

BCHM 664/BIOL 600– Bioenergetics;
“Energy Transduction in Biological Membranes” (2 credits)
Fall, 2012
T, Th, 9:30– 10:20; Lilly G-401

I. COURSE SUMMARY

This course provides an introduction to the biophysical and biochemical basis for energy transduction in biological membranes.

After deriving the foundations of the thermodynamics of membrane energy transduction, the course will focus on mechanisms of electron transfer, proton, and light-energy transfer, utilizing the extensive information that has emerged from high resolution atomic structures of energy-transducing membrane proteins. This will include discussion of mitochondrial cell biology and myopathies. In the context of experimental studies on electron transport in protein complexes and in membranes, the methodology of kinetic spectroscopy and difference spectrophotometry will be discussed. In connection with the molecular basis of photosynthesis, principles of photochemistry, fluorescence, fluorescence resonance energy transfer, and electron paramagnetic resonance will be presented, as will modern developments in synthetic solar energy conversion, O₂ evolution and biofuel production.

II. TOPICS

1. **Thermodynamic background of biological energy transduction**

- Energy, Enthalpy, Entropy, Free energy; concentration dependence
- Energy consumption in human physiology
- Other kinds of work: electrical, chemical
- “Chemiosmotic” concept for membrane energy transduction, ATP synthesis
- $\Delta\tilde{\mu}_{H^+}$ -linked active transport: symport, uniport, antiport
- Oxidation-reduction reactions, direction of redox reactions; meaning of redox potentials (E°, E); concentration, and pH dependence; coupled electron and proton transfer; measurement of potentials; protein determinants of redox potentials.

2. **Energy storage-membrane structure**

- Fundamental aspects of membrane structure; hydrophobicity, membrane capacitance
- Topography of mitochondrial, bacterial, and thylakoid membranes
- Generation, utilization of $\Delta\tilde{\mu}_{H^+}$ electrochemical potential gradient
- Experimental basis for chemiosmotic energy transduction
- Coupled and uncoupled reactions
- Nature of ionophore uncouplers

3. **Primitive transmembrane proton transfer, mechanisms and pathways**

- Structure-function of bacteriorhodopsin; rhodopsin

4. **Structure-function of electron/proton transporting membrane proteins/protein complexes**

- Respiratory, photosynthetic electron transfer chains
- Structures of heme proteins; protoheme proteins; cytochrome *c*, cytochrome *f*
- Iron-sulfur proteins
- Spectroscopic signatures of metallo-proteins; optical, electron paramagnetic spectroscopy
- Integral membrane electron/H⁺ transfer proteins
- Isolation and crystallization of integral membrane protein electron transfer complexes

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5. Structure-function of proteins in the respiratory and photosynthetic electron transport chains

- A.** Respiratory electron transport; generation of the $\Delta\tilde{\mu}_H^+$.
- (i) NADH dehydrogenase; mitochondrial myopathies.
 - (ii) Cytochrome complexes (*bc* and oxidase).
 - (iii) Cytochrome oxidase
- B.** Photosynthesis, Photosynthetic electron transport chain
- (i) Light-harvesting, light-energy transfer
Structure of:
 - (a) Light-harvesting pigment proteins;
 - (b) Bacterial photosynthetic reaction center
 - (c) The O₂ evolving reaction center, photosystem II; mechanism of oxygen evolution
 - (d) The Mr 1,000,000 photosystem I complex of oxygenic photosynthesis

6. ATPase/ATP synthase; proton-and sodium motive ATPase

- Atomic structure of ATPase
- ATPase as a rotational nanomotor
- Coupling of electrochemical potential to ATP synthesis.

7. Evolution of Respiratory and Photosynthetic Energy Transduction

8. Synthetic Solar Energy Conversion

III. EXAMS [Midterm, Final]; Homework Problems

IV. TEXTS AND READING

Eisenberg, D. S., and D. Crothers. 1979. **Physical Chemistry with Application to the Life Sciences**. Benjamin Cummings (on reserve, Life Sciences Library).

Cramer, W. A., and D. B. Knaff. 1991. **Energy Transduction in Biological Membranes**, Springer-Verlag, New York (on reserve, Life Science Library).

Nicholls D. G., and S. J. Ferguson. 2002. **Bioenergetics**3, 297 pp. Academic Press, New York (on reserve, Life Science Library).

Website, Biophysical Society: www.biophysics.org/education/mechanisms.htm

Readings in the current literature.

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