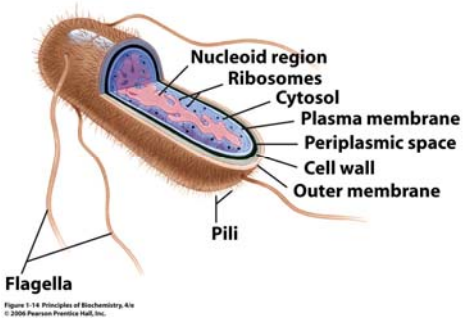
Chapter 14

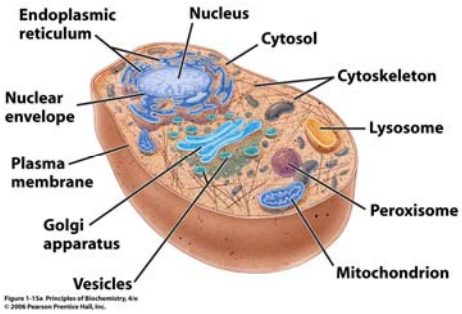
Oxidative Phosphorylation

Prokaryotes are bacteria containing a single chromosome and no membrane-bound organelles or nuclear envelope. Gram negative bacteria have two membranes – an inner and an outer.

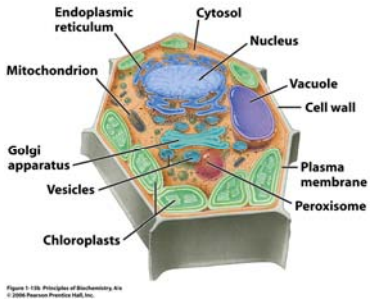


Eukaryotes contain multiple chromosomes surrounded by a membrane (nucleus) and membrane-bound organelles. Some organelles such as the nucleus and mitochondrion have two membranes.

Animal Cell



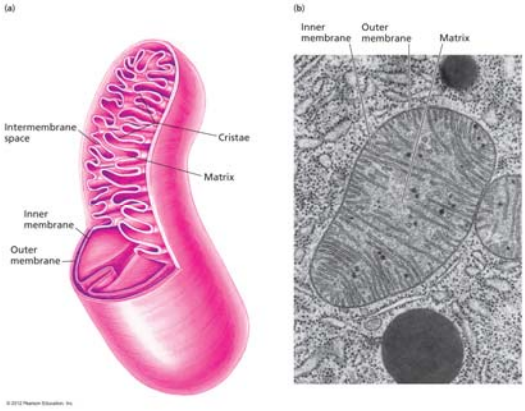
Plant Cell



The **mitochondrion** is thought to be an ancient prokaryotic, gram-negative, aerobic bacterium that took up **symbiotic** residence in a primitive, eukaryotic, anaerobic host.

Mitochondria have their own DNA, ribosomes, and transfer RNAs.

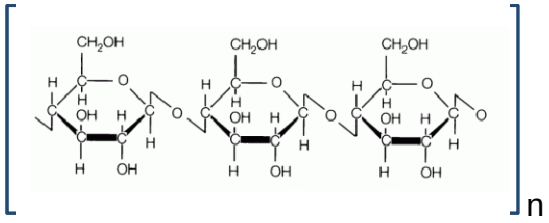
They contain an outer, highly permeable membrane and an inner impermeable membrane.



The interior **matrix** contains pyruvate deH_2ase, TCA cycle enzymes, and enzymes for oxidation of amino acids and fatty acids.

It is the **"furnace"** of the cell.

*(The **burning** of paper:* $(C_6H_{10}O_5)_n + 6nO_2 \rightarrow + 6nCO_2 + 5nH_2O)$



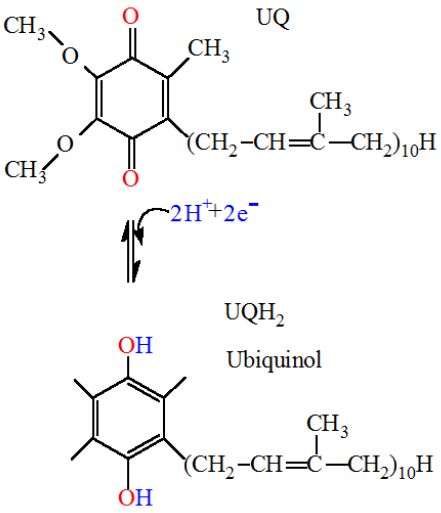
Part 1: Electron Flow

High *G* electrons from glycolysis, TCA cycle, AA, and fatty acid oxidation are funneled into universal electron carriers:

NADH / NADPH / $FADH_2$ The e^- are then transferred to a chain of e^- carriers in the inner membrane of the mitochondrion.

This is called the ***respiratory chain***.

The electron carriers are 4 protein complexes and their coenzymes.

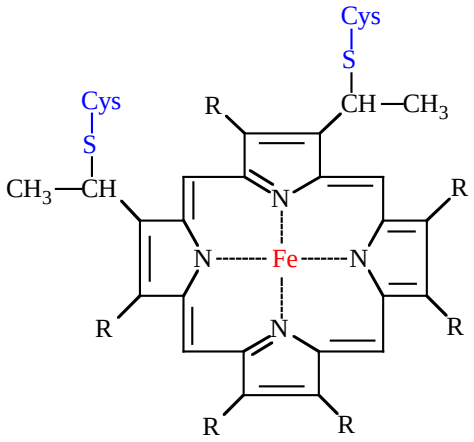


1. Coenzyme Q = Ubiquinone

It is lipid soluble and can diffuse through the membrane accepting and donating e^{-1}.

2. A family of cytochromes – all cytochromes except cyt c are integral membrane proteins. They have different amino acid sequences and bind slightly different ***iron-containing hemes.***

Part of cytochrome c



$Fe^{2+} \longrightarrow Fe^{3+} + e^-$

Ferrous Ferric

Cyt c is a peripheral membrane protein that binds Heme C covalently through Cys residues.

The ***standard reduction potential***, a measure of the *G* of the e^-, is different in each protein.

Tables 10-4 & 14-1.

Table 14.1 Standard reduction potentials of mitochondrial oxidation–reduction components

Substrate of Complex	$E^{\circ\prime}$ (V)
NADH	−0.32
Complex I	
FMN	−0.30
Fe–S clusters	−0.25 to −0.05
Succinate	+0.03
Complex II	
FAD	0.0
Fe–S clusters	−0.26 to 0.00
QH_2/Q	+0.04
$(\cdot Q^{\ominus}/Q$	−0.16)
$(QH_2/\cdot Q^{\ominus}$	+0.28)
Complex III	
Cytochrome b_1	−0.01
Cytochrome b_H	+0.03
Fe–S cluster	+0.28
Cytochrome c_1	+0.22
Cytochrome *c*	+0.22
Complex IV	
Cytochrome *a*	+0.21
Cu_A	+0.24
Cytochrome a_3	+0.39
Cu_B	+0.34
O_2	+0.82

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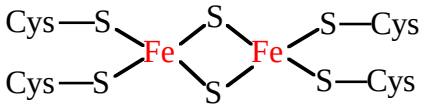
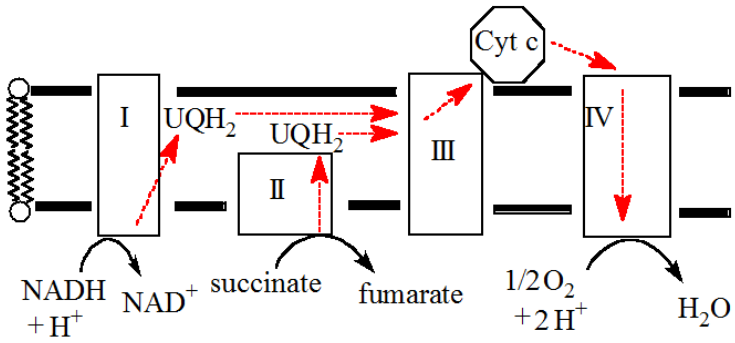
3. Fe-S Proteins



The *G* of the bound and released e^- is different in different proteins. Here is a summary of the passage of e^- and H^+ through the respiratory chain.

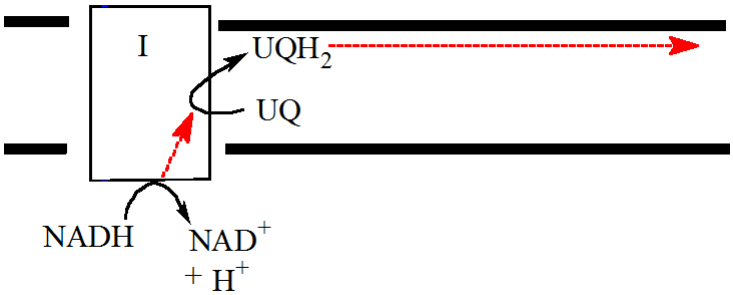


(see Figure 14.6: Textbook uses Q instead of UQ)

Complex I - NADH deH$_2$ase

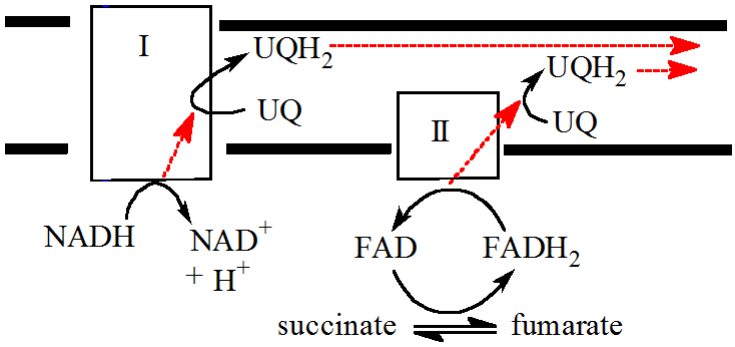
Consists of more than 25 proteins, 7 Fe-S centres, and FMN (FMN = Flavin mononucleotide)

Net reaction: $NADH + H^+ + UQ \rightleftharpoons NAD^+ + UQH_2$



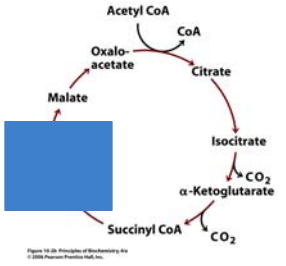
Complex II – Succinate deH_2ase

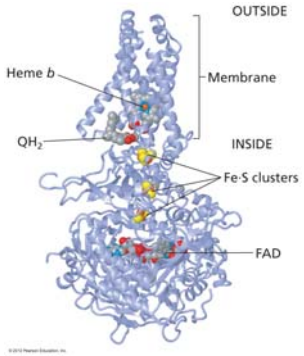
Consists of 4 proteins including Fe-S proteins, and covalently-bound FAD. It is the only membrane-bound enzyme of the TCA Cycle.

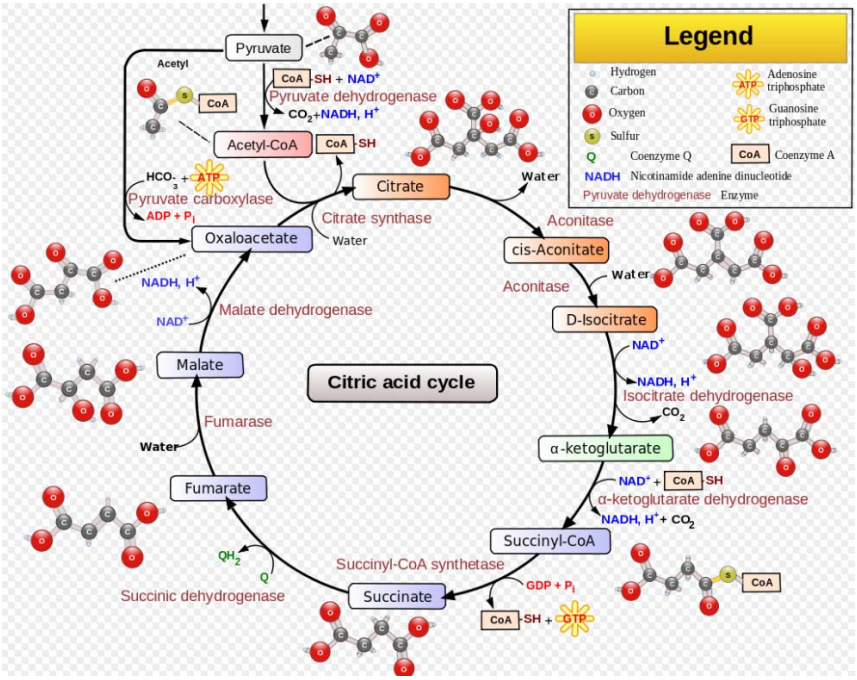


Net reaction:

$$FADH_2 + UQ \rightleftharpoons FAD + UQH_2$$





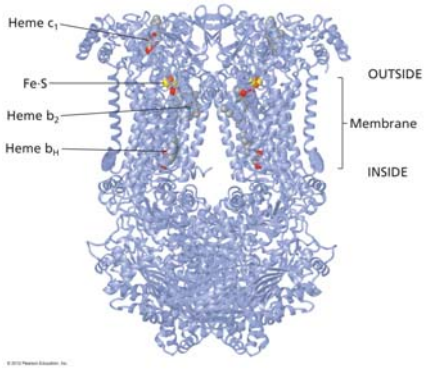


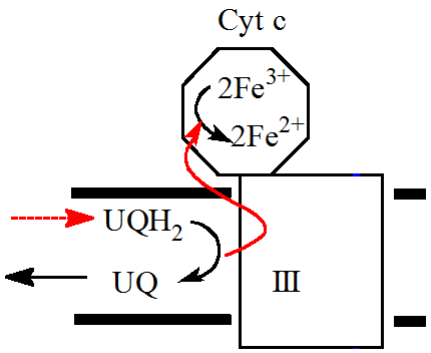
Complex III - UQ-Cyt c oxidoreductase

Consists of 10 proteins including Cyt b_{562}, Cyt b_{566}, Cyt c_1, Fe-S protein.

The last e^- acceptor is Cyt c which dissociates from Complex III and carries one e^- to Complex IV.

This is an ancient protein with homologs in chloroplasts and bacteria.



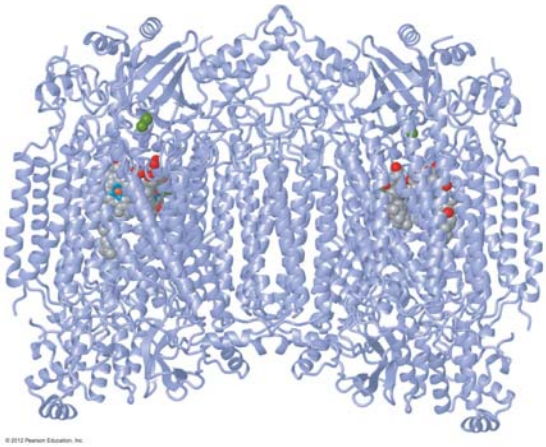


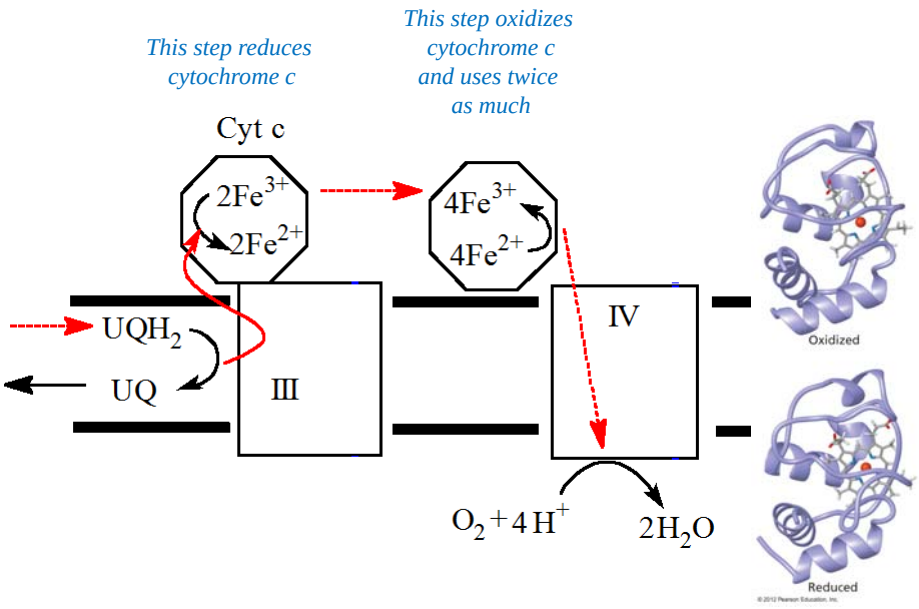
$2\text{Cyt c-Fe}^{3+} + \text{UQH}_2 \rightleftharpoons 2\text{Cyt c-Fe}^{2+} + \text{UQ} + 2\text{H}^+$

Net reaction

Complex IV - Cytochrome Oxidase

Consists of about 10 proteins including cytochromes a and a_3.





Energetics:

e^{-1} in NADH and $FADH_2$ have high *G*;
From Complex I to Complex IV e^- flow is down the *G* hill,
i.e. reactions favoured.