Oxidative Phosphorylation

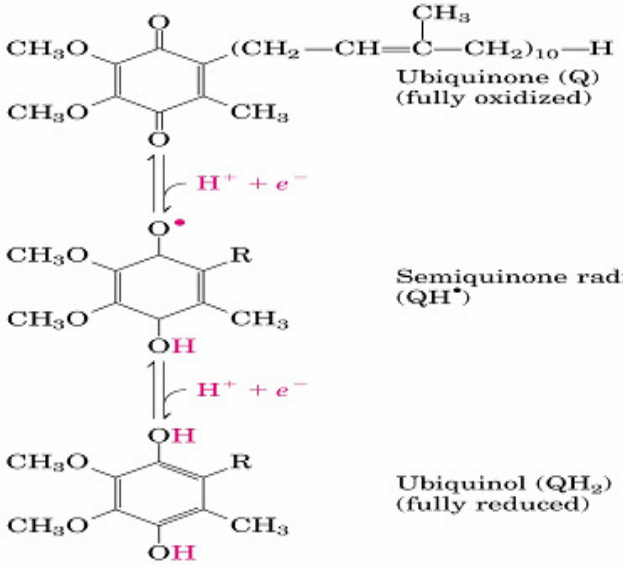
Electron pass through a series of membrane-bound carriers

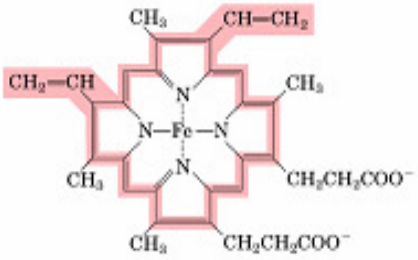
3 types of electron transfers occurs in oxidative phosphorylation:

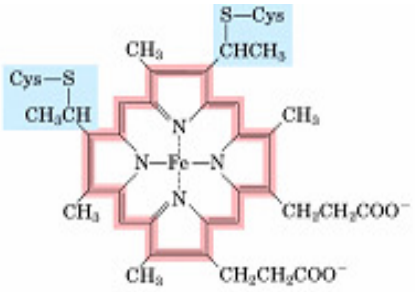
1. direct transfer of electrons, as in the reduction of Fe3+ or Fe2+
2. transfer as hydrogen atom (H+ + e-)
3. transfer as hydride ion (:H-), which bears two electrons

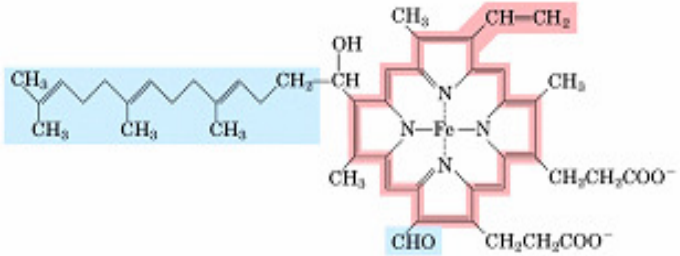
In addition to NAD and flavoproteins, three other types of electron-carrying molecules function in the respiratory chain; a hydrophobic quinone (ubiquinone) and two different types of iron-containing proteins (cytochromes and iron-sulfur proteins).

UPIQUINONE (also called Coenzyme Q or Q) is a lipid soluble benzoquinone with a long isoprenoid side chain



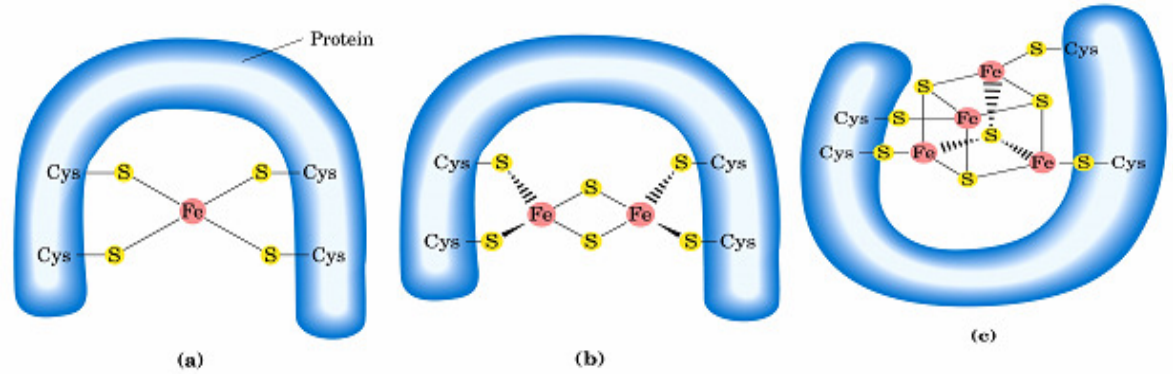

Iron protoporphyrin IX
(in *b*-type cytochromes)


Heme C
(in *c*-type cytochromes)


Heme A
(in *a*-type cytochromes)

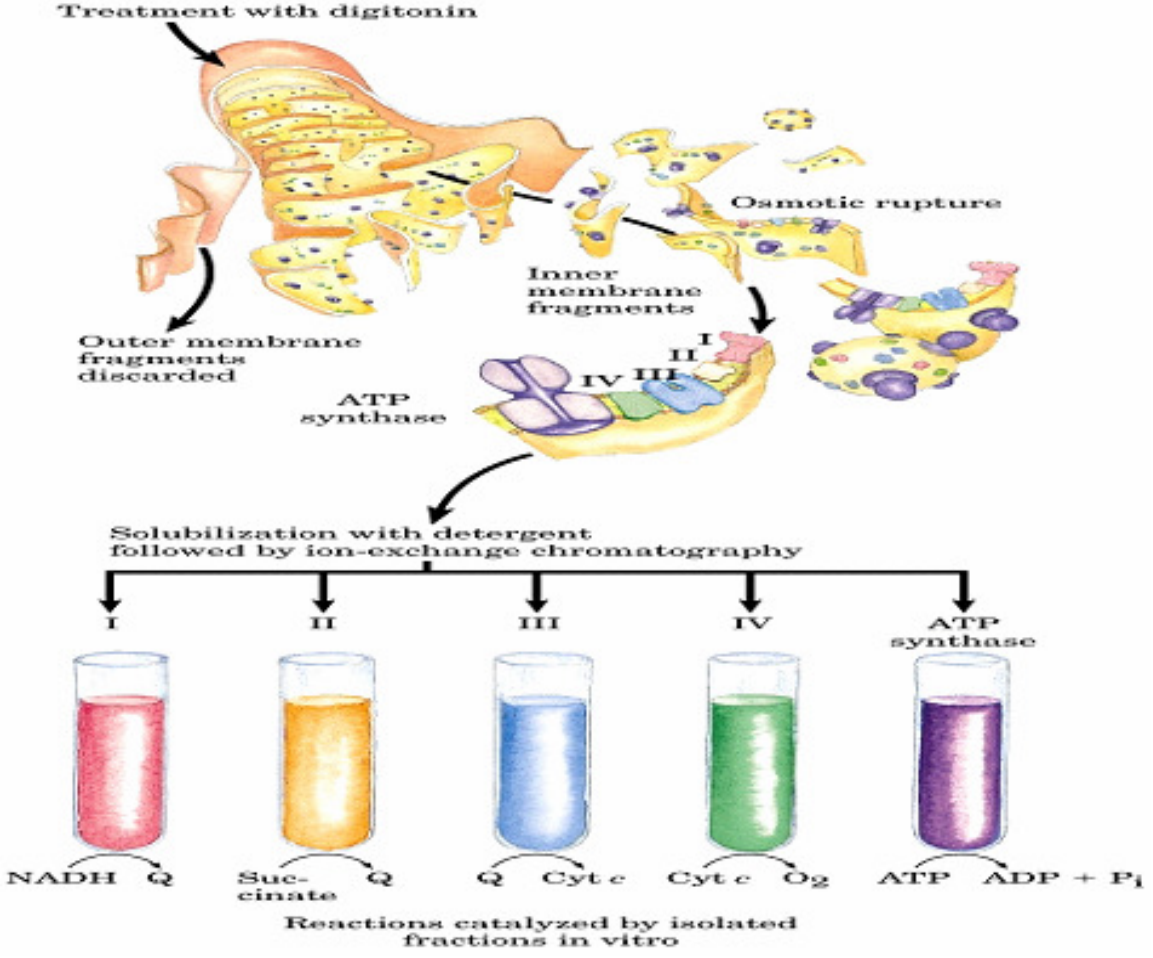
Cytochromes are proteins with characteristic strong absorption of visible light, due to their iron-containing heme prosthetic group

Iron-sulfur proteins



The iron is present not in the heme but in association with inorganic sulfur atoms or with the sulfur atoms of Cys residues in the protein or both.
Rieske iron-sulfur proteins are variation, in which one Fe atom is coordinated to two His residues rather than two Cys residues

Electron carriers function in multienzyme complexes



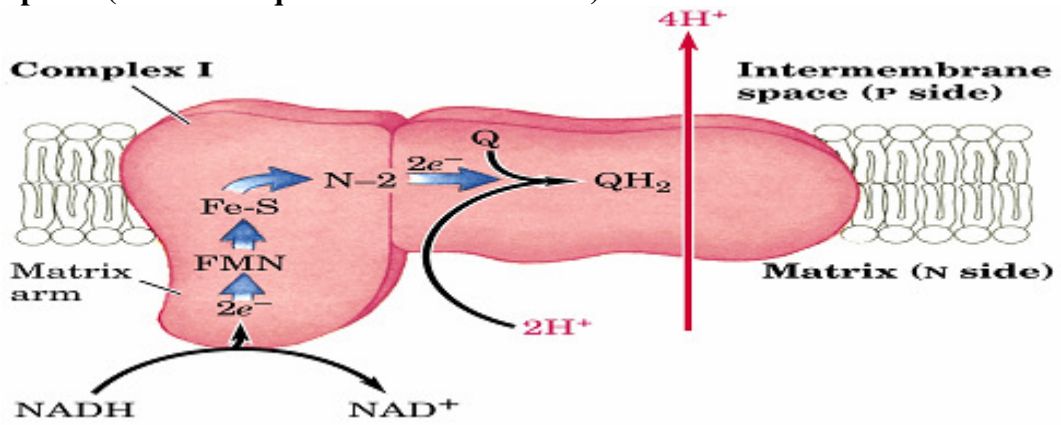
Protein Components of the Mitochondrial Electron-Transfer Chain

Enzyme complex	Mass (kDa)	Number of subunits*	Prosthetic group(s)
I NADH dehydrogenase	850	42 (14)	FMN, Fe-S
II Succinate dehydrogenase	140	5	FAD, Fe-S
III Ubiquinone: cytochrome *c* oxidoreductase	250	11	Hemes, Fe-S
Cytochrome *c*†	13	1	Heme
IV Cytochrome oxidase	160	13 (3–4)	Hemes; Cu_A, Cu_B

*Numbers of subunits in the bacterial equivalents in parentheses.

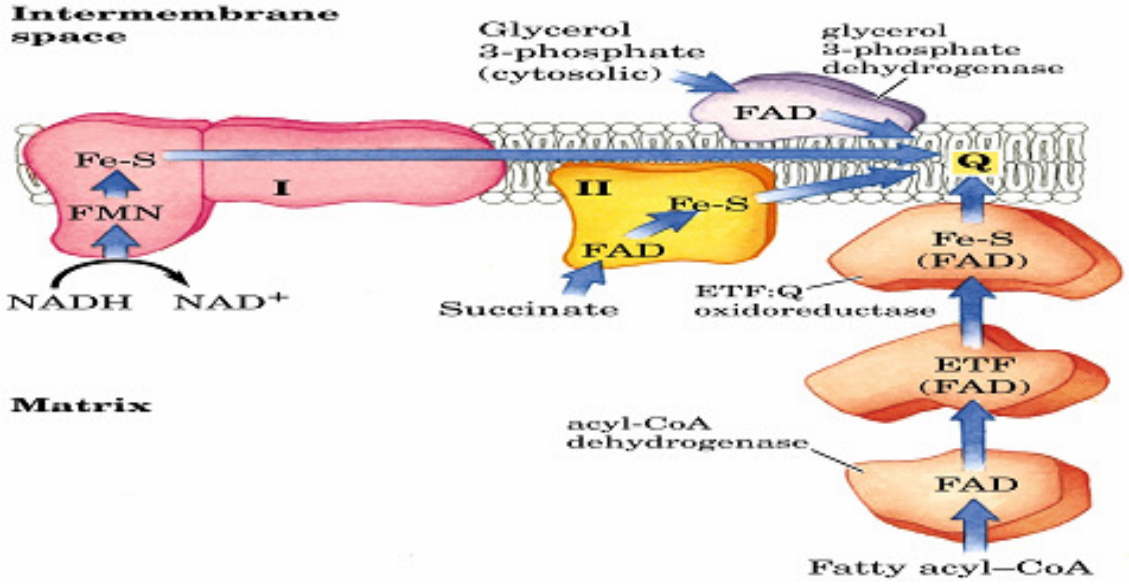
†Cytochrome *c* is not part of an enzyme complex; it moves between Complexes III and IV as a freely soluble protein.

Complex I (NADH-ubiquinone oxidoreductase)

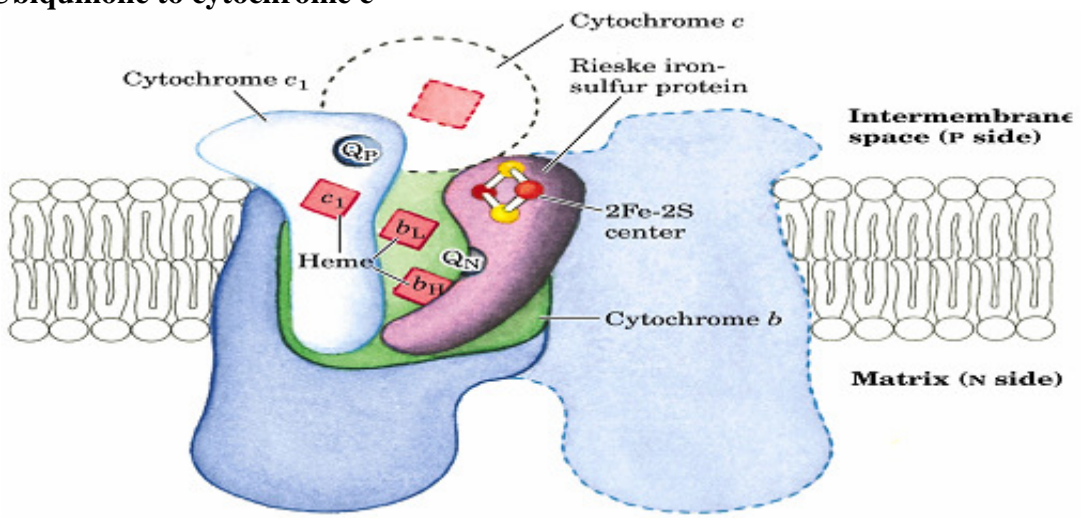


Catalysis electron transfer to ubiquinone from NADH

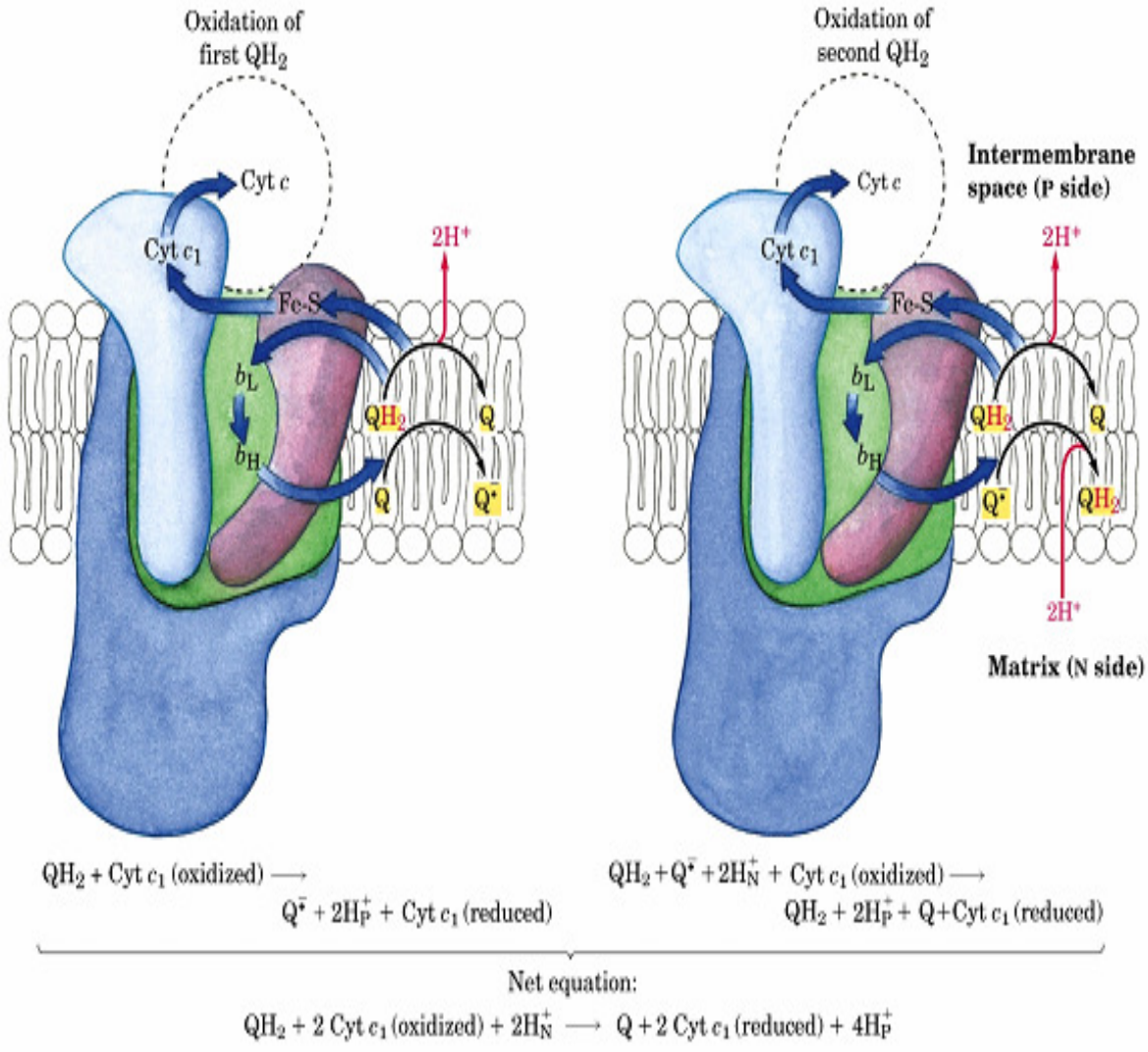
Complex II (Succinate dehydrogenase) – Succinate to Ubiquinone



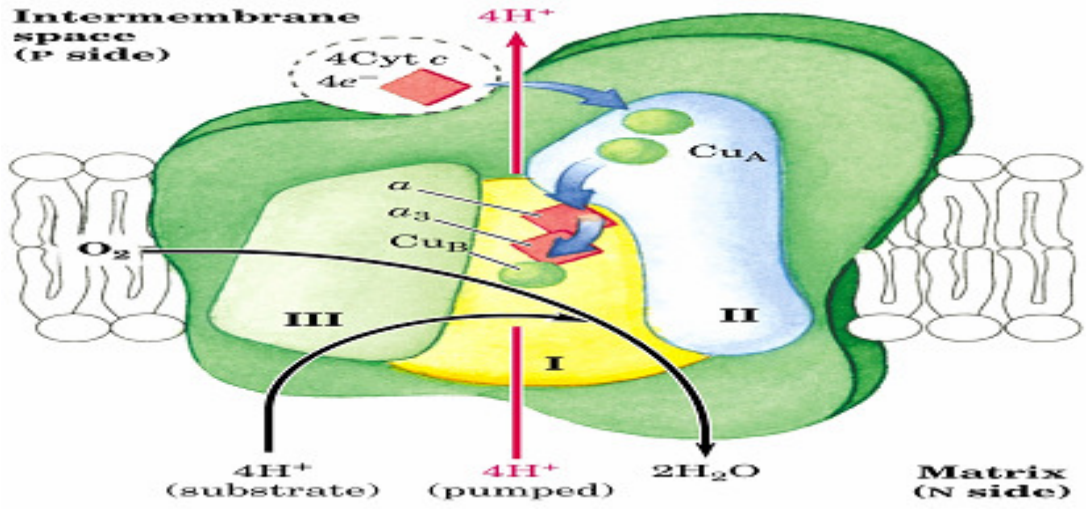
Complex III (Cytochrome bc1 complex or ubiquinone-cytochrome c oxidoreductase) – Ubiquinone to cytochrome c

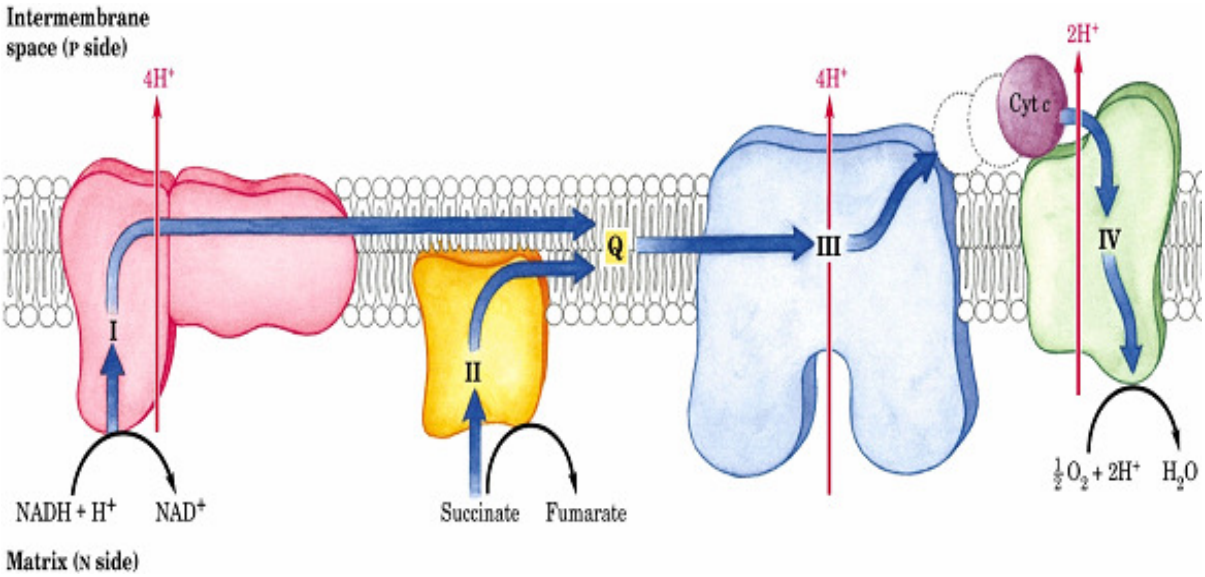


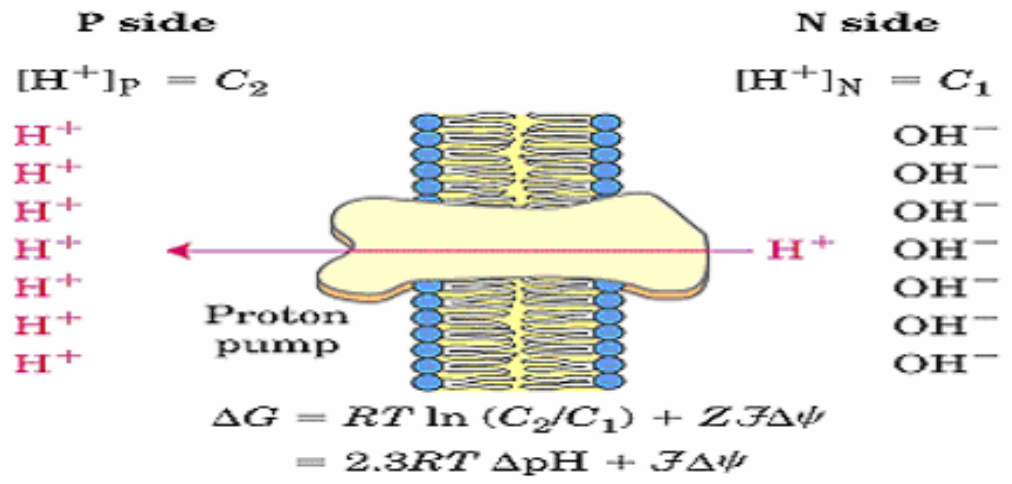
The Q cycle



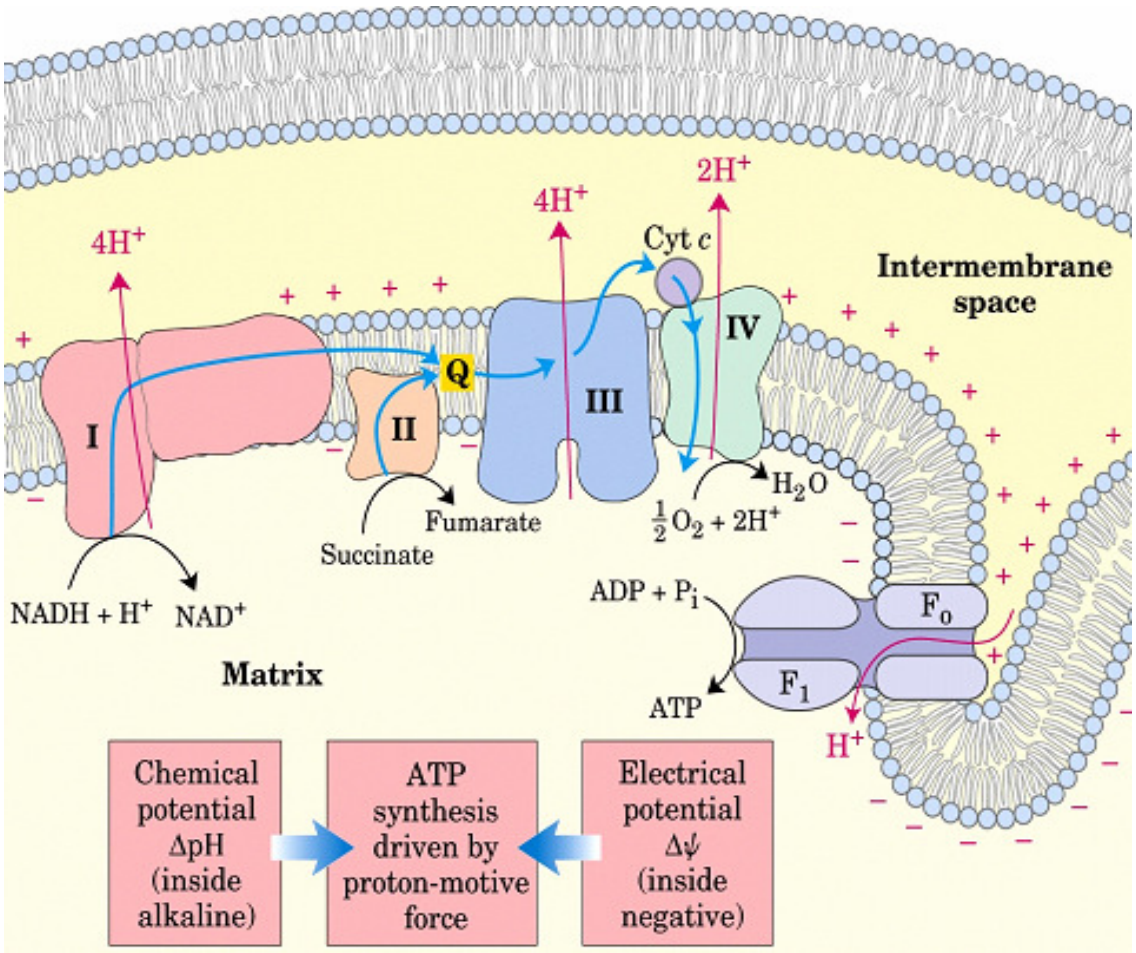
Complex IV (Cytochrome oxidase) – Cytochrome to O2







ATP Synthase – Chemiosmotic model

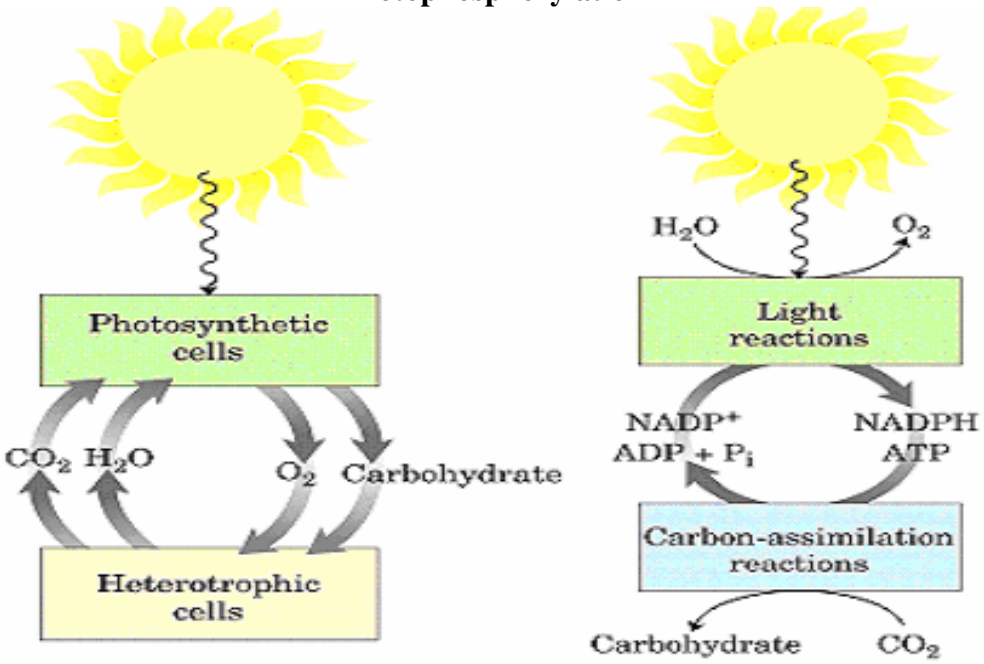


ATP Yield from Complete Oxidation of Glucose

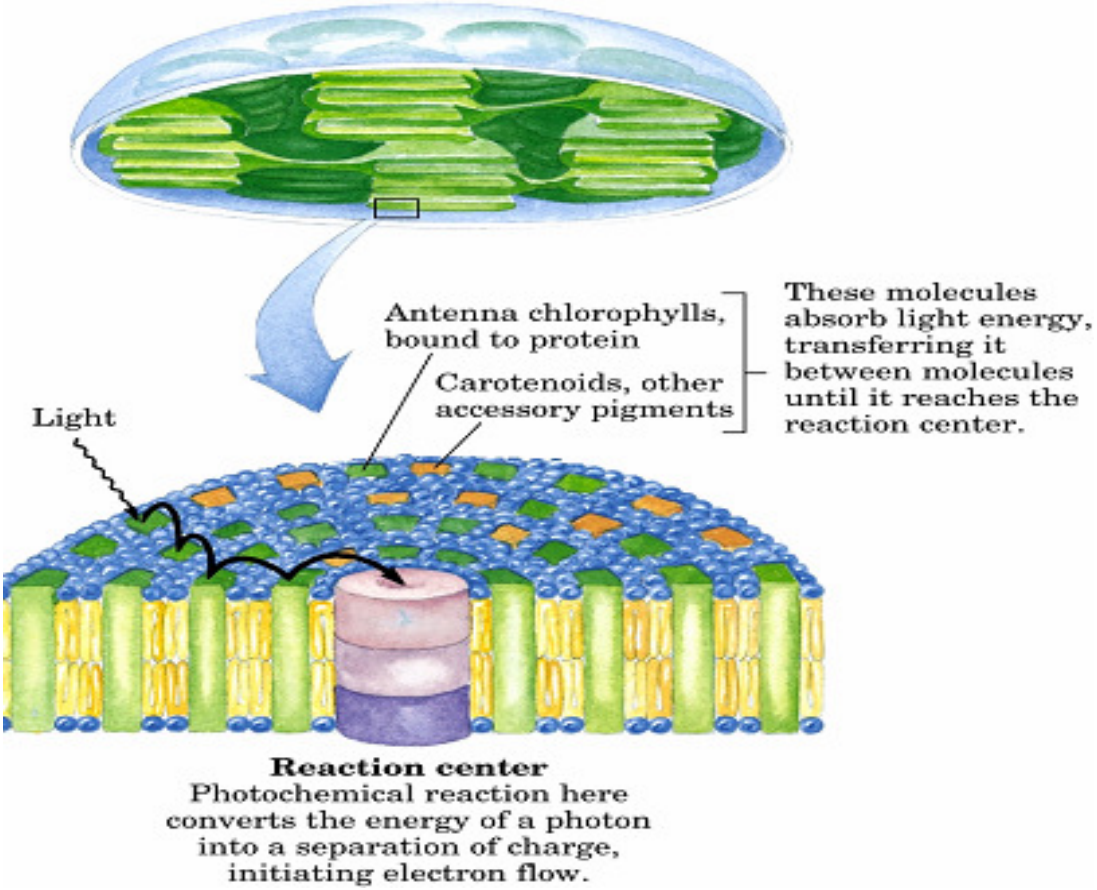
Process	Direct product	Final ATP
Glycolysis	2 NADH (cytosolic)	3 or 5*
	2 ATP	2
Pyruvate oxidation (two per glucose)	2 NADH (mitochondrial matrix)	5
Acetyl-CoA oxidation in citric acid cycle (two per glucose)	6 NADH (mitochondrial matrix)	15
	2 $FADH_2$	3
	2 ATP or 2 GTP	2
Total yield per glucose		30 or 32

*The number depends on which shuttle system transfers reducing equivalents into mitochondria.

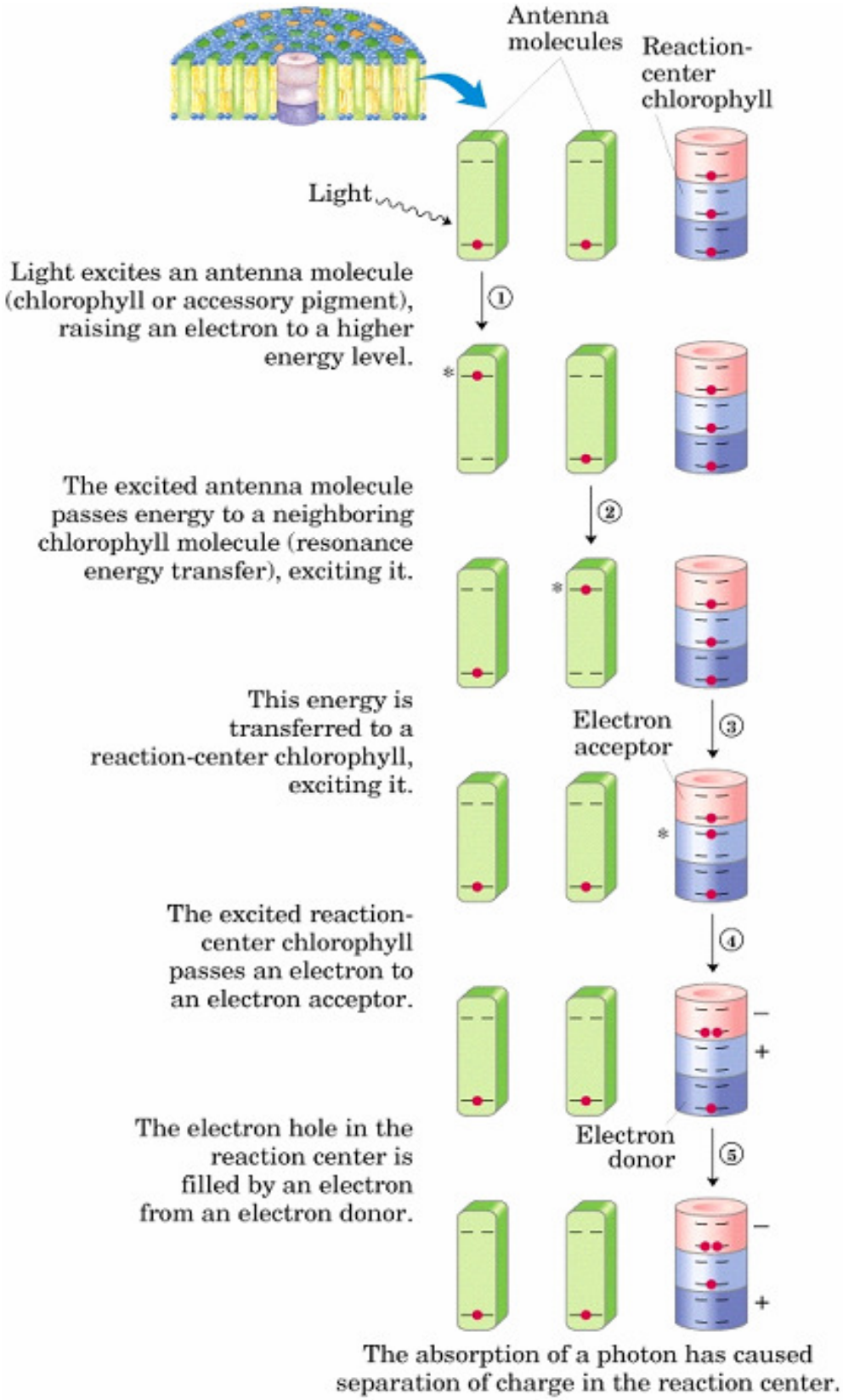
Photophosphorylation



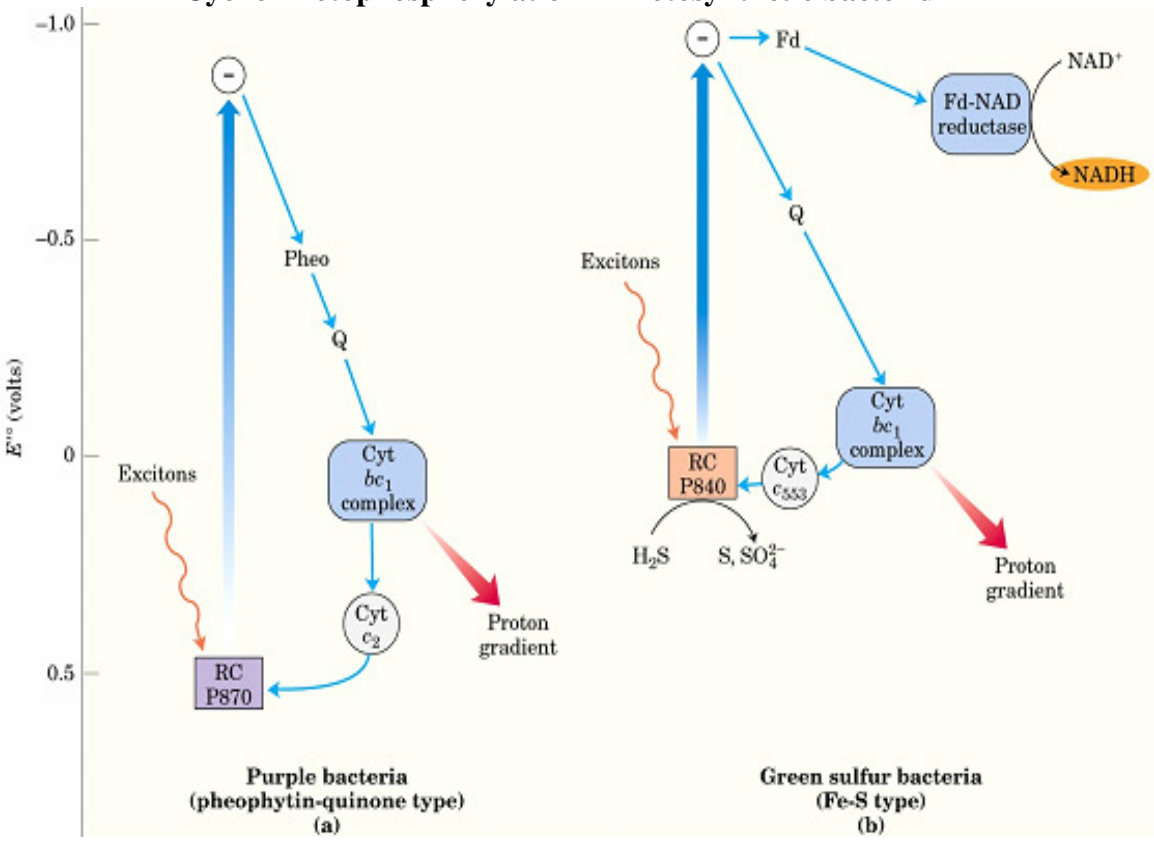
Organisation of photosystems in the thylakoid membrane



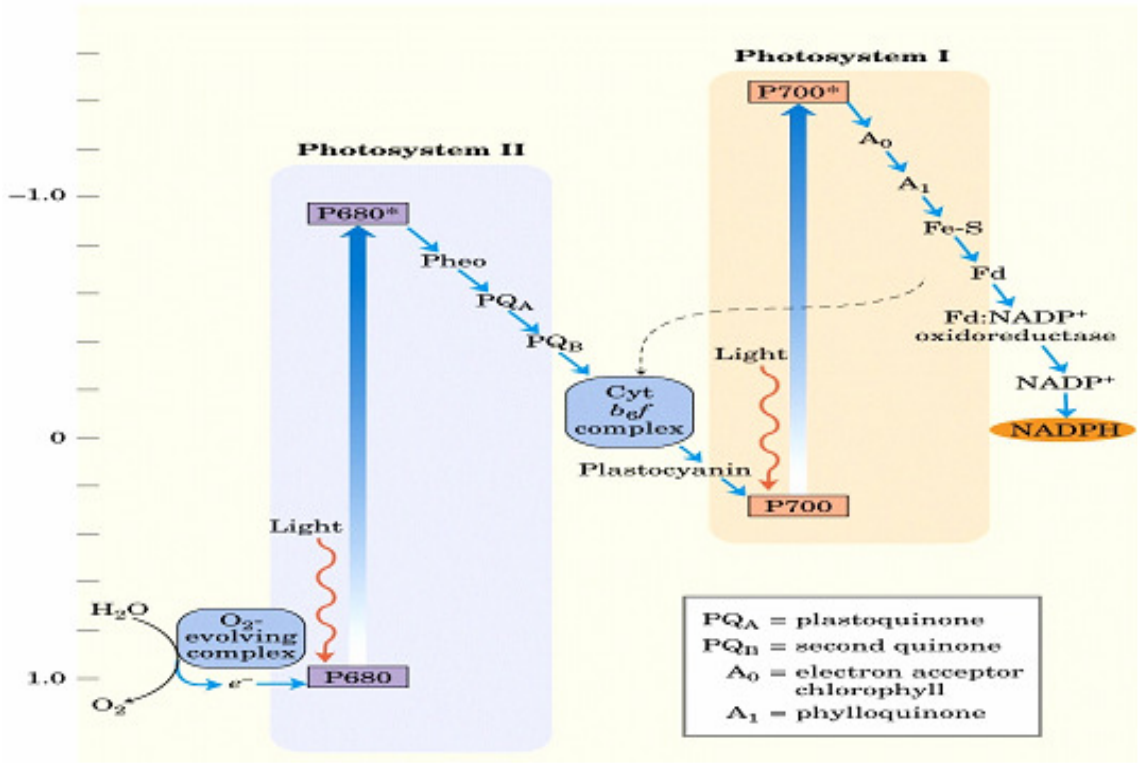
Exciton transfer

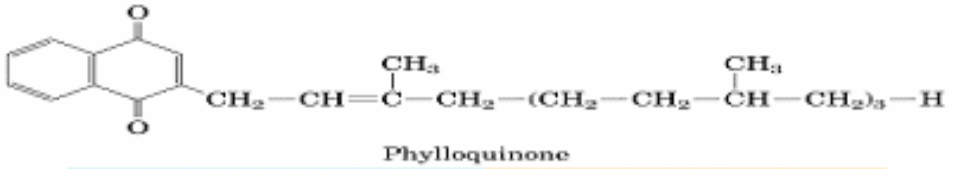


Cyclic Photophosphorylation – Photosynthetic bacterium

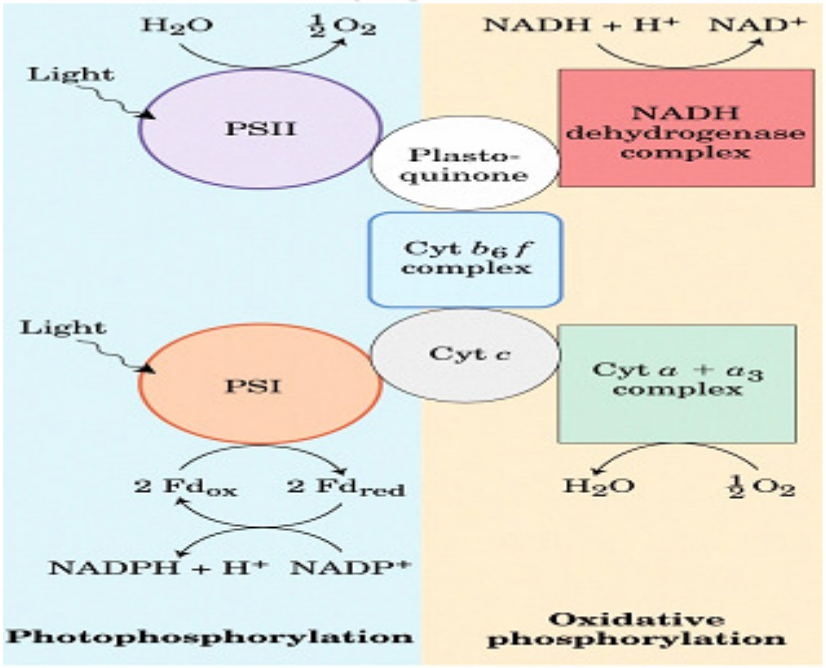


Noncyclic Photophosphorylation

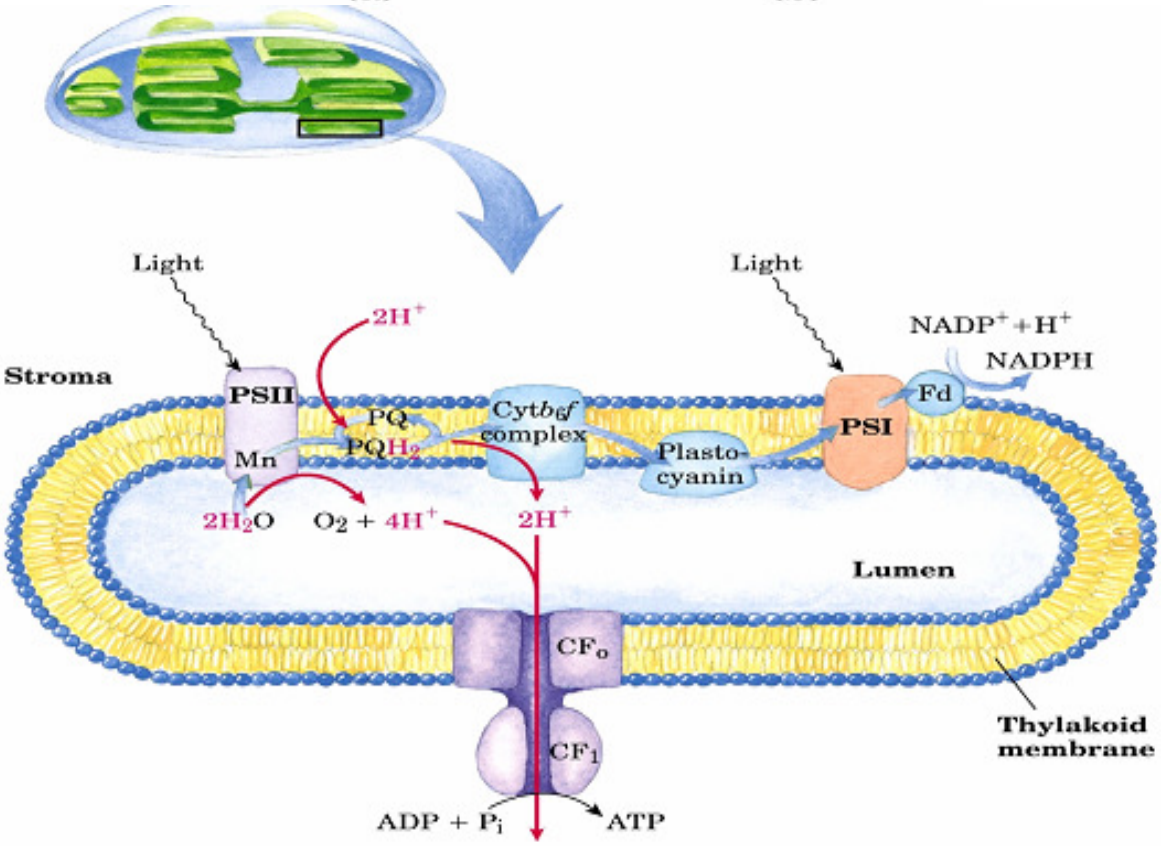


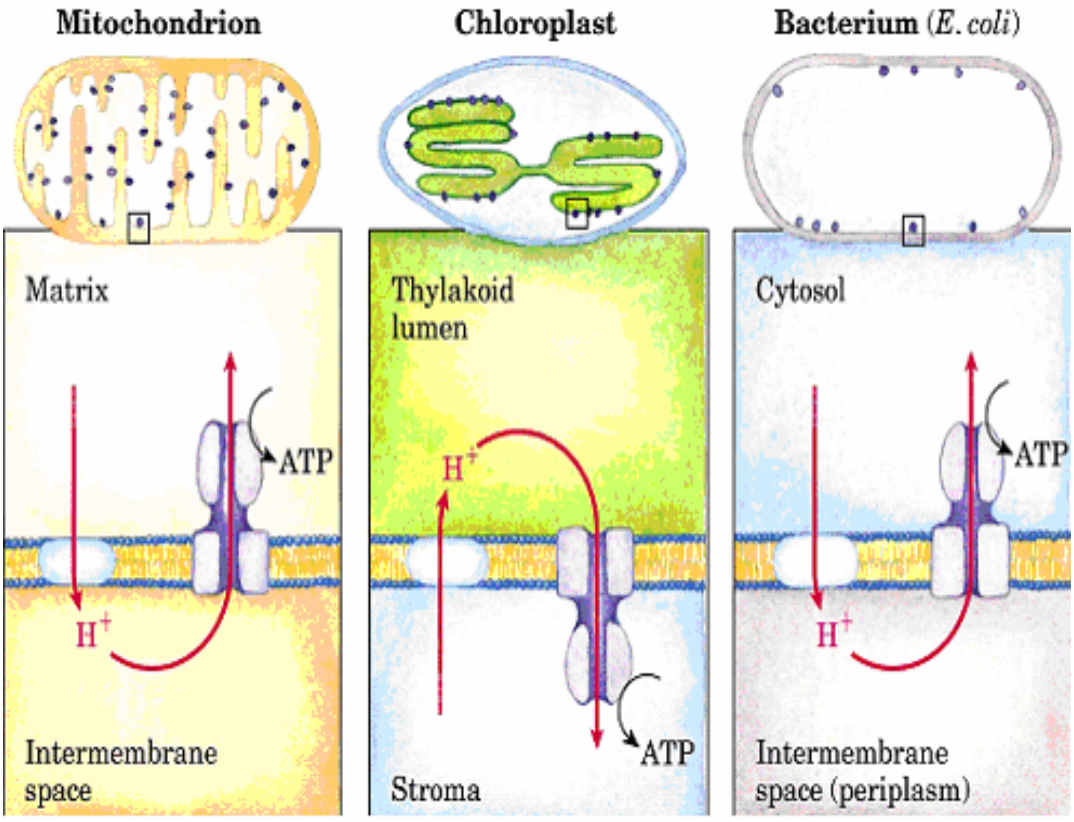


Phylloquinone



(a) (b)




Mitochondrion
Chloroplast
Bacterium (E. coli)
Matrix
Thylakoid lumen
Cytosol
ATP
ATP
ATP
H+
H+
H+
Intermembrane space
Stroma
Intermembrane space (periplasm)