

Electron Transport Chain (Respiratory Chain)

Respiratory Block

Objectives

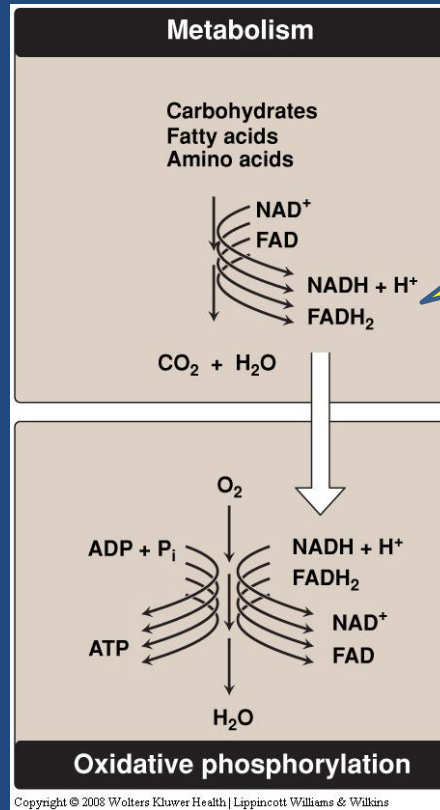
- Understand how energy-rich molecules including glucose are metabolized by a series of oxidation-reduction reactions ultimately yielding CO_2 and water
- Explain the process of electron transport chain that releases free energy, which is used for ATP synthesis and heat production
- Recognize the reactions of electron transport chain taking place in mitochondria that are coupled to oxidative phosphorylation

Electron Transport Chain (ETC)

- A system of electron transport that uses respiratory O_2 to finally produce ATP (energy)
- Located in the inner mitochondrial membrane
- Final common pathway of metabolism
- Electrons from food metabolism are transported to O_2
- Uses maximum amount of body's oxygen

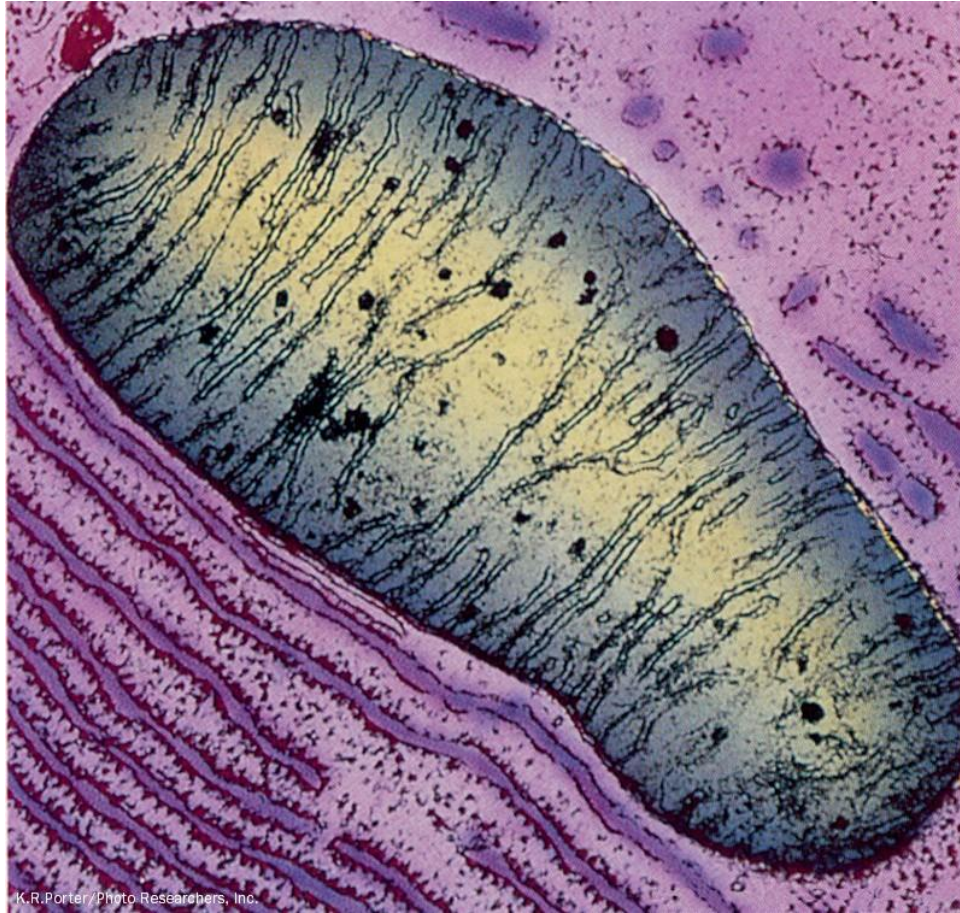
Metabolic breakdown of energy-yielding molecules

Electrons
(e^-) lose their
free energy



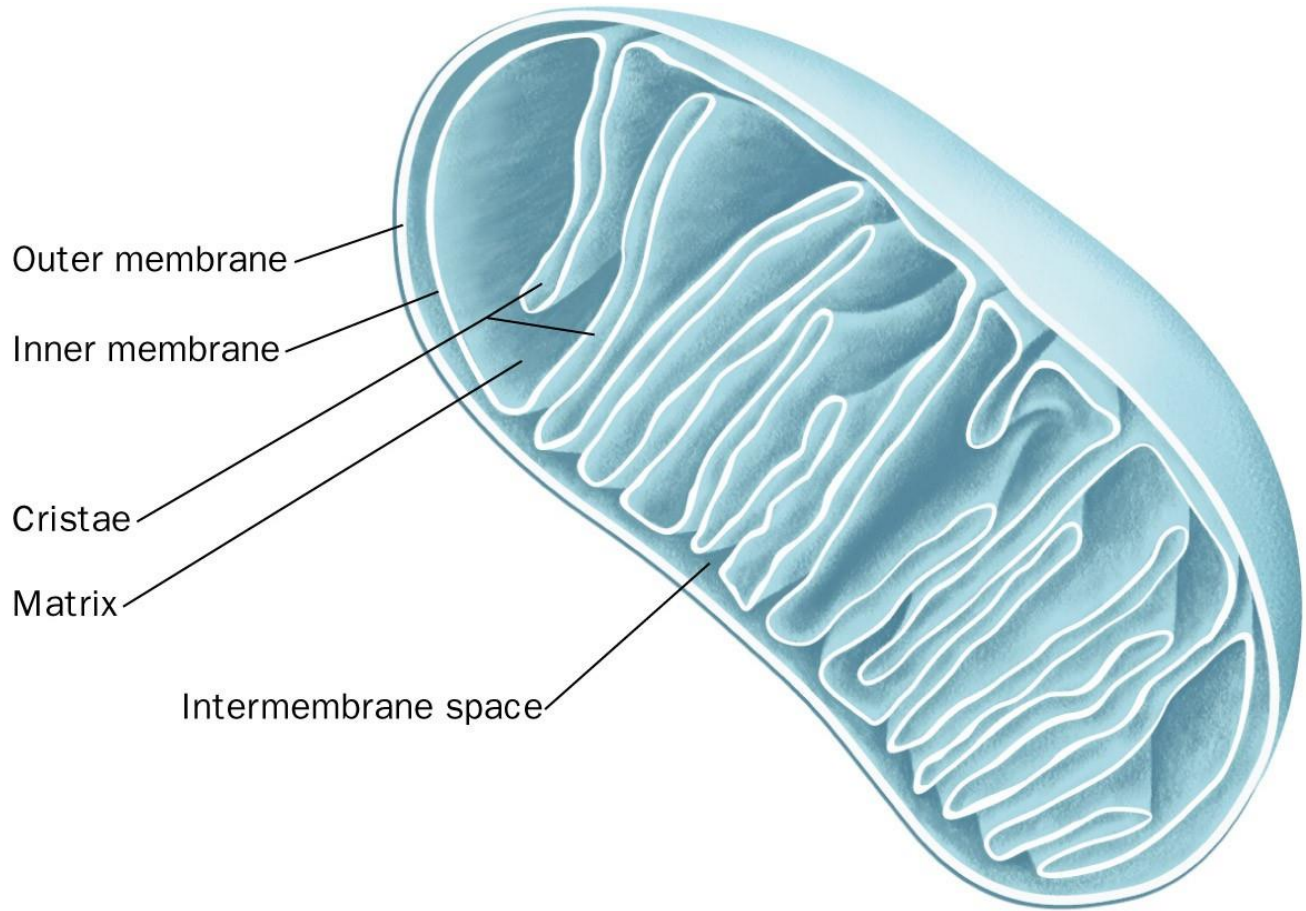
Energy-rich
reduced
coenzymes

Excess energy
generates heat



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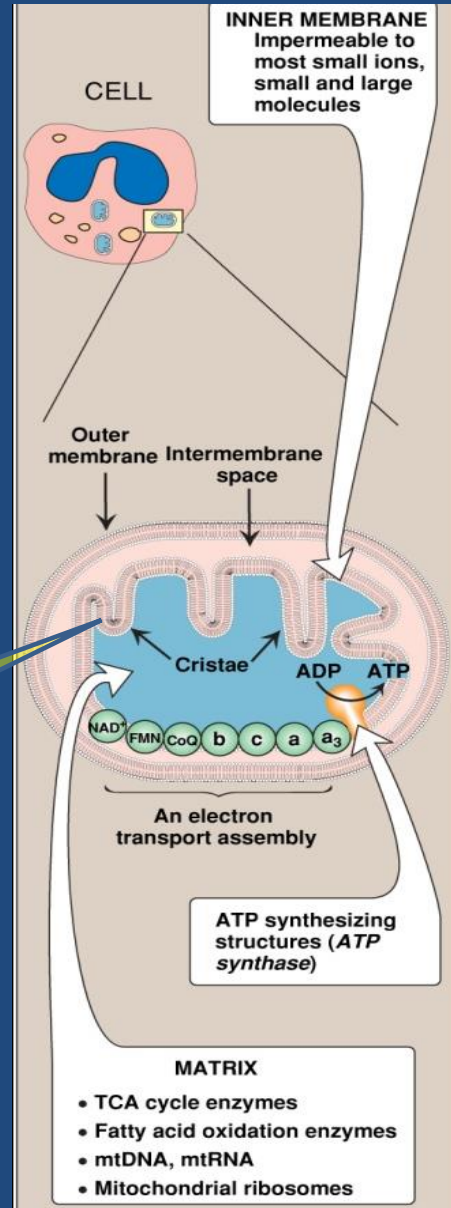
An electron micrograph of an animal mitochondrion



Cutaway diagram of a mitochondrion

Mitochondrion

Cristae increase the surface area



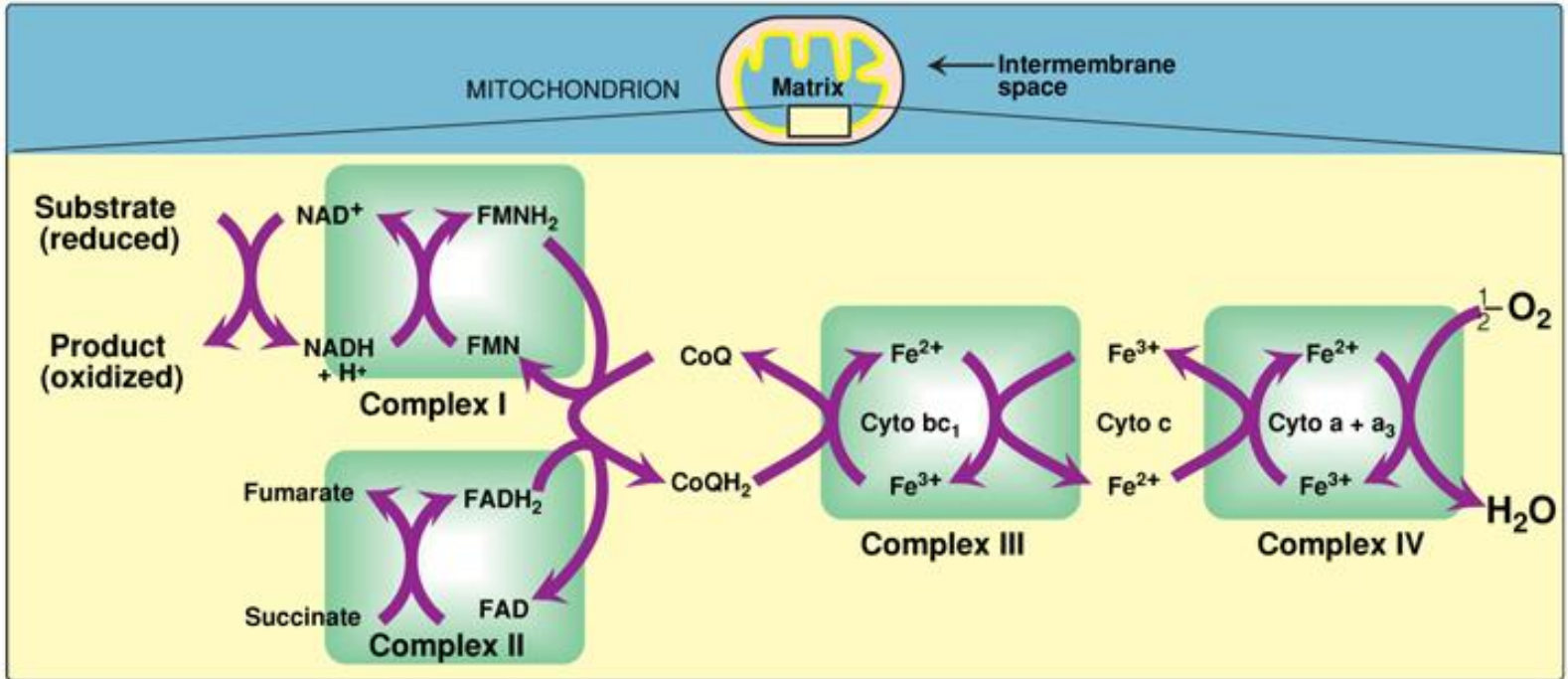
Components of ETC

- All members/components are located in the inner mitochondrial membrane (IMM)
- IMM contains 5 complexes:
 - Complex I, II, III, IV (part of ETC)
 - Complex V (ATP synthase: catalyzes ATP synthesis)
 - Mobile electron carriers
 - CoQ
 - Cytochrome c

Organization of ETC

- Each complex accepts or donates electrons to mobile carriers
- Carriers accept electrons from donors and then donate to the next carrier in chain
- Electrons finally combine with oxygen and protons to form water
- Oxygen is required as a final acceptor (respiratory chain)

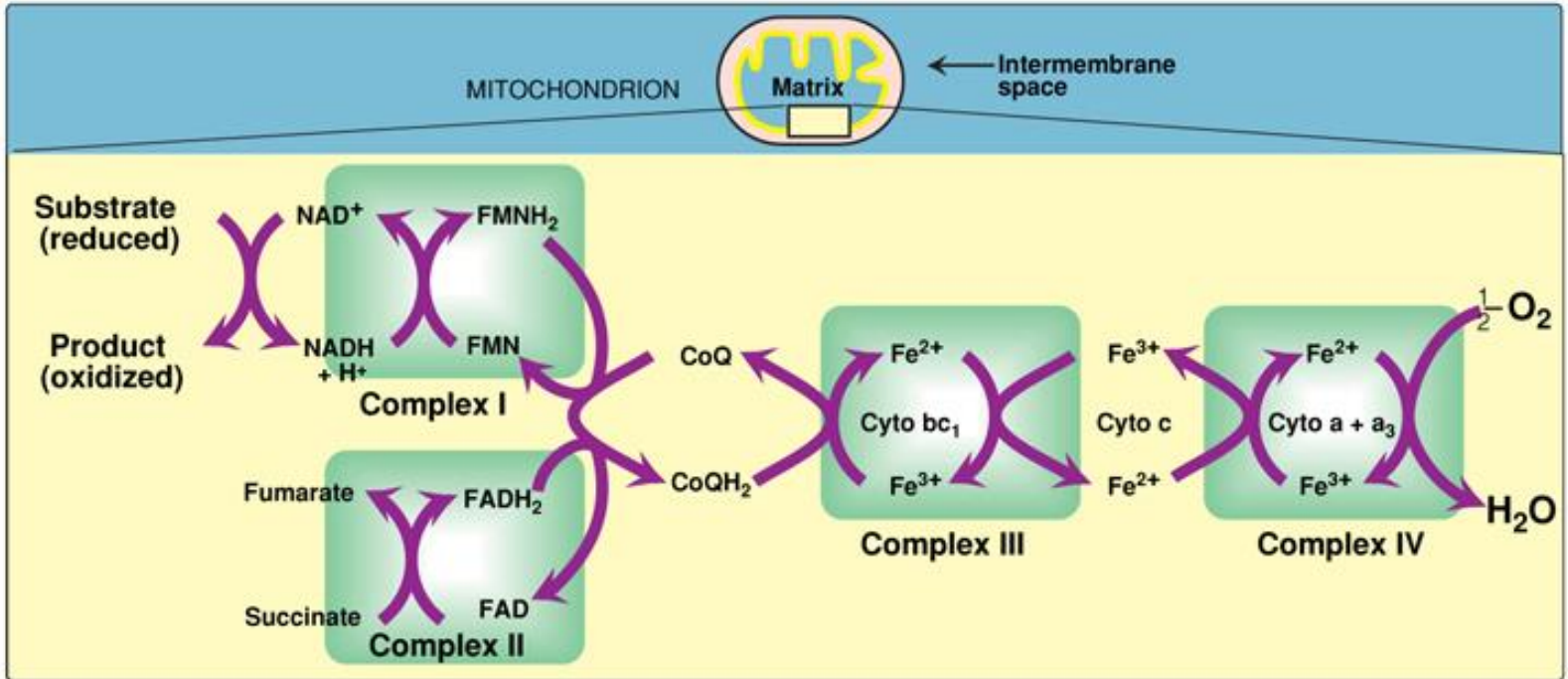
Electron Transport Chain



Complex I – NADH Dehydrogenase

- This complex collects the pair of electrons from NADH and passes them to CoQ

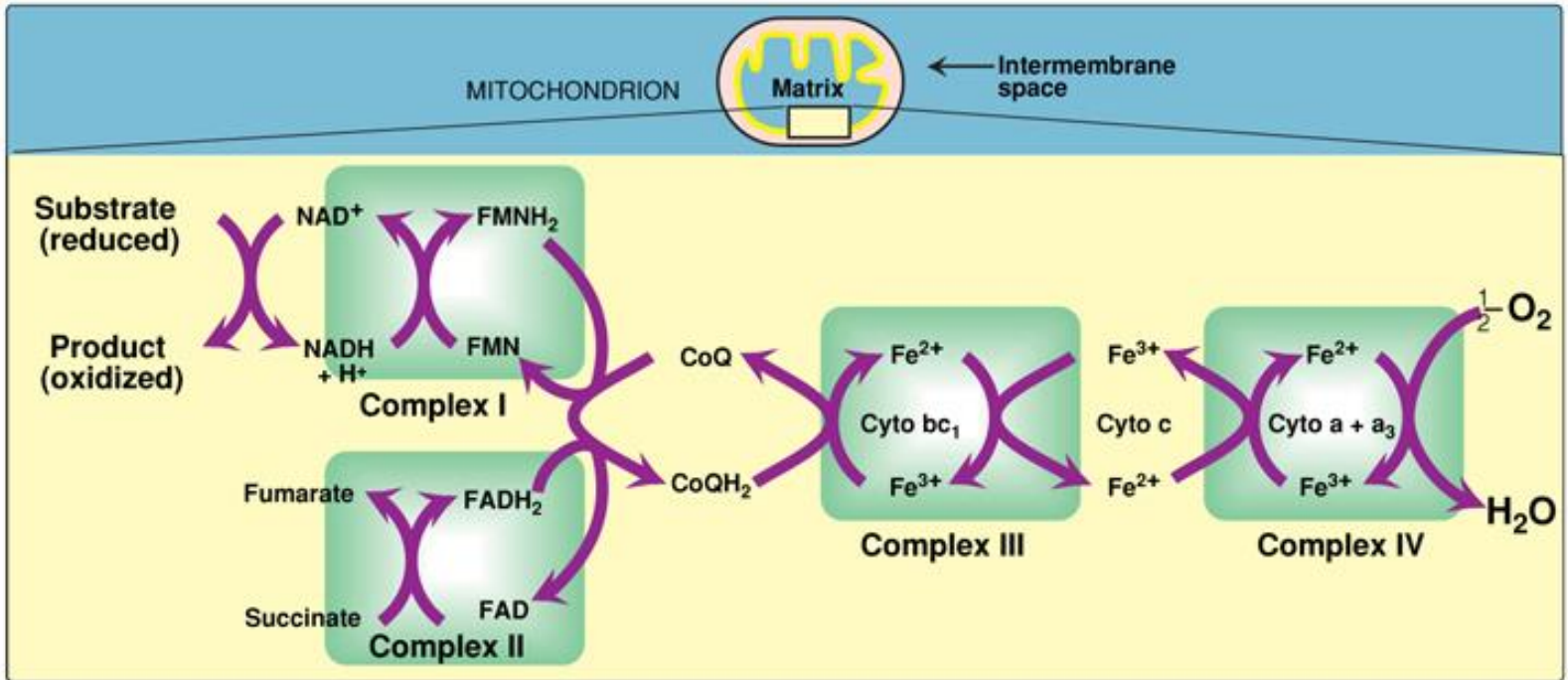
Electron Transport Chain



Complex II – Succinate dehydrogenase

- It is also a part of the Krebs cycle
- Transfers electrons to CoQ

Electron Transport Chain



Coenzyme Q (CoQ)

- Also called ubiquinone (ubiquitous in biological systems)
- A non-protein member of the ETC
- Lipid soluble and mobile

Cytochromes

- Each cytochrome is a protein that contains
 - Heme group (porphyrin ring + iron in Fe^{3+} state)
- When cytochromes accept electron
 - Fe^{3+} (ferric) is converted to Fe^{2+} (ferrous)
 - Fe^{2+} is reoxidized to Fe^{3+} when it donates electrons to the next carrier

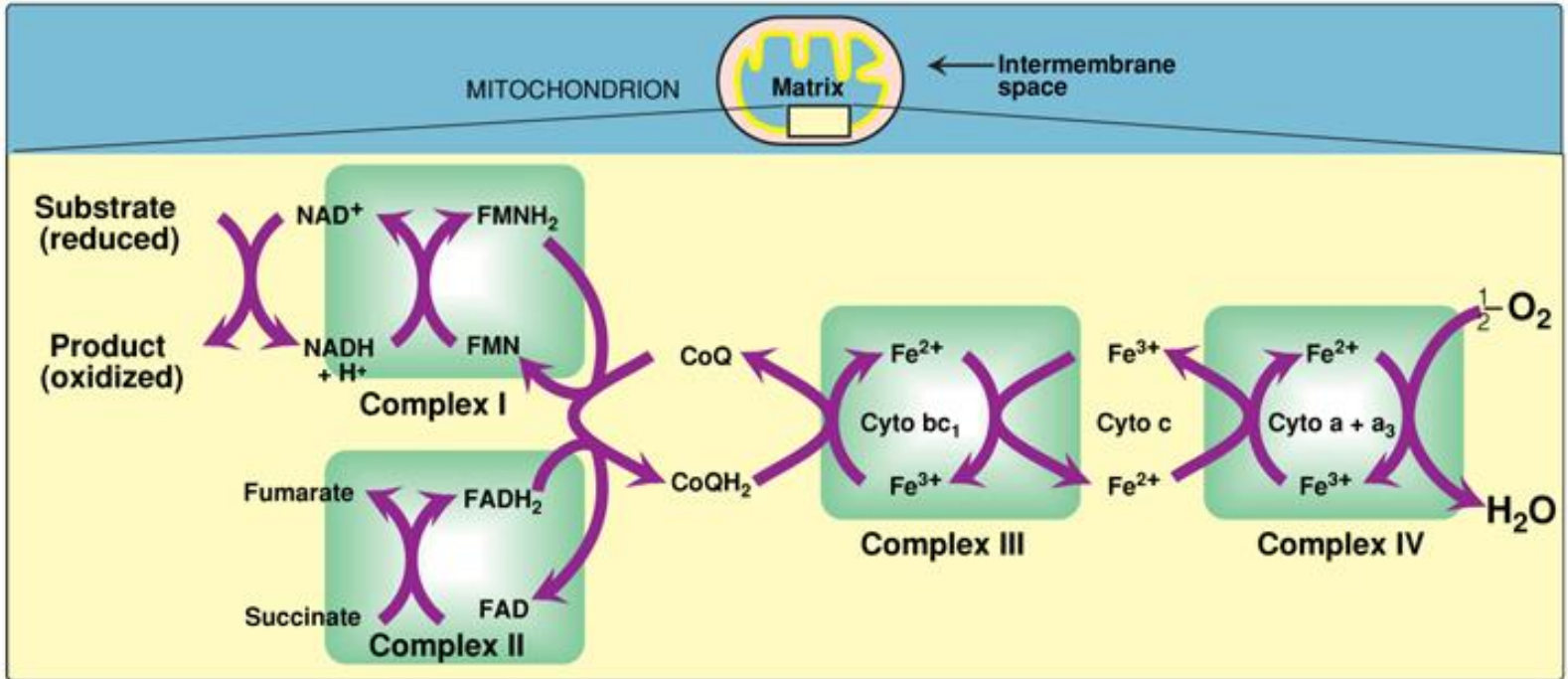
Complex III and IV

- Complex III: Cytochrome bc₁
- Complex IV: Cytochrome a + a₃

Electrons flow from:

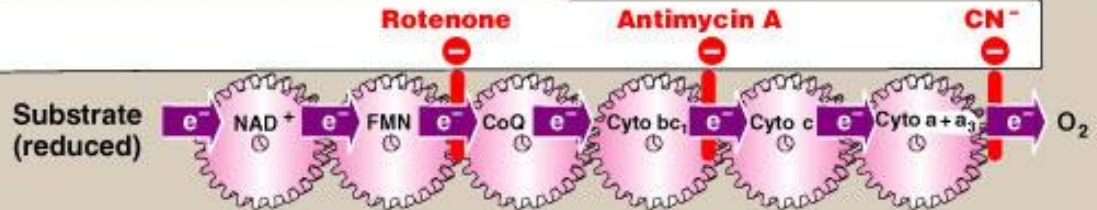
- CoQ → Complex III → Cyt. c → Complex IV

Electron Transport Chain



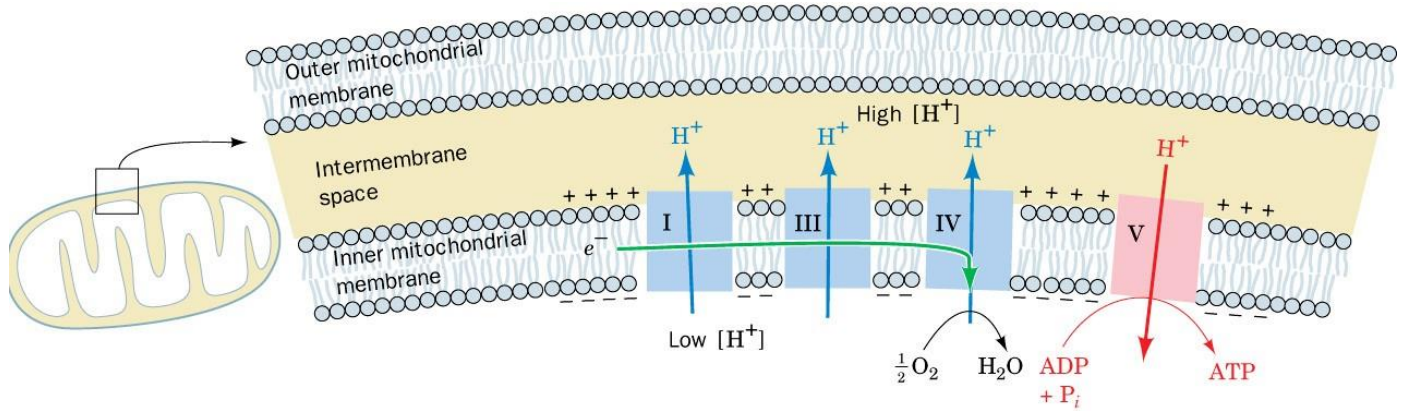
Site-specific inhibitors of ETC

Blocking electron transfer by any one of these inhibitors stops electron flow from substrate to oxygen because the reactions of the electron transport chain are tightly coupled like meshed gears.



ETC is coupled to proton transport for ATP synthesis

- The energy of electron transfer is used to drive the protons out of the matrix
- It is done by complexes I, III and IV (proton pumps)
- This creates a proton gradient across the IMM to synthesize ATP

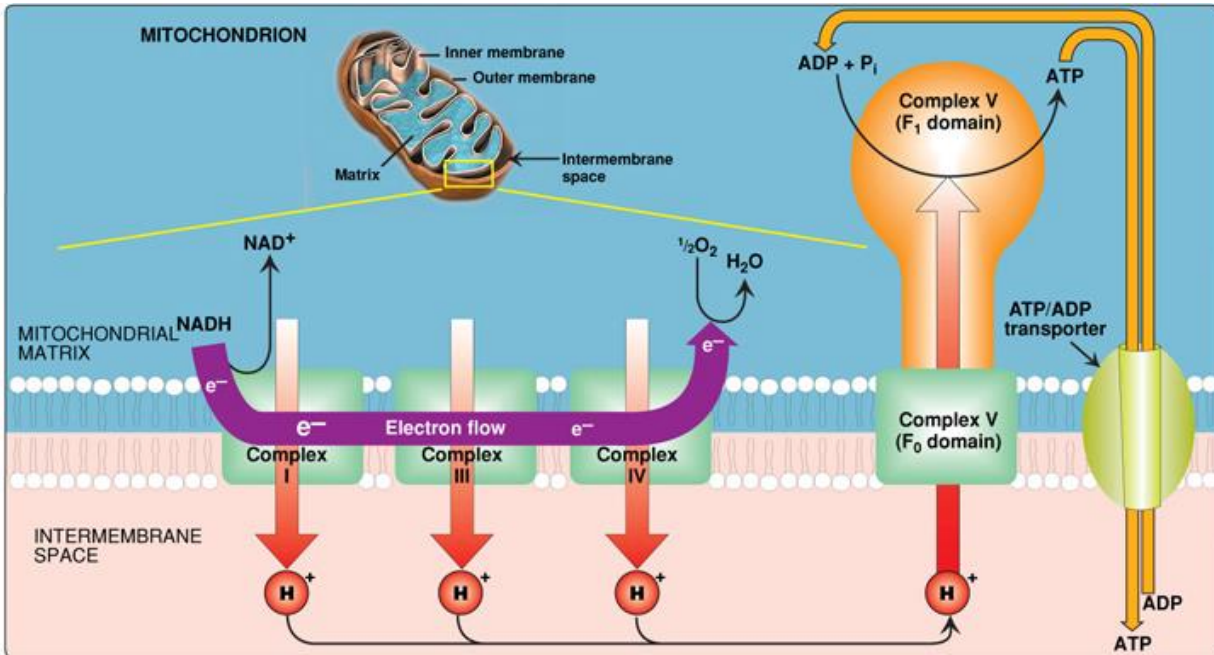


Coupling of electron transport (*green arrow*) and ATP synthesis

ATP synthase

- ATP synthase (Complex V) synthesizes ATP
- Consists of two domains:
 - F_0 – membrane spanning domain
 - F_1 – extramembranous domain

Transport of protons



Energetics of ATP synthesis

- The energy required for phosphorylation of ADP to ATP = 7.3kcal/mol
- Energy produced from the transport of a pair of electrons from NADH to O₂ = 52.58 kcal
- No. of ATP molecules produced is 3 (NADH to O₂)
- Excess energy is used for other reactions or released as heat

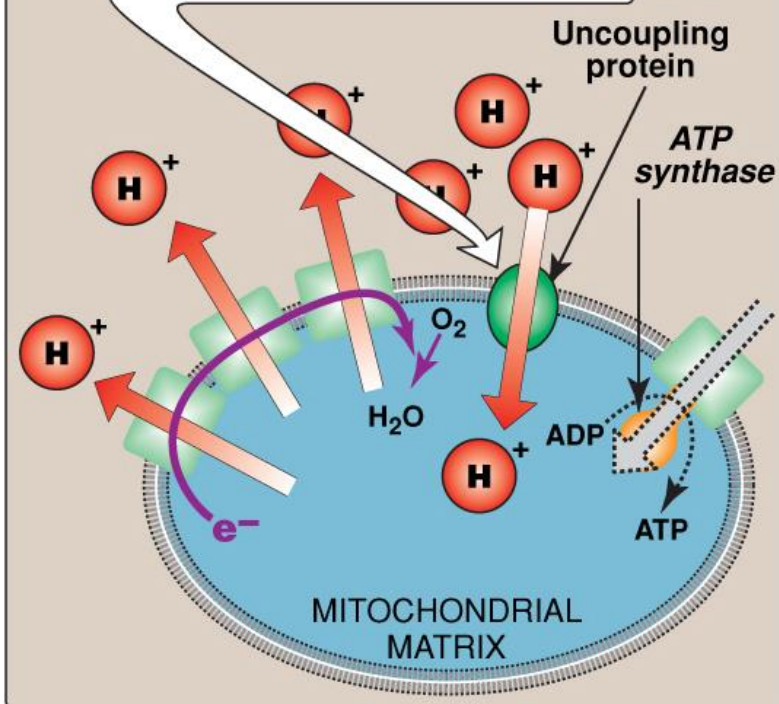
P:O ratio

- ATP made per O atom reduced
 - For NADH
 - P:O = 3:1
 - For FADH₂
 - P:O = 2:1

Inhibitors of ATP synthesis

- Oligomycin:
 - Binds to F_0 domain of ATP synthase and closes the H^+ channel
- Uncoupling proteins (UCPs):
 - Create proton leaks (allow protons to reenter the matrix without ATP synthesis)
 - Energy is released as heat (nonshivering thermogenesis)

Uncoupling proteins create a "proton leak," allowing protons to reenter the mitochondrial matrix without capturing any energy as ATP.



Take home message

- ETC is a common pathway of transferring energy-rich electrons from metabolism finally yielding CO₂ and water
- The energy of the electrons transferred is used for ATP synthesis and heat production

References

- Lippincott's Illustrated Reviews, Biochemistry, 6th Edition, Denise R. Ferrier, Lippincott Williams & Wilkins, USA, pp. 73-79.