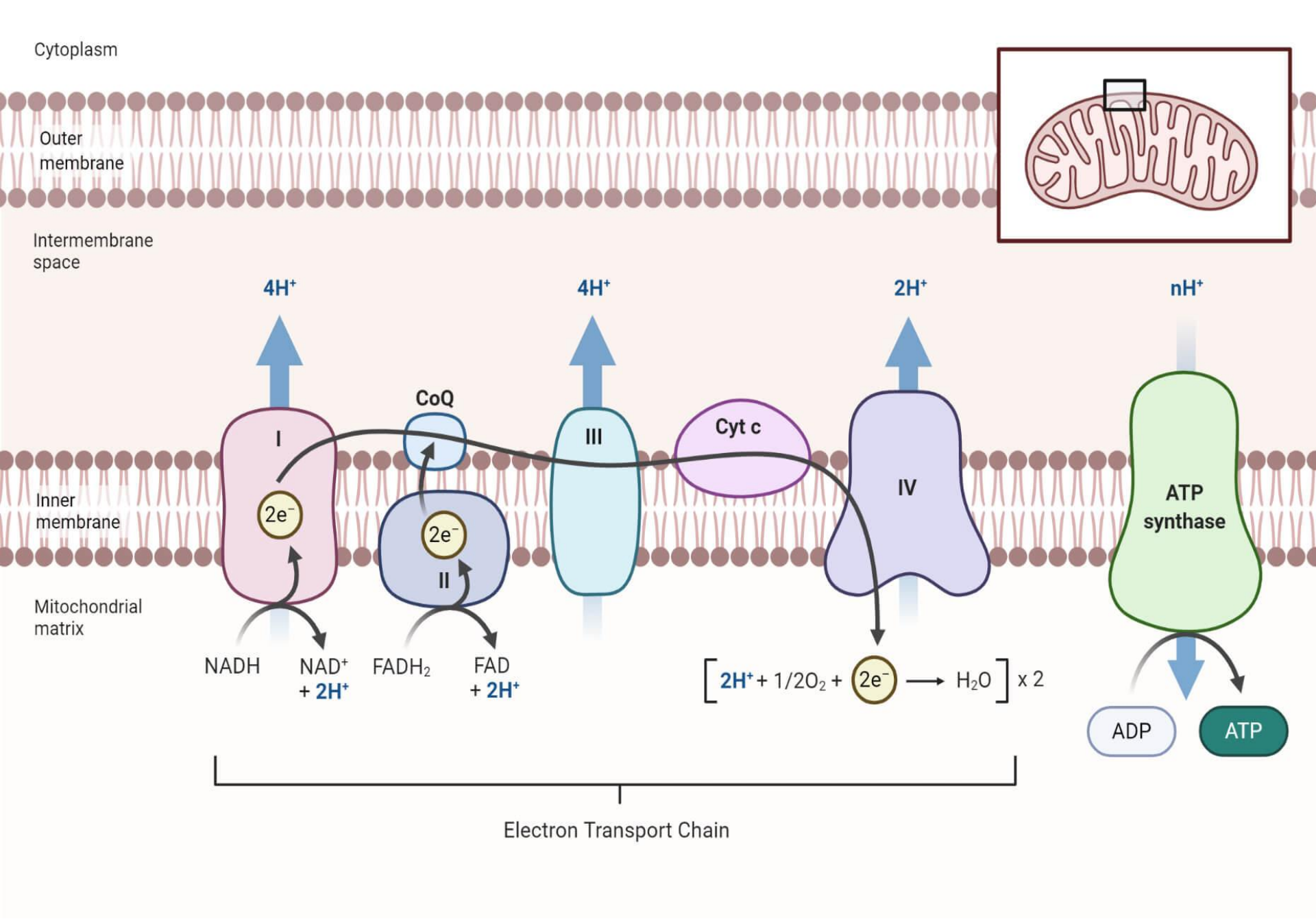

Cytoplasm
Outer membrane
Intermembrane space
Inner membrane
Mitochondrial matrix
4H+
4H+
2H+
nH+
CoQ
I
II
III
IV
Cyt c
2e−
2e−
ATP synthase
NADH
NAD+ + 2H+
FADH2
FAD + 2H+
[2H+ + 1/2O2 + 2e− → H2O] x 2
ADP
ATP
Electron Transport Chain

- **Electron donors**
  - NADH (from glycolysis) is transferred into the mitochondrial matrix via the Malate-aspartate shuttle or glycerol-3-phosphate shuttle
  - $FADH_2$ is produced by succinate dehydrogenase in the TCA cycle

- **Protein complexes**: located within the inner mitochondrial membrane
  - The electrons from NADH and $FADH_2$ move along specific complexes of the electron transport chain via redox reactions until they are transferred to oxygen.
  - NADH enters the electron transport chain at complex I, whereas FADH enters at complex II. Therefore, NADH promotes the passage of more protons across the electron transport chain and yields more ATP compared to FADH

Complex I

- **Complex I (NADH dehydrogenase)**
- Transfers two protons (H^+) and two electrons (e^-) to coenzyme Q
- $NADH \rightarrow NAD^+ + H^+ + 2\ e^-$
- Pumps four protons into the intermembrane space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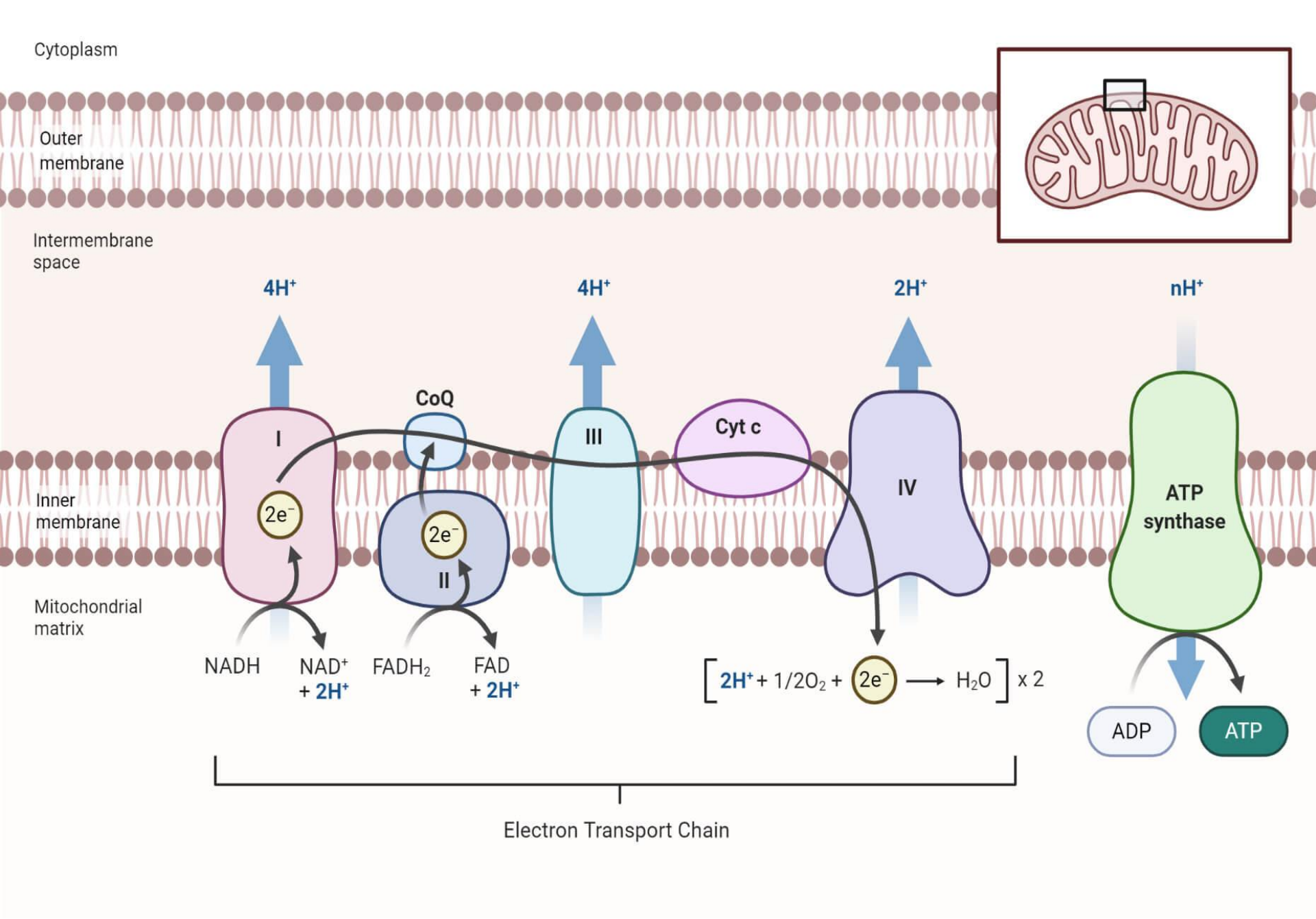
Complex II

- **Complex II (contains succinate dehydrogenase)**
- Transfers two protons (H^+) and two electrons (e^-) to coenzyme Q
- $FADH_2 \rightarrow FAD + 2\ H^+ + 2\ e^-$
- Does not pump protons into the intermembrane space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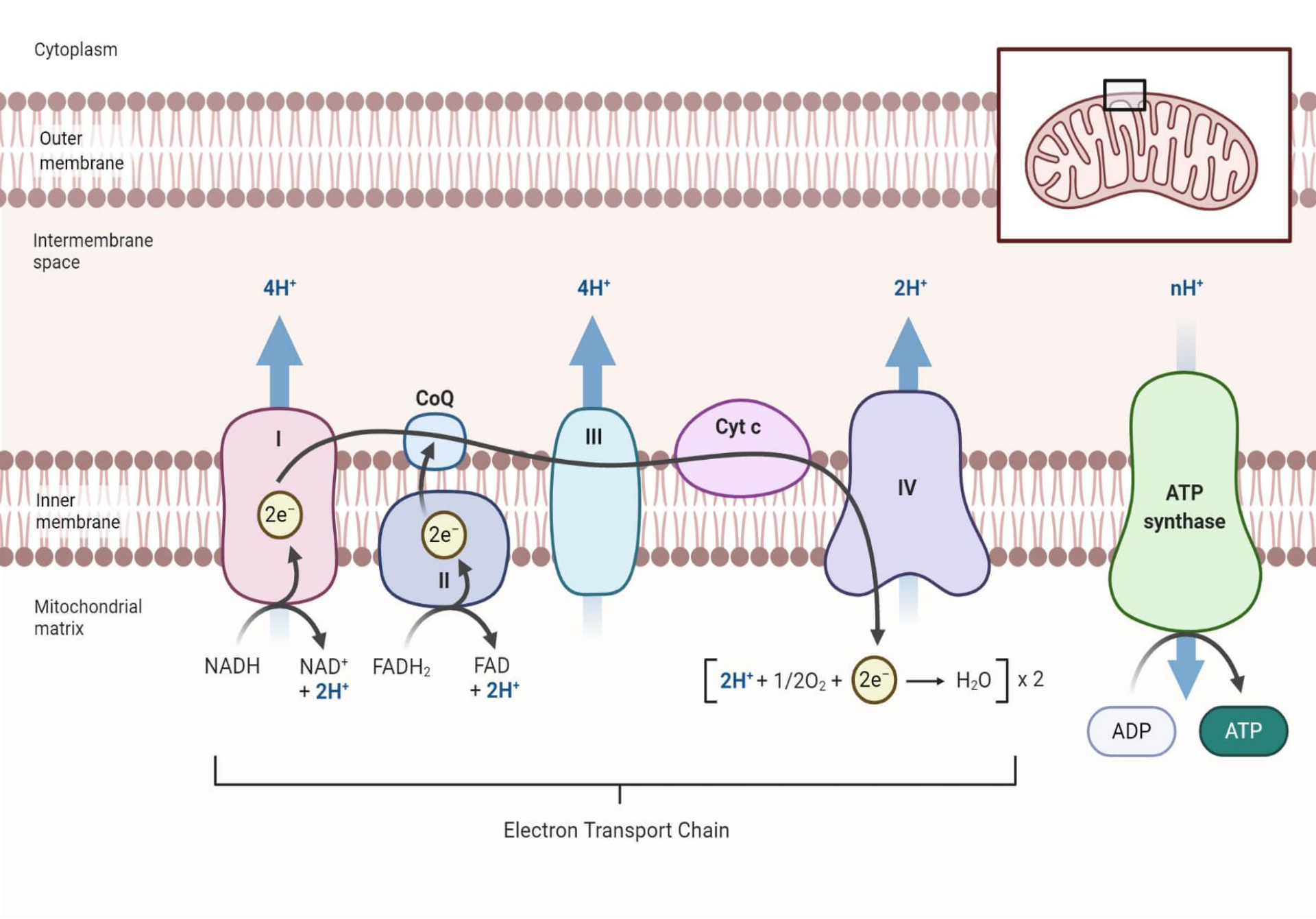
Complex III

- **Complex III (coenzyme Q-cytochrome c reductase)**
- Transfers two electrons (e^-) from coenzyme Q to two molecules cytochrome c
- Reduced coenzyme Q (QH_2) + 2 H^+ + 2 oxidized cytochrome c → oxidized coenzyme Q + 4 H^+ + 2 reduced cytochrome c
- Transfers 4 protons (H^+) into the intermembrane space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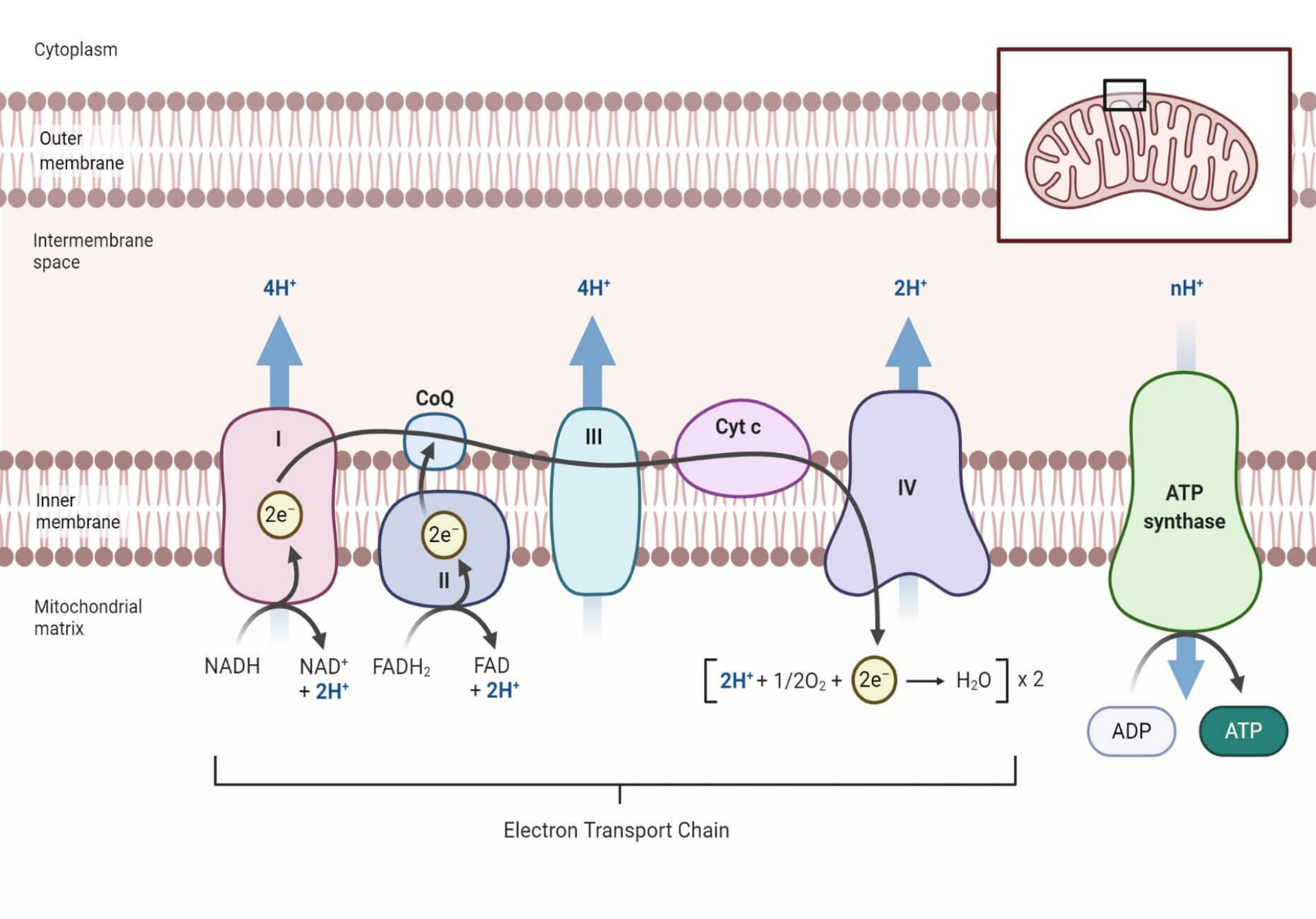
Complex IV

- **Complex IV (cytochrome c oxidase)**
- Reduces oxygen (O_2) to water (H_2O) via cytochrome a/a_3 (Cu/heme protein)
- 2 reduced cytochrome c + ½ O_2 + 4 H^+ → 2 oxidized cytochrome c + H_2O + 2 H^+
- Pumps two protons (H^+) into the intermembrane space
- The transfer of electrons powers the transport of protons across the inner mitochondrial membrane into the intermembrane space → creates an electrochemical gradient across the inner mitochondrial membrane → powers the ATP synthase
- Transfer of 4 H^+ back into the mitochondrial matrix through ATP synthase (complex V) → phosphorylation of 1 adenosine diphosphate (ADP) → 1 adenosine triphosphate (ATP)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ETC up to complex 4

- https://youtu.be/LQmTKxI4Wn4

ATP synthase

- https://youtu.be/kXpzp4RDGJI