Electron Transport Chain (Respiratory Chain)

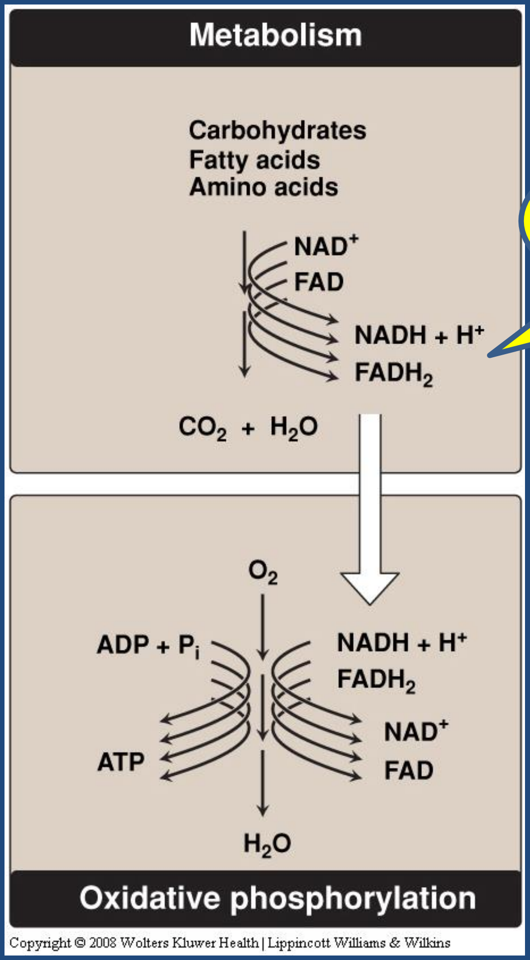
Respiratory Block

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

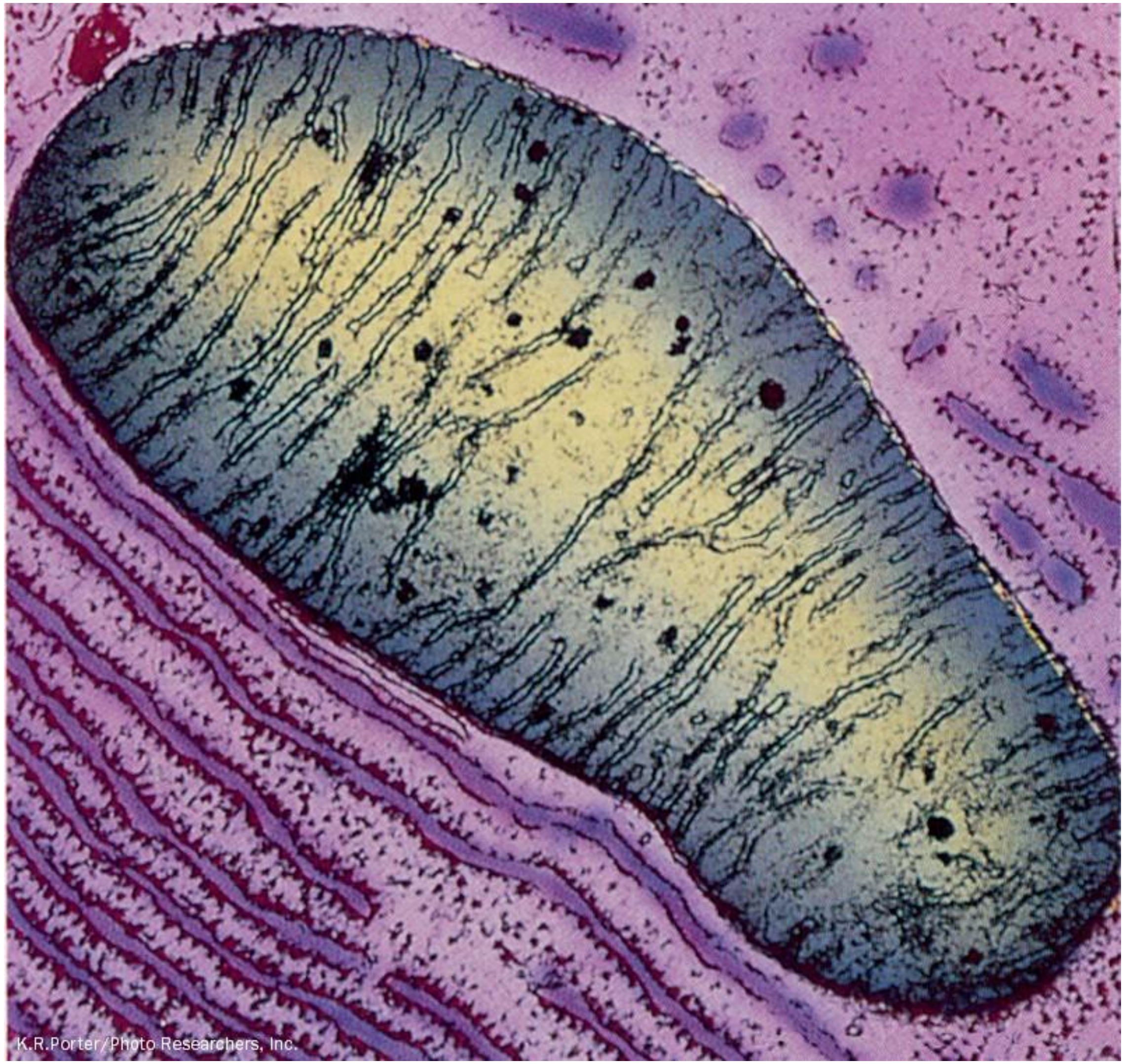
Metabolic breakdown of energy-yielding molecules

Electrons (e^-) lose their free energy

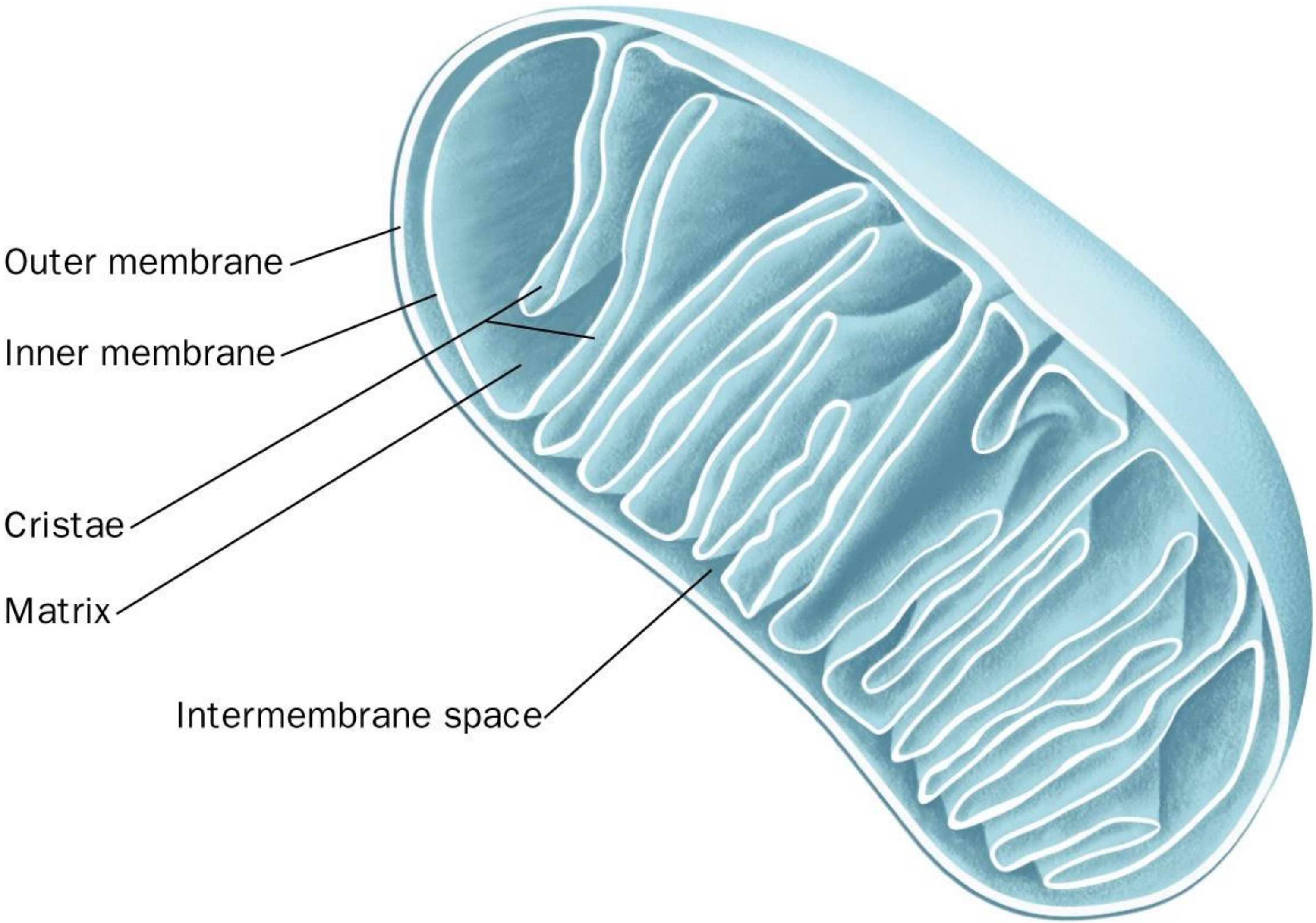


Energy-rich reduced coenzymes

Excess energy generates heat



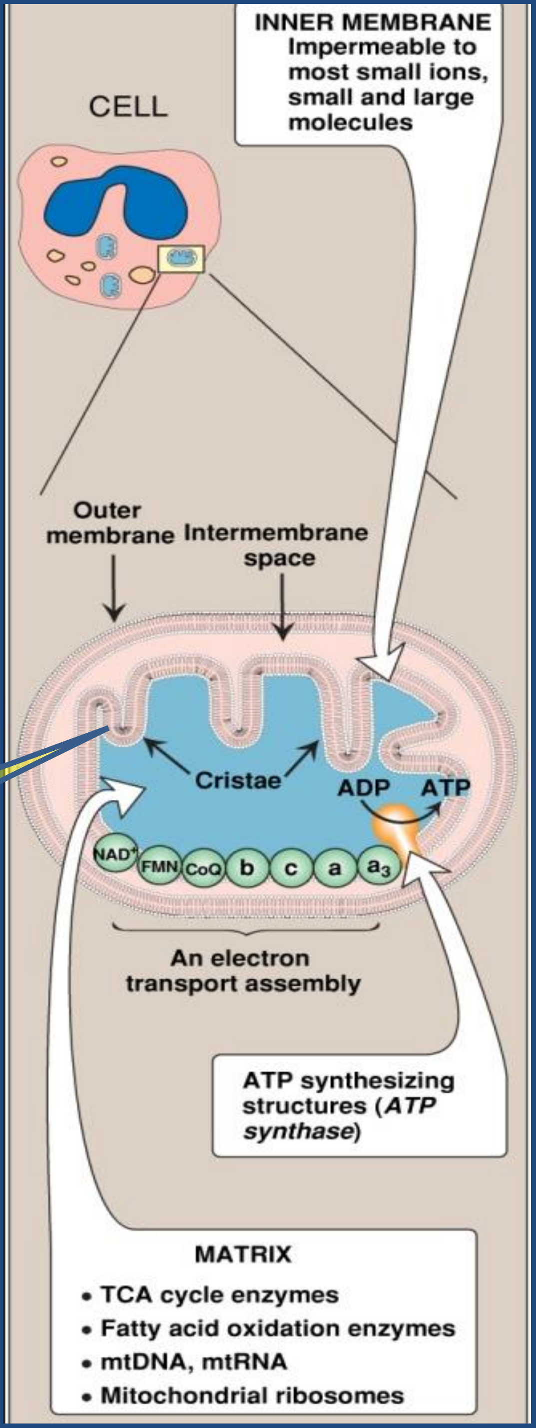
An electron micrograph of an animal mitochondrion



Cutaway diagram of a mitochondrion

Mitochondrion

Cristae increase the surface area



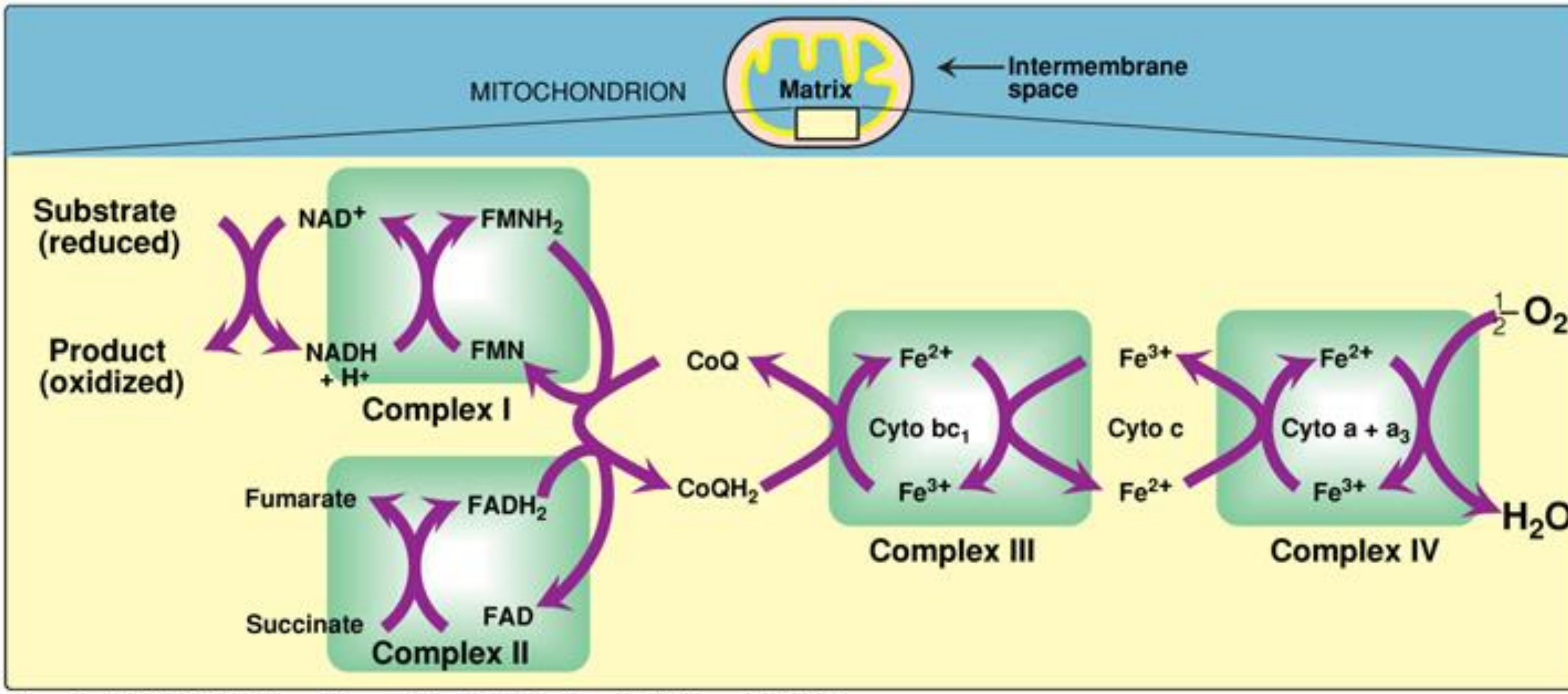
Components of ETC

- 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 that 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)

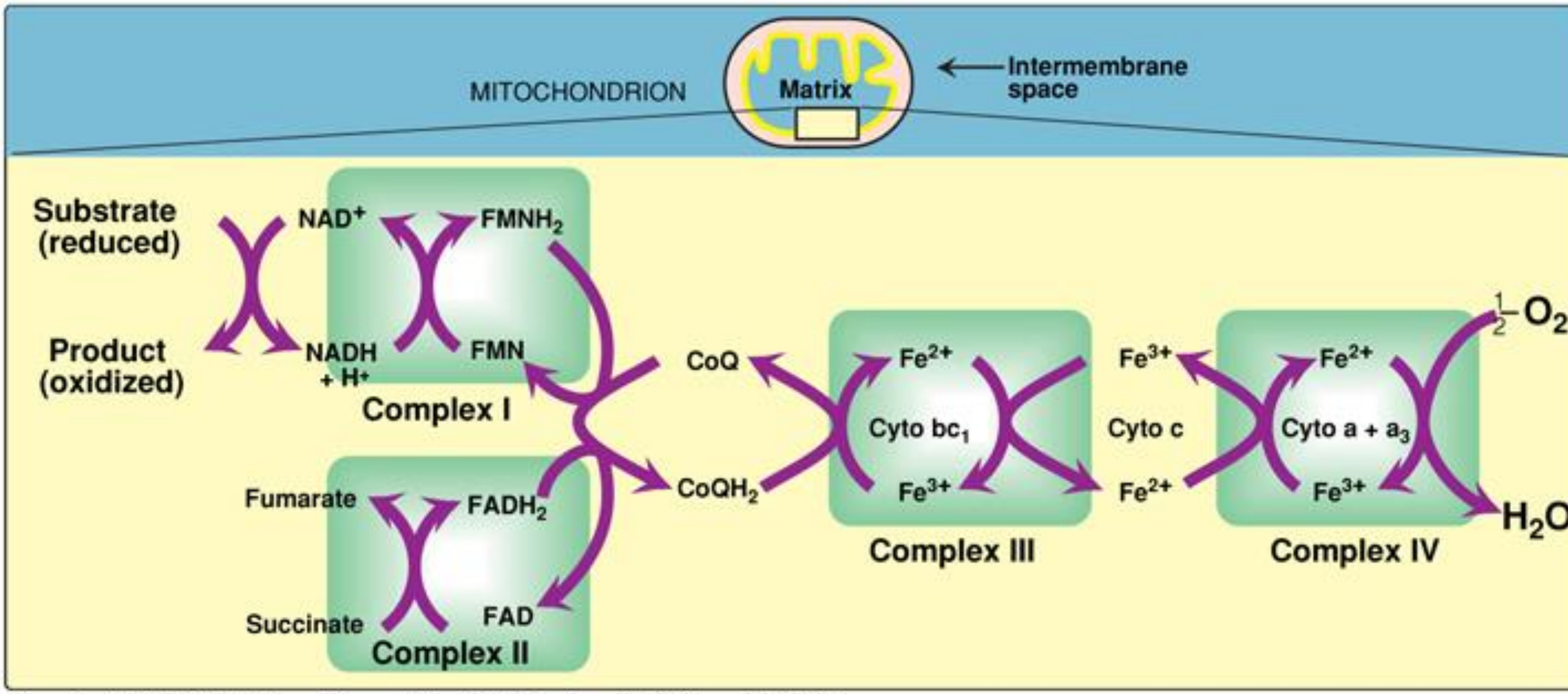
Electron Transport Chain



Complex I – NADH Dehydrogenase

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

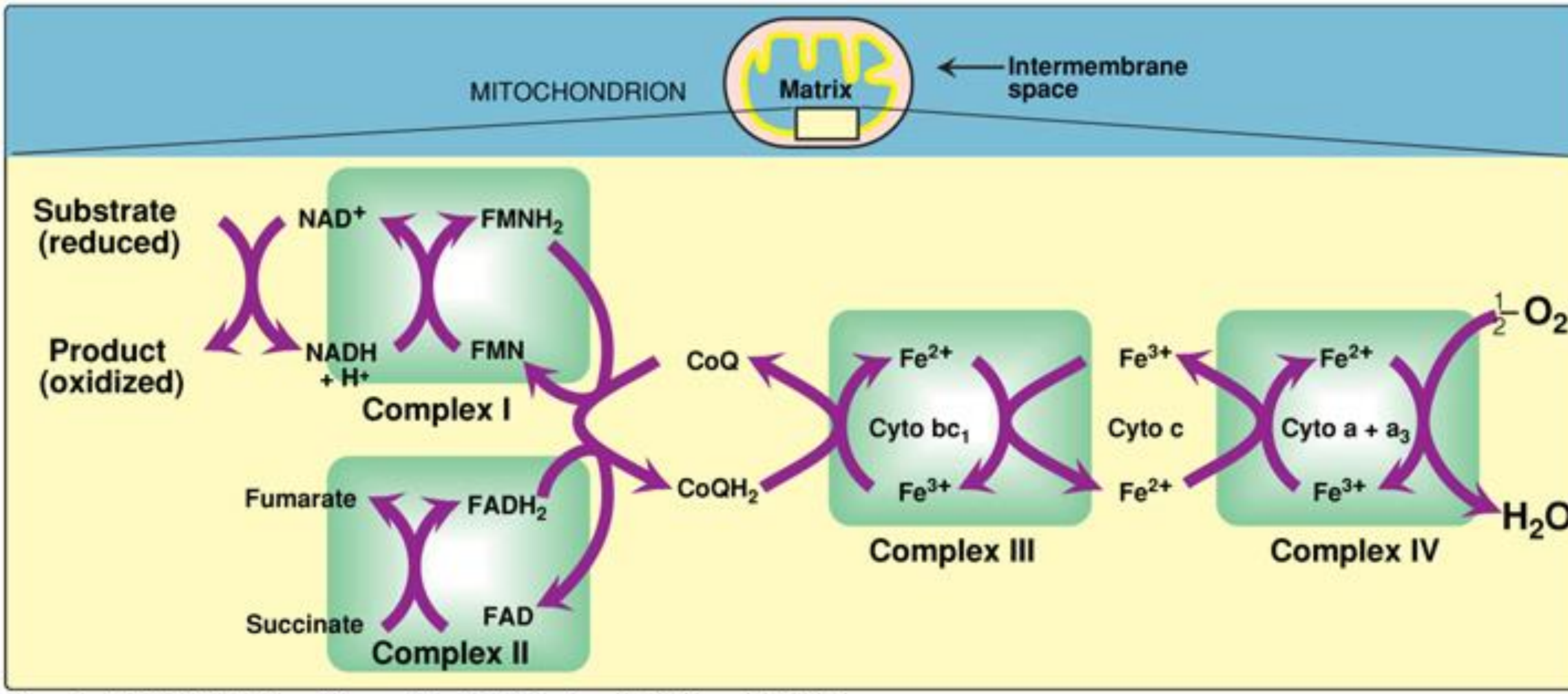
Electron Transport Chain



Complex II – Succinate dehydrogenase

- It is also a part of the TCA 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+} is converted to Fe^{2+}
  - Fe^{2+} is reoxidized to Fe^{3+} when it donates electrons to the next carrier

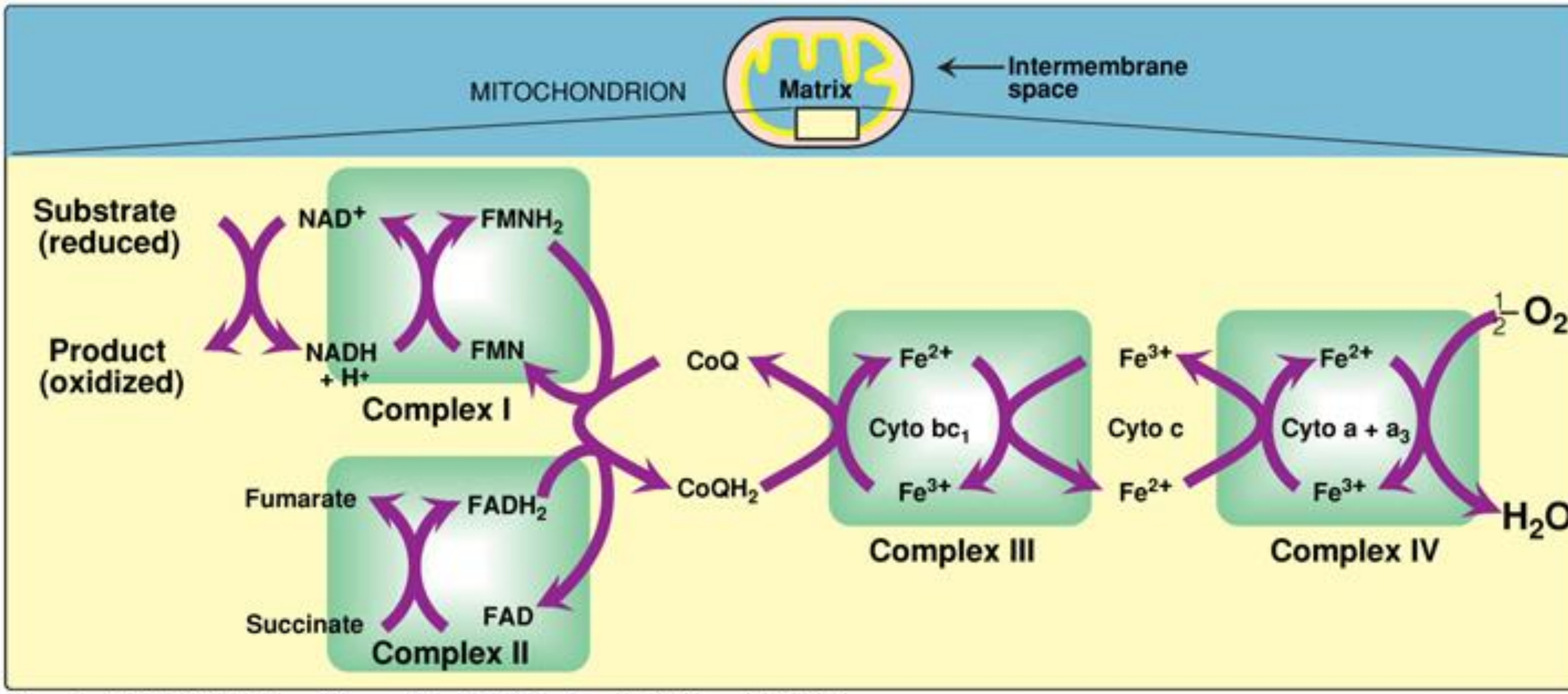
Complex III and IV

- Complex III: Cytochrome bc1
- Complex IV: Cytochrome a + a_3

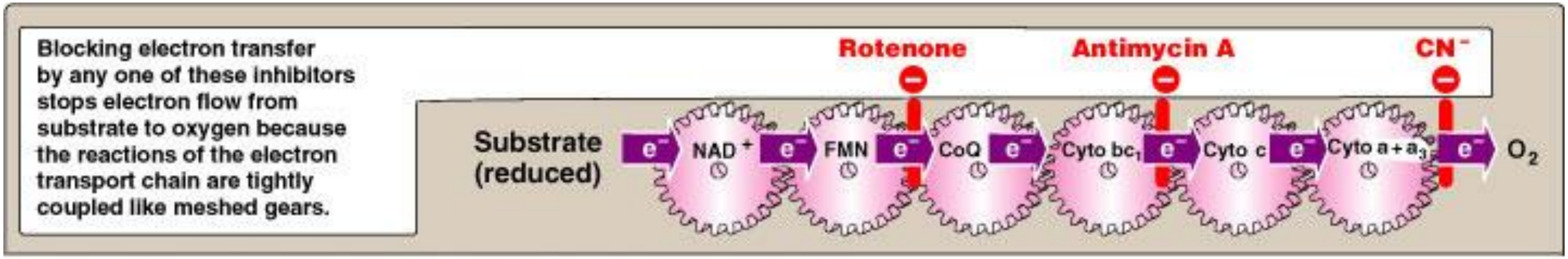
Electrons flow from:

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

Electron Transport Chain

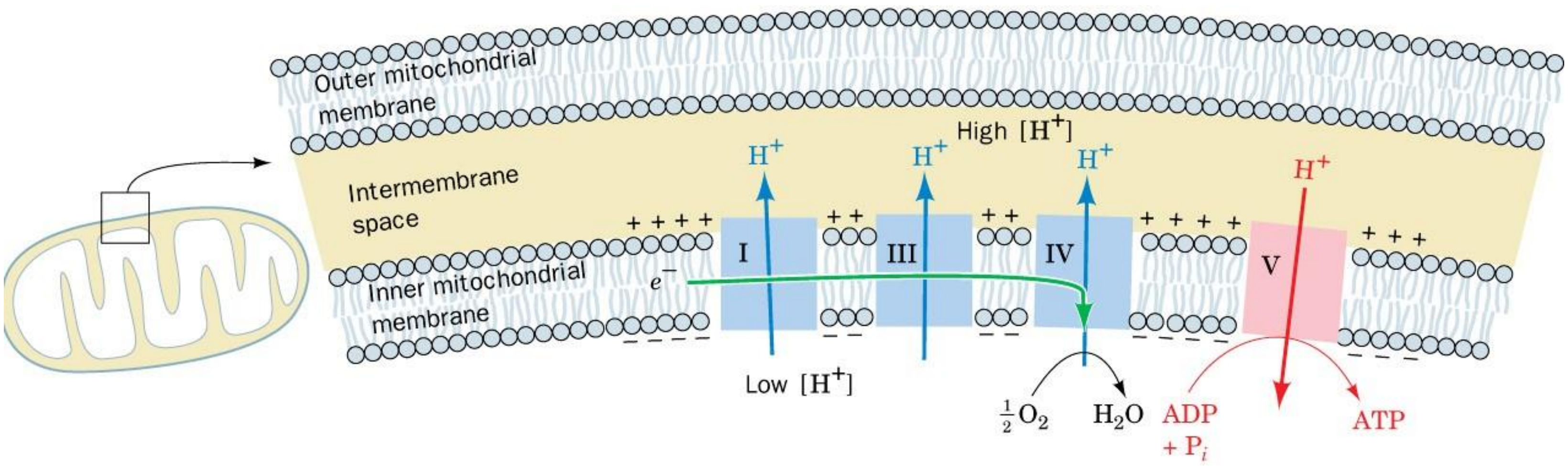


Site-specific inhibitors of ETC



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

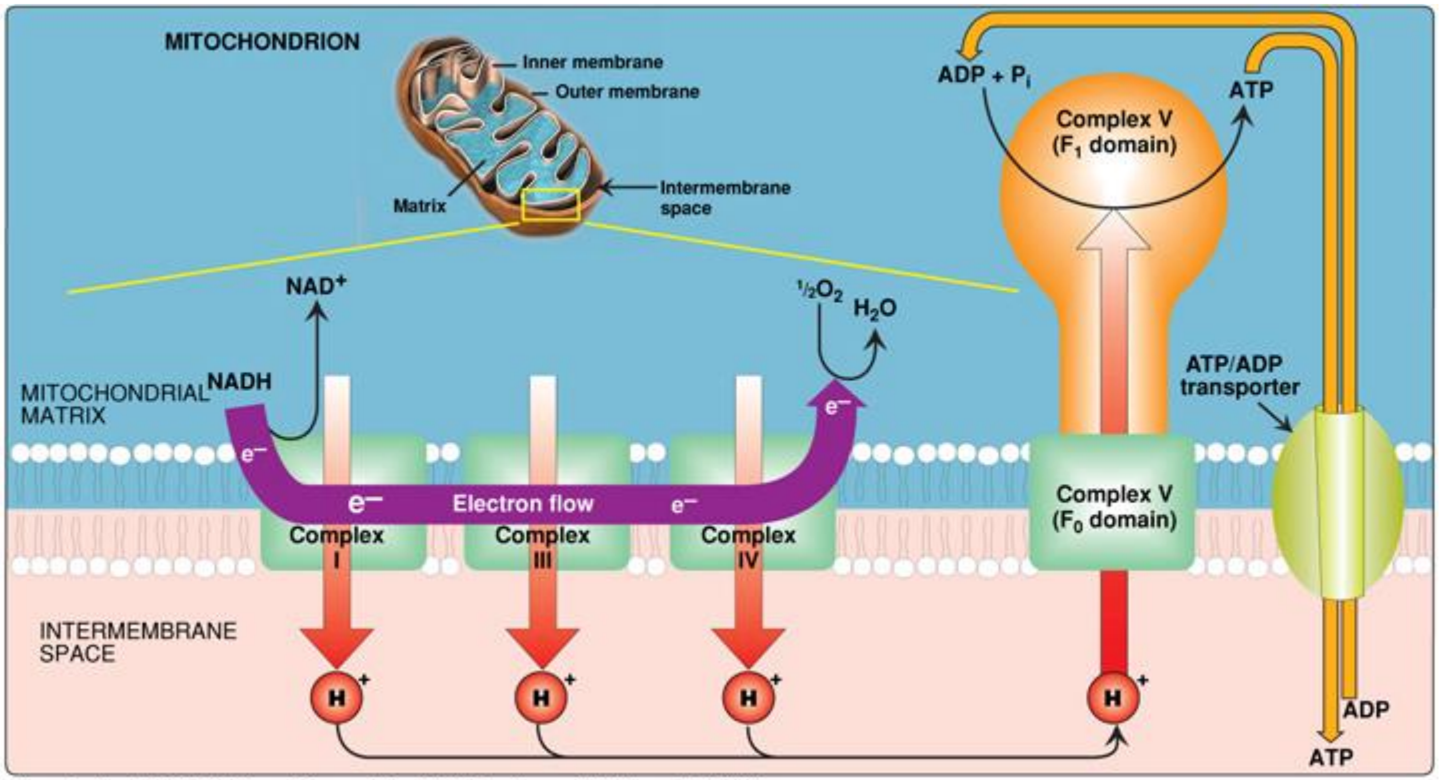


Coupling of electron transport (*green arrow*) and ATP synthesis

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

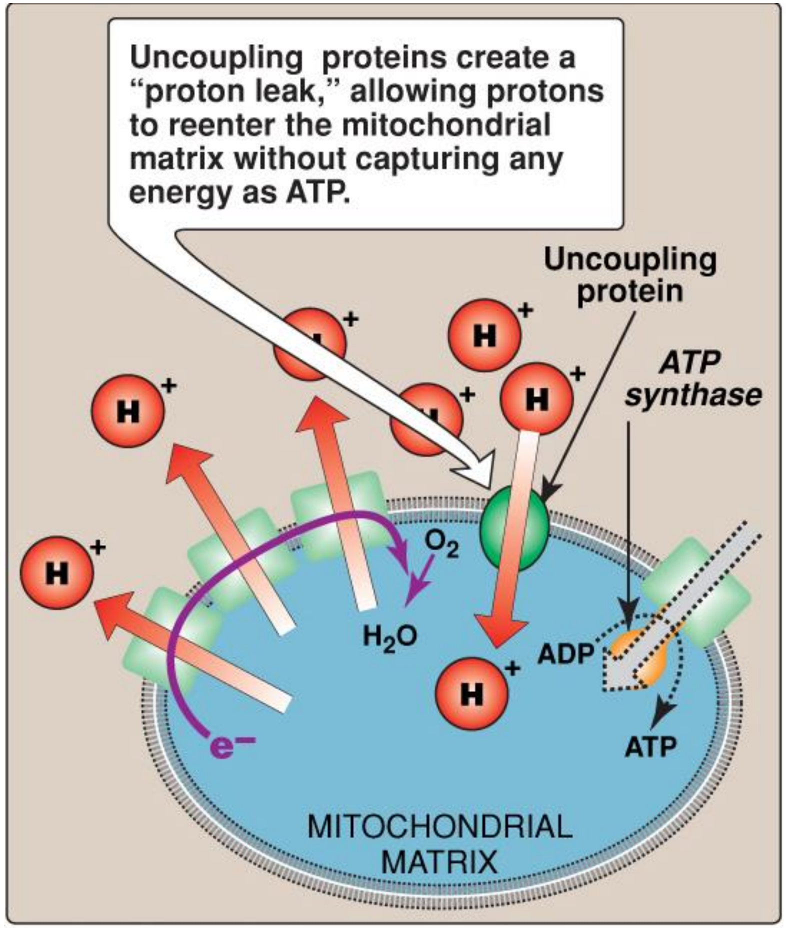
- The energy required for phosphorylation of ADP to ATP = 7.3kcal/mol
- Energy produced from the transport of a pair of electrons from NADH to O_2 = 52.58 kcal
- No. of ATP molecules produced is 3 (NADH to O_2)
- Excess energy is used for other reactions or released as heat

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.
Uncoupling protein
ATP synthase
H+
O2
H2O
e−
ADP
ATP
MITOCHONDRIAL MATRIX