
JK
2004

Membrane Proteins

Mitochondria and respiratory chains

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Presentations

and

supplementary information

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Lectures in Membrane Proteins by John F. Allen

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References

- Nicholls DJ, Ferguson, SJ. Bioenergetics3. Academic Press/Elsevier Science 2002
- Molecular Biology of the Cell Bruce Alberts, Alexander Johnson, Julian Lewis, Martin Raff, Keith Roberts, and Peter Walter. 2002. Garland Science
- Lane N. Power, Sex, Suicide. Mitochondria and the Meaning of Life. Oxford University Press. October 2005

Specialist web sites

- Complex I Home Page
- News on the 3D structure from the Complex I Home Page
- Complex III Home Page
- Cytochrome oxidase home page. Complex IV, the subject of the lecture by Professor Peter Rich

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Qo. The movie

- Qo.mov

Molecule of the Month

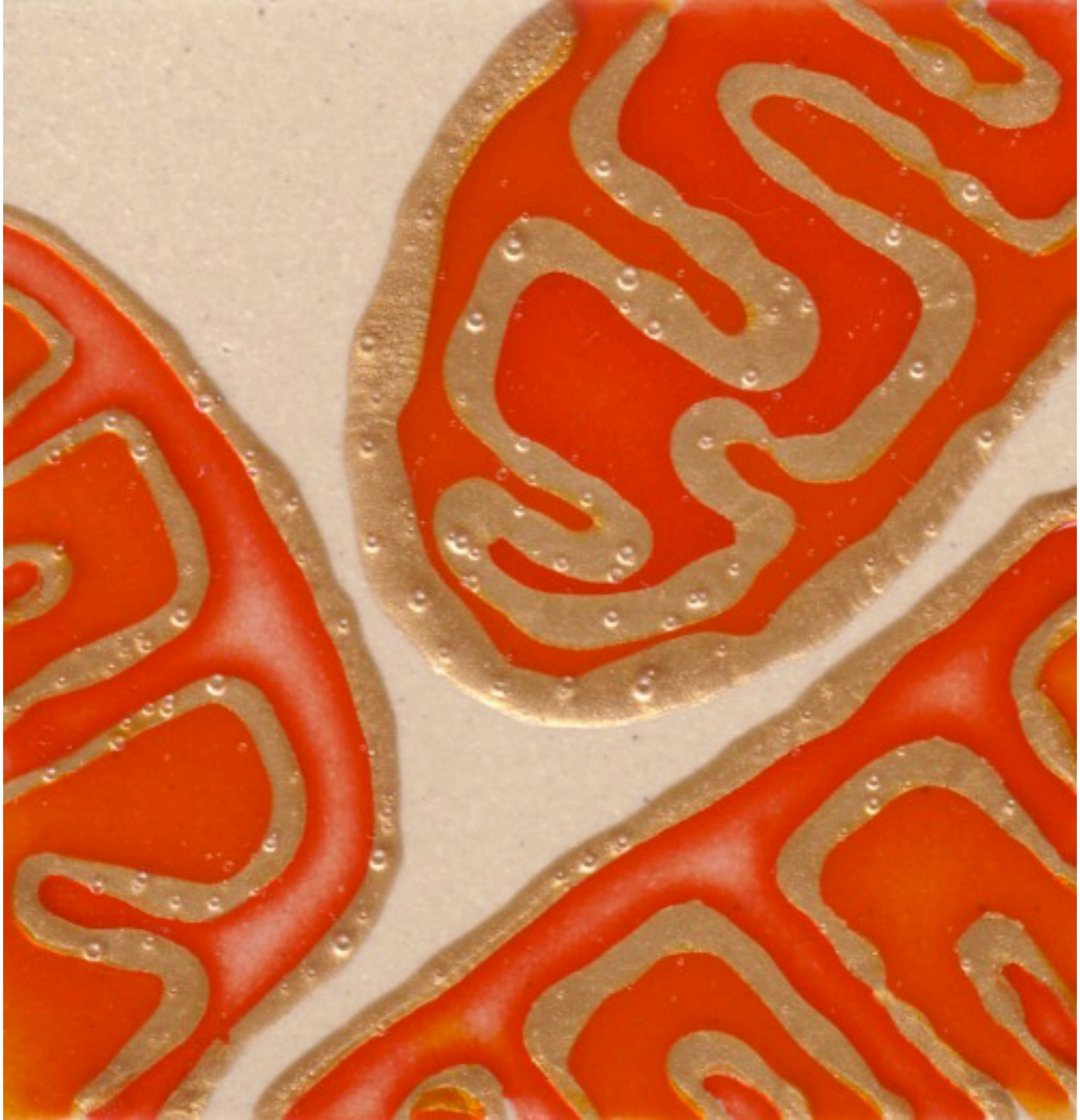
- ATP Synthase
- Bacteriorhodopsin
- Cytochrome c
- Cytochrome c Oxidase
- Photosystem I
- Photosystem II
- Potassium Channels

Relevant papers as pdf files. Please observe copyright

- Structure of the Hydrophilic Domain of Respiratory Complex I from Thermus thermophilus
- Structure of the Hydrophilic Domain of Respiratory Complex I from Thermus thermophilus pdf file
- An atypical haem in the cytochrome b6f complex pdf file
- Structure of the Cytochrome b6f Complex of Oxygenic Photosynthesis: Tuning the Cavity pdf file
- Protein synthesis by isolated pea mitochondria is dependent on the activity of respiratory complex II
- Structure for signalling and vectorial metabolism
- Energy transduction anchors genes in organelles
- The function of genomes in bioenergetic organelles
- Why do we still have a maternally inherited mitochondrial DNA? Insights from evolutionary medicine
- Power for life
- Chemiosmotic coupling: The Cost of Living Professor Peter Rich
- Power Games By Nick Lane
- Biodiversity: On the origin of bar codes By Nick Lane
- Photosynthesis - telling it like it is Review of Blankenship's Molecular Mechanisms of Photosynthesis

Nobel prizes

- 1978 Chemistry Nobel Prize to Peter Mitchell
- 1988 Chemistry Nobel Prize to Johann Deisenhofer, Robert Huber and Hartmut Michel
- 1997 Chemistry Nobel Prize to Paul D. Boyer, John E. Walker and Jens C. Skou



Redox carriers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Mitochondrial DNA—a tiny circular genome in the mitochondria, inherited from the mother. Males have sperm and females have eggs. Both pass on the genes in their nucleus, but under normal circumstances only the egg passes on mitochondria to the next generation—along with their tiny but critical genomes. The maternal inheritance of mitochondrial DNA has been used to trace the ancestry of all human races back to ‘Mitochondrial Eve’, in Africa 170 000 years ago. Recent data challenge this paradigm, but give a fresh insight into why it is normally the mother who passes on mitochondria. The new findings help explain why it was ever necessary for two sexes to evolve at all.

3.3.3 Redox potential and [oxidized]/[reduced] ratio

Just as the standard Gibbs energy change ΔG^{o} does not reflect the actual conditions existing in the cell, the standard redox potential E^{o} must be qualified to take account of the relative concentrations of the oxidized and reduced species.

The actual redox potential E at pH = 0 for the redox couple:

$$\text{Oxidized} + ne^{-} \rightleftharpoons \text{Reduced}$$

is given by the relationship:

$$E = E^{o} + 2.3\frac{RT}{nF}\log_{10}\left(\frac{[\text{oxidized}]}{[\text{reduced}]}\right) \qquad [3.20]$$

where R is the gas constant and F the Faraday constant. Note that this equation is closely analogous to the 'conventional' equation involving standard Gibbs energy changes (equation 3.9).

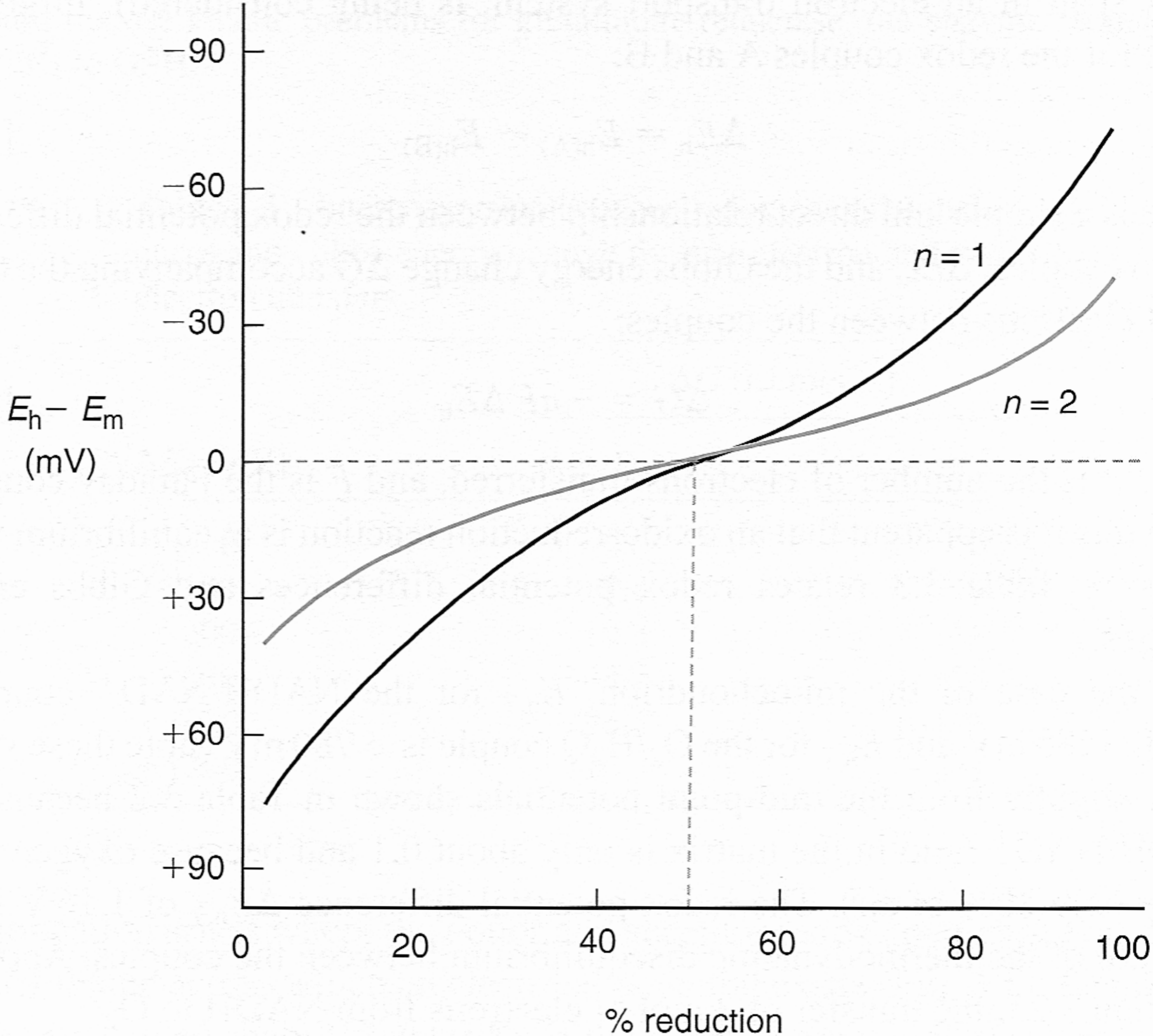


Figure 3.3 The variation of E_h with the extent of reduction of a redox couple. $n = 1$, $n = 2$ refer to one- and two-electron oxido-reductions, respectively.

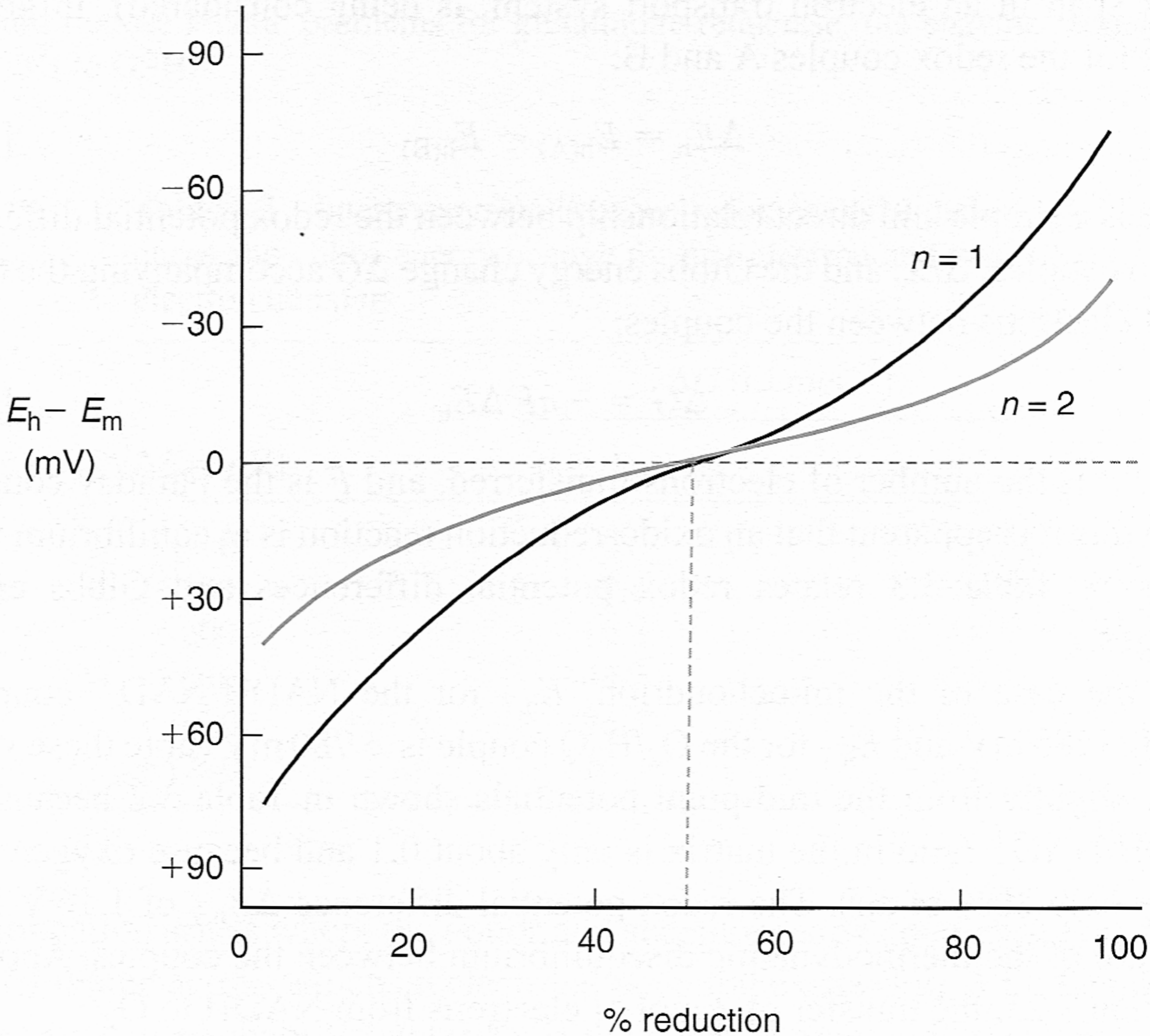


Figure 3.3 The variation of E_h with the extent of reduction of a redox couple. $n = 1$, $n = 2$ refer to one- and two-electron oxido-reductions, respectively.

Table 3.2 Some mid-point potentials and examples of actual redox potentials

$$\text{Oxidized} + ne^- + m\text{H}^+ = \text{reduced}$$

	n	m	$E_{m,7}$ (mV)	ΔE_m per pH	Typical ox/red ratio	$E_{h,7}$ (mV)*
Ferredoxin oxidized/reduced	1	0	−430	0		
$H^+/\frac{1}{2}H_2$ (at 1 atm)	1	1	−420	−60		
O_2 (1 atm†)/(superoxide)	1	0	−330	0	10^{-5}	−30
NAD^+/NADH	2	1	−320	−30	10	−290
$NADP^+$/NADPH	2	1	−320	−30	0.01	−380
Menaquinone/menaquinol	2	2	−74	−60		
Glutathione oxidized/reduced (when GSH + GSSG = 10 mM)	2	2	−172	−60	0.01	−240‡
Fumarate/succinate	2	2	+30	−60		
Ubiquinone/ubiquinol	2	2	+60	−60		
Ascorbate oxidized/reduced	2	1	+60	−30		
Cyt *c* oxidized/reduced	1	0	+220	0		
Ferricyanide oxidized/reduced	1	0	+420	0		
O_2 (1 atm†)/$2H_2O$ (55 M)	4	4	+820	−60		

* Approximate values for mitochondrial matrix under typical conditions.
† 1 atm oxygen = 1.25 mM.
‡ See equation 3.22.

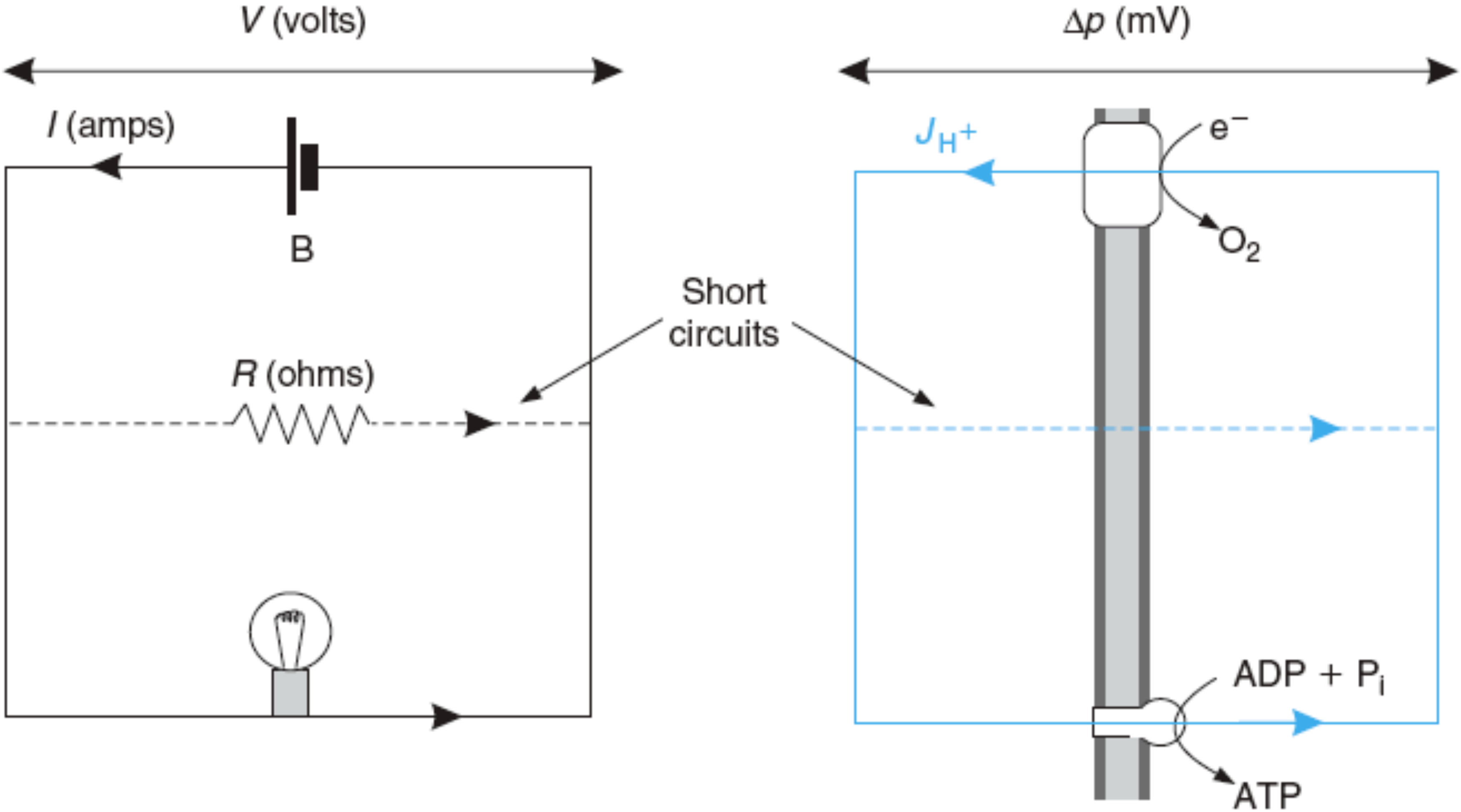


Figure 1.3 Proton circuits and electrical circuits are analogous.
A simple electrical circuit comprising battery and light bulb is analogous to a basic proton circuit. Voltage (Δp equivalent to V), current (J_{H^+} equivalent to I) and conductance C_MH^+ (equivalent to electrical conductance – reciprocal ohms) terms can be derived. Short-circuits have similar effects and more complex circuits with parallel batteries can be devised to mimic the multiple proton pumps in the mitochondrion (see Chapter 4).

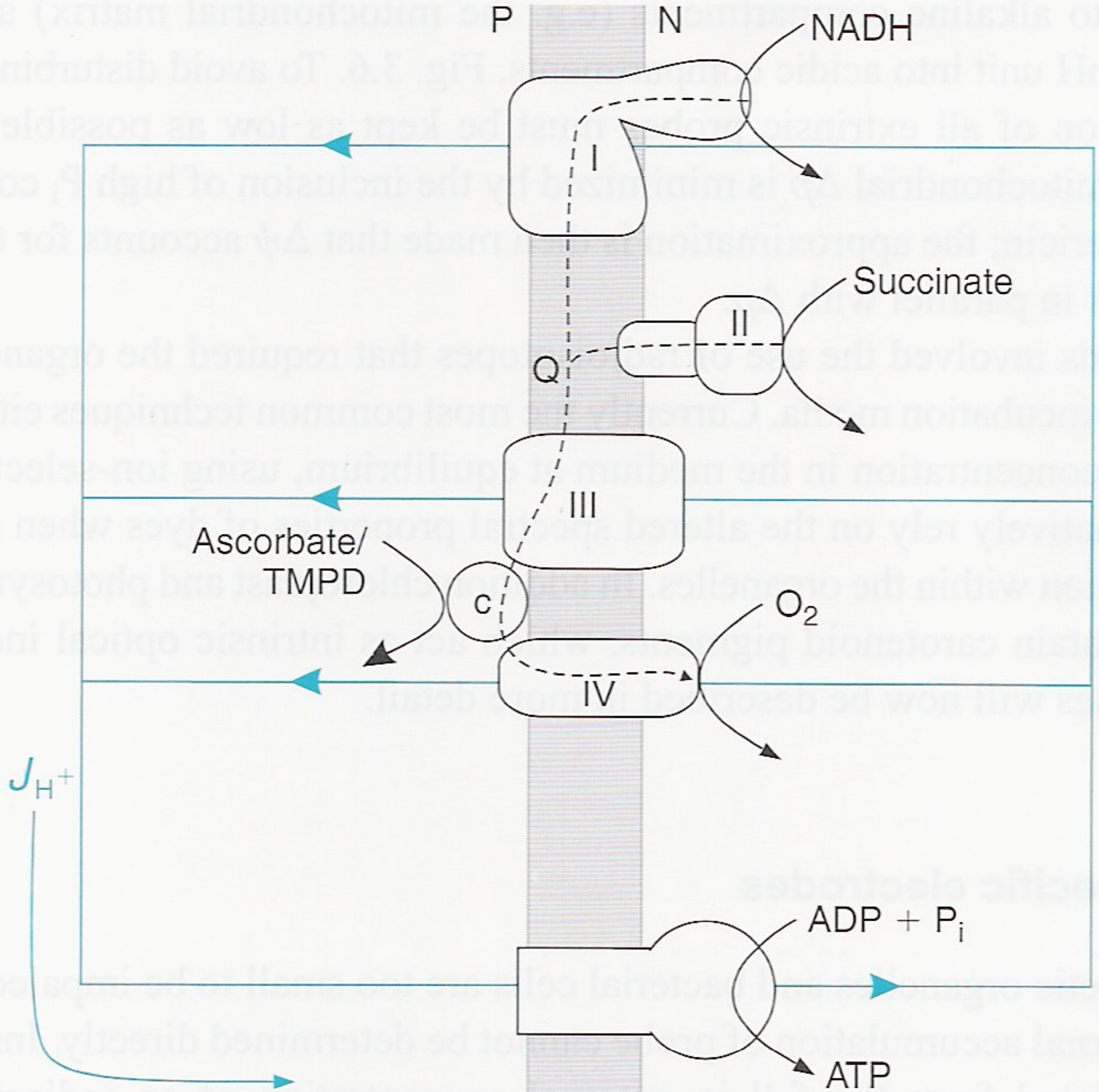


Figure 4.2 The mitochondrial respiratory chain consists of three proton pumps (complexes I, III and IV), which act in parallel with respect to the proton circuit and in series with respect to the electron flow.
Solid lines: pathway of proton flux; dotted line: pathway of electron transfer. For redox couples, see Table 3.2.

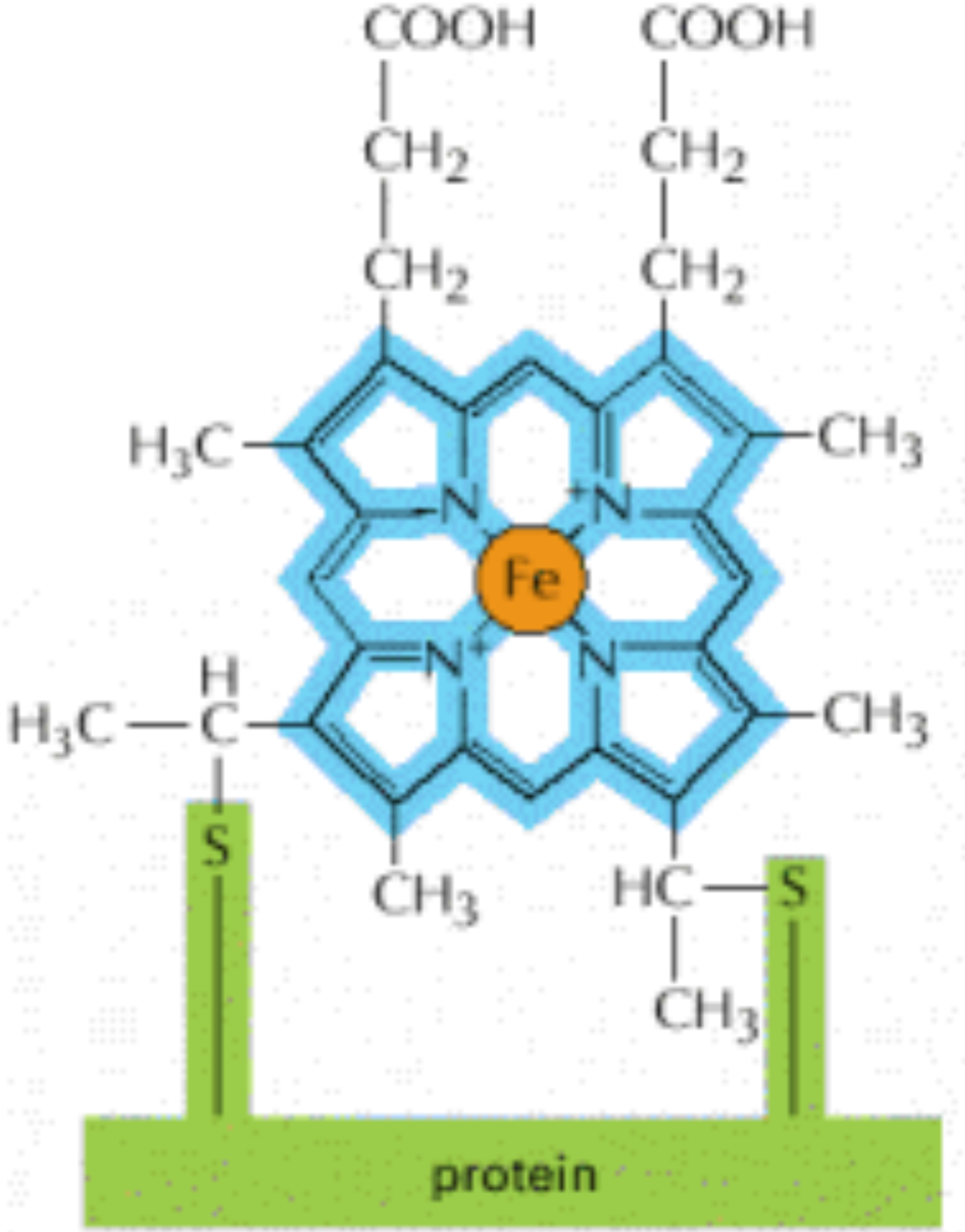


Figure 14-22. The structure of the heme group attached covalently to cytochrome *c*. The porphyrin ring is shown in *blue*. There are five different cytochromes in the respiratory chain. Because the hemes in different cytochromes have slightly different structures and are held by their respective proteins in different ways, each of the cytochromes has a different affinity for an electron.

(Alberts et al. Molecular Biology of the Cell)

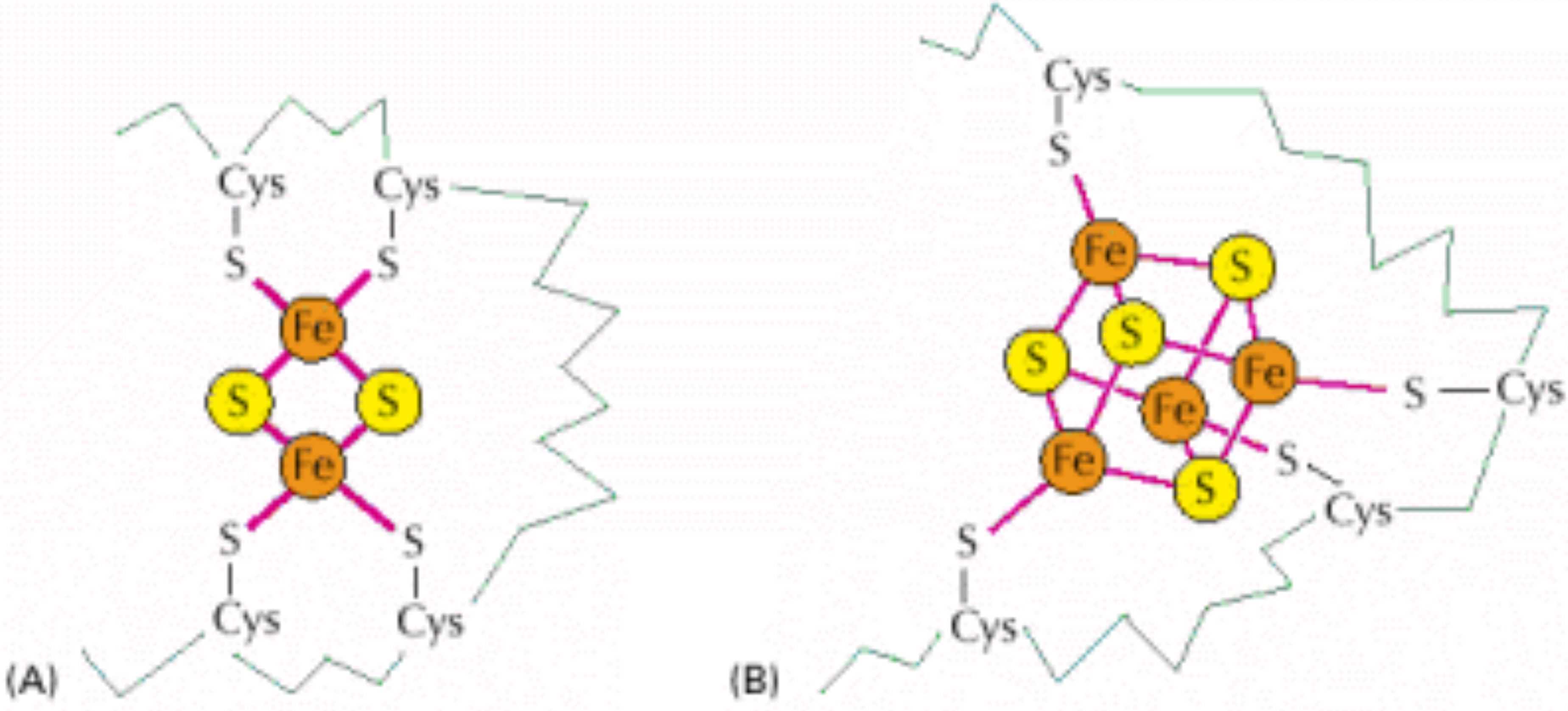


Figure 14-23. The structures of two types of iron-sulfur centers. (A) A center of the 2Fe2S type. (B) A center of the 4Fe4S type. Although they contain multiple iron atoms, each iron-sulfur center can carry only one electron at a time. There are more than seven different iron-sulfur centers in the respiratory chain.

(Alberts et al. Molecular Biology of the Cell)

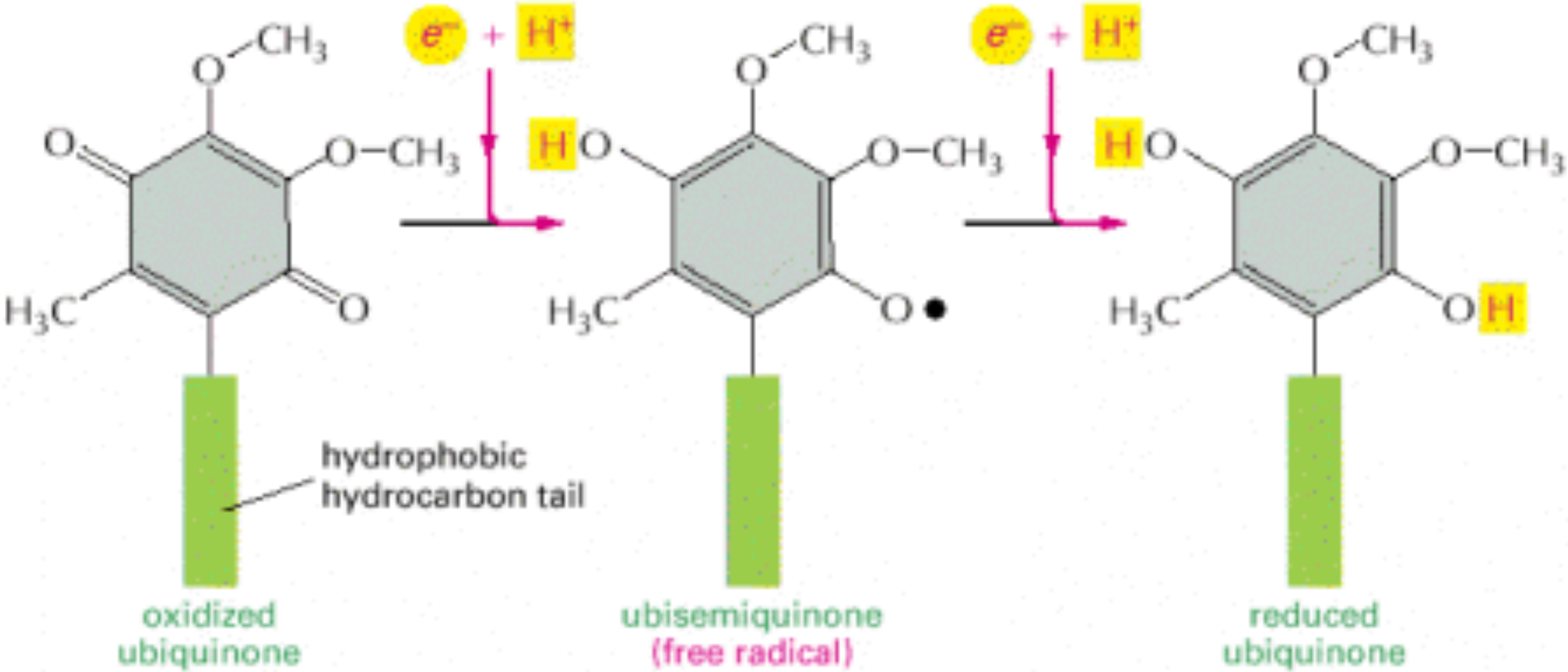


Figure 14-24. Quinone electron carriers. Ubiquinone in the respiratory chain picks up one H^+ from the aqueous environment for every electron it accepts, and it can carry either one or two electrons as part of a hydrogen atom *(yellow)*. When reduced ubiquinone donates its electrons to the next carrier in the chain, these protons are released. A long hydrophobic tail confines ubiquinone to the membrane and consists of 6–10 five-carbon isoprene units, the number depending on the organism. The corresponding electron carrier in the photosynthetic membranes of chloroplasts is plastoquinone, which is almost identical in structure. For simplicity, both ubiquinone and plastoquinone are referred to in this chapter as quinone (abbreviated as Q)

(Alberts et al. Molecular Biology of the Cell)

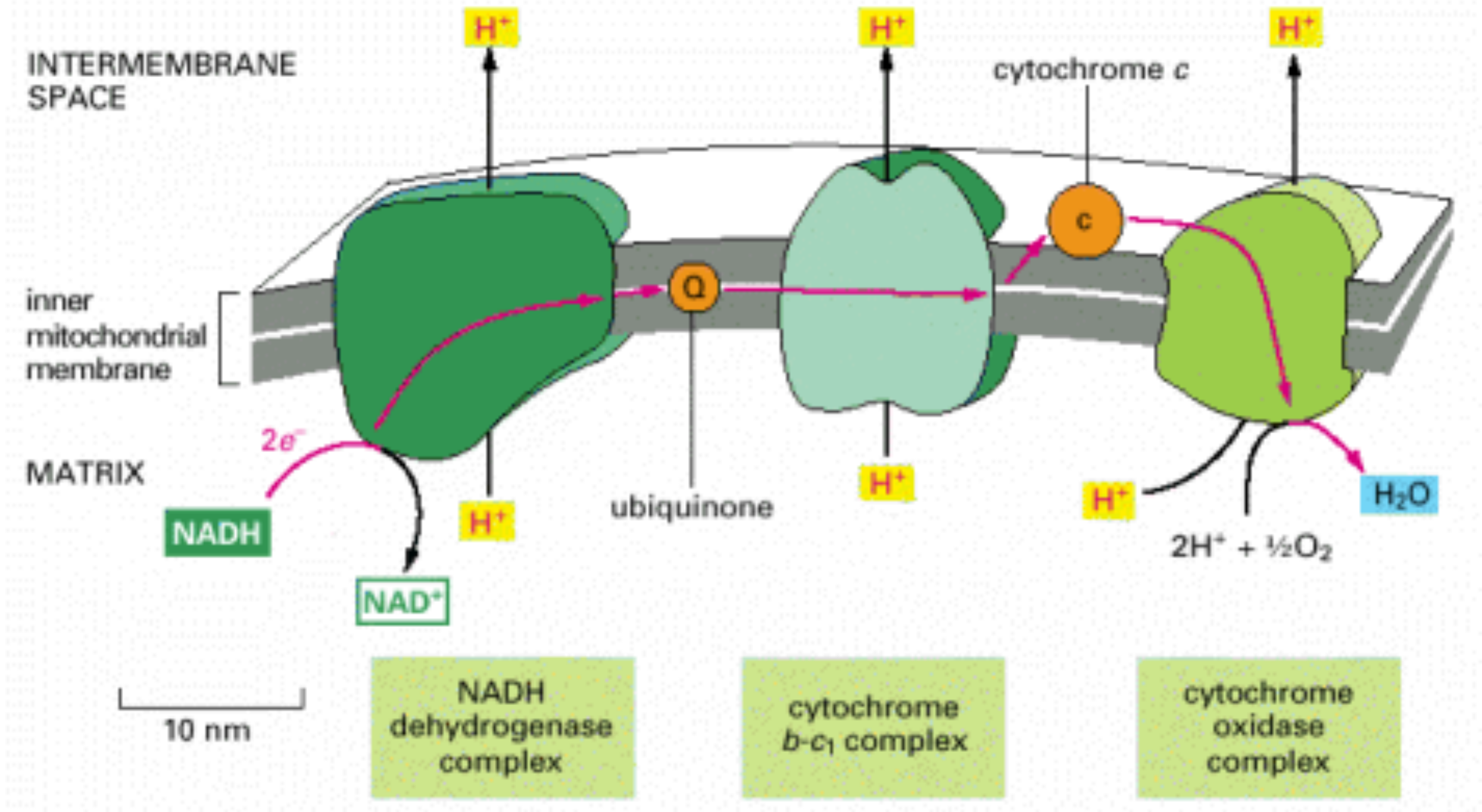
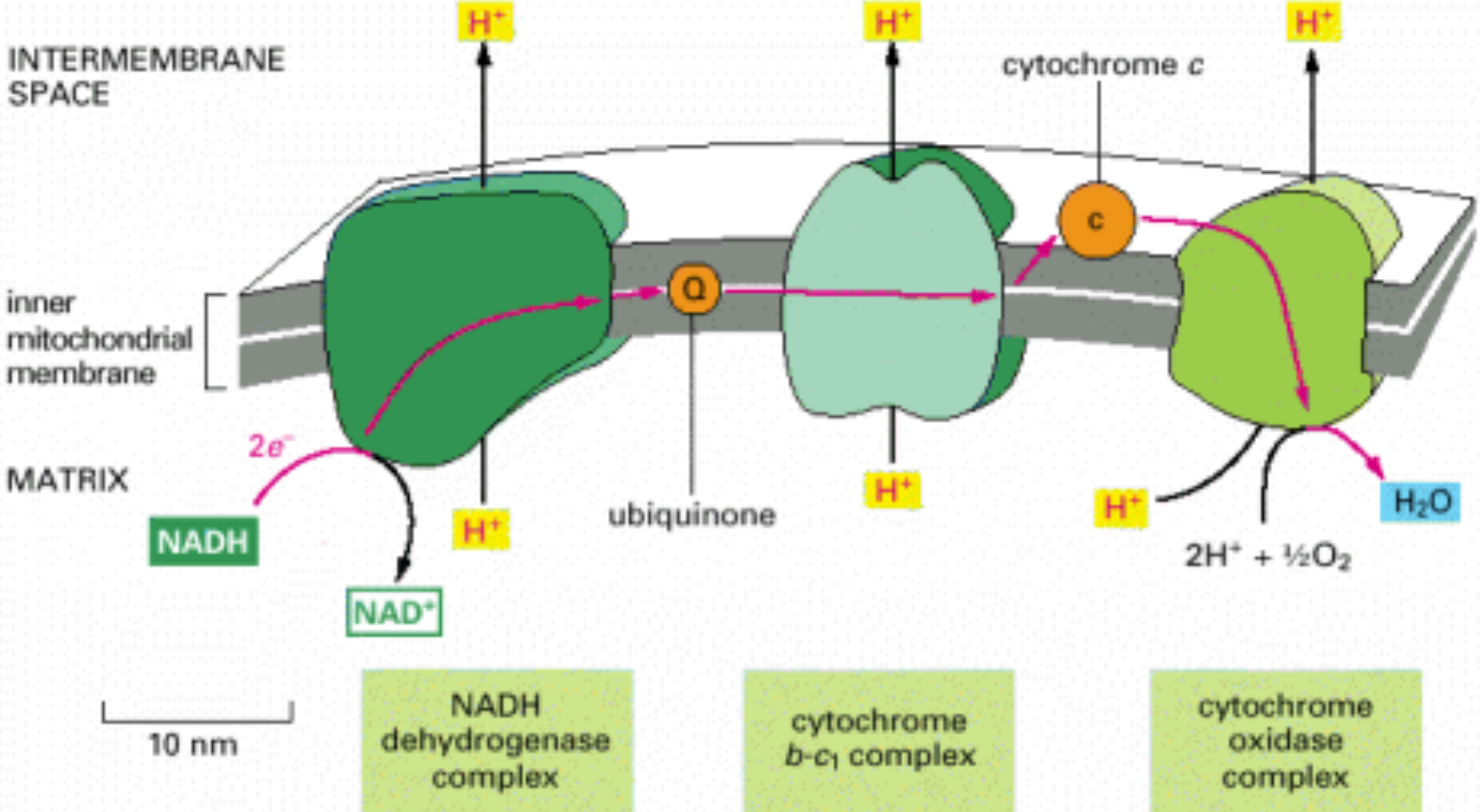


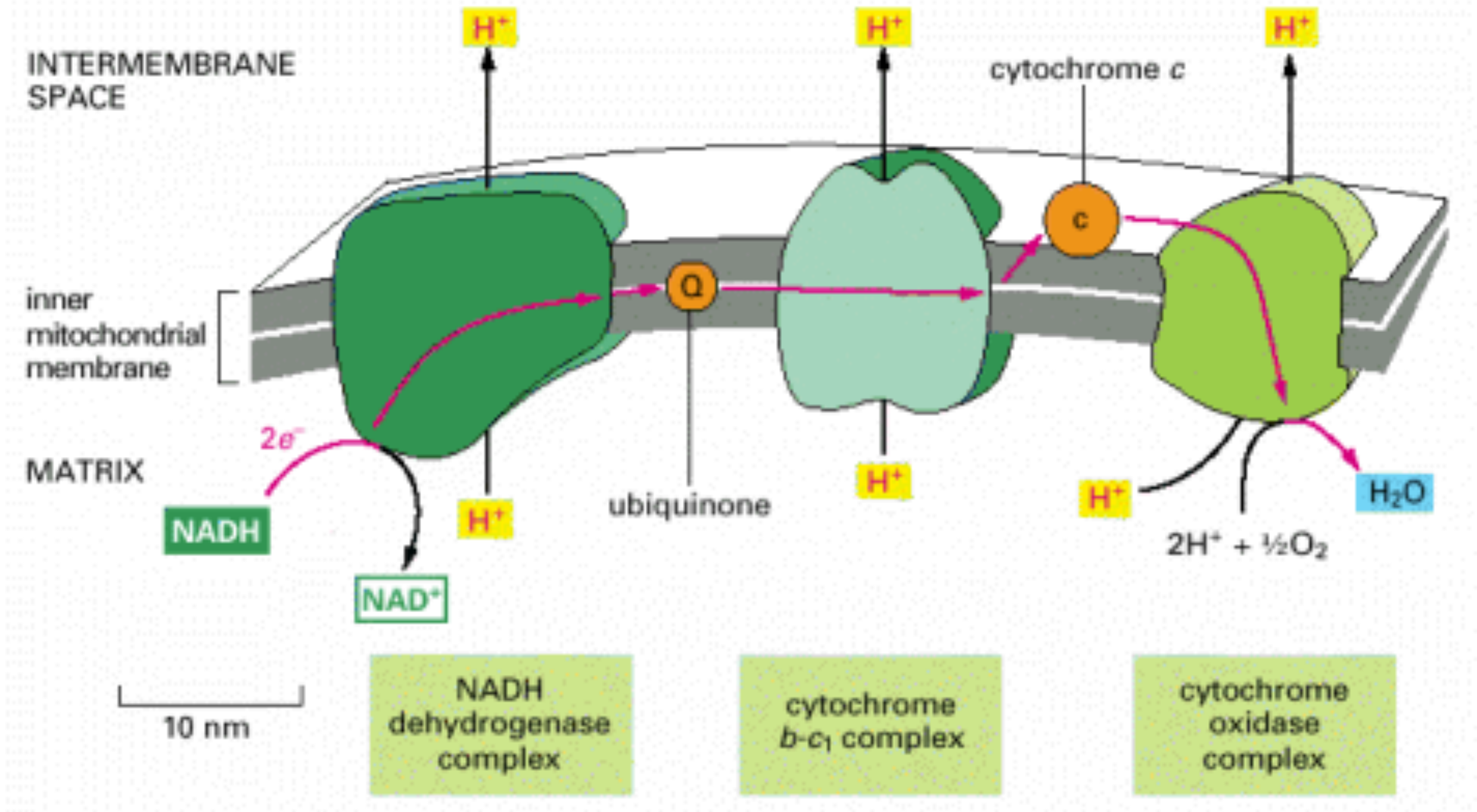
Figure 14-26. The path of electrons through the three respiratory enzyme complexes. The relative size and shape of each complex are shown. During the transfer of electrons from NADH to oxygen *(red lines),* ubiquinone and cytochrome *c* serve as mobile carriers that ferry electrons from one complex to the next. As indicated, protons are pumped across the membrane by each of the respiratory enzyme complexes.

Molecular Biology of the Cell Bruce Alberts, Alexander Johnson, Julian Lewis, Martin Raff, Keith Roberts, and Peter Walter. 2002



The Respiratory Chain Includes Three Large Enzyme Complexes Embedded in the Inner Membrane

Molecular Biology of the Cell Bruce Alberts, Alexander Johnson, Julian Lewis, Martin Raff, Keith Roberts, and Peter Walter. 2002



1. The NADH dehydrogenase complex (generally known as complex I) is the largest of the respiratory enzyme complexes, containing more than 40 polypeptide chains. It accepts electrons from NADH and passes them through a flavin and at least seven iron-sulfur centers to ubiquinone. Ubiquinone then transfers its electrons to a second respiratory enzyme complex, the cytochrome b-c_1 complex.

Molecular Biology of the Cell Bruce Alberts, Alexander Johnson, Julian Lewis, Martin Raff, Keith Roberts, and Peter Walter. 2002

Next lecture

Complex I. Structure and Function. Part 1.

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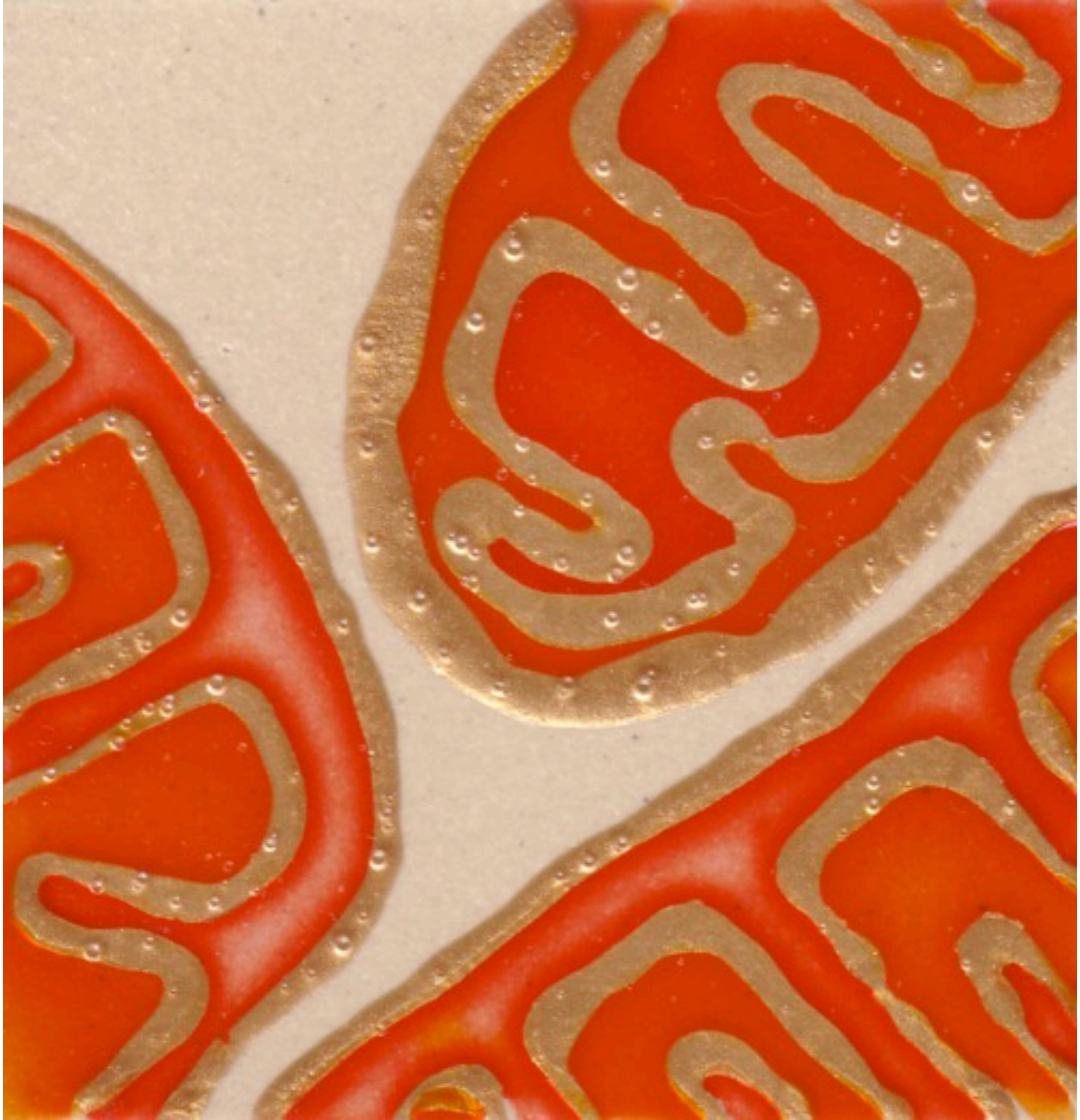


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