**I. COURSE SUMMARY**

This course provides an introduction to (1) the biophysical and biochemical basis for energy transduction in biological membranes; and (2) the structure and functions of the unique hetero-oligomeric membrane proteins that mediate the transduction.

We will discuss mechanisms of electron transfer, proton, and light-energy transfer, utilizing the information that has recently emerged from high resolution atomic structures of energy-transducing membrane proteins.

In connection with the molecular basis of photosynthesis, principles of photochemistry, fluorescence, fluorescence resonance energy transfer, and electron paramagnetic resonance will be presented. The evolution of photosynthesis will be discussed, along with recent ideas of engineering solar energy input for crop production.

Special problems of structure and function associated with mitochondrial dysfunction in cancer and in the brain.

**II. TOPICS**

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

• Energy, Enthalpy, Entropy, Free energy

* Energy consumption in human physiology

• Other kinds of work: electrical, chemical

• “Chemiosmotic” concept for membrane energy transduction, ATP synthesis

• -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 of redox proteins.

**2.** **Energy storage-membrane structure**

• Fundamental aspects of membrane structure; hydrophobicity, membrane capacitance

• Topography of mitochondrial, bacterial, and thylakoid membranes

• Generation, utilization of  electrochemical potential gradient

• Experimental basis for chemiosmotic energy transduction

• Coupled and uncoupled reactions

• 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

• Spectroscopic signatures of metallo-proteins; optical, electron paramagnetic spectroscopy

• Integral membrane electron/proton transfer proteins

• Isolation and crystallization of integral membrane protein electron transfer complexes

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

**A**. Respiratory electron transport; generation of the Δµ~н+.

(i) NADH dehydrogenase; mitochondrial myopathies.

(ii) Cytochrome complexes (*bc* and oxidase).

(iii) Cytochrome oxidase

(iv) Super-complexes

**B**. Mitochondrial dysfunction in cancer and neurodenerative diseases.

**6. Photosynthetic electron transport**

(i) Light-harvesting, light-energy transfer

(ii) Structure of:

* + 1. The hetero-oligomeric cytochrome *b6f* lipoprotein complex; heterogeneity of internal dielectric constants

(b) Reaction centers; mechanism of oxygen evolution;

(c) fsec structure studies of the 1MDa molecular weight photosystem reaction center complex

(d) Evolution of Respiratory and Photosynthetic Energy Transduction

(e) Synthetic Solar Energy Conversion

**7.** **ATPase/ATP synthase; proton-and sodium motive ATPase**

• Atomic structure of ATPase

• ATPase as a rotational nanomotor

• Coupling of electrochemical potential to ATP synthesis.

• ATPase as a Lipoprotein; Mass Spectrometry

**III.** **EXAMS [Midterm(25%), Final(50%)]; Homework Problems(25%)**

**IV**. **NOTES and TEXTS**

**1.** Lecture notes (first set, today, pp. 1-33)

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

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

**4.** Luckey, M. 2014. **Membrane** **Structural Biology,** Cambridge University Press.

**5.** Nicholls D. G., and S. J. Ferguson. 2013. **Bioenergetics4**, Academic Press, New York (on reserve, Life Science Library).

**6.** Readings in the current literature.

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