COURSE ANNOUNCEMENT

BIOLOGICAL PHYSICS (8.593J) and HST (450J)

PROF. GEORGE B. BENEDEK

Tues. and Thurs. 1:00 – 2:30 PM Rm. 2-105

Spring Term 2006

This interdisciplinary course has been developed under the auspices of the M.I.T. Department of Physics and the Harvard- M.I.T. Division of Health Sciences and Technology. It is addressed to seniors and graduate students in the Schools of Sciences, Engineering and the Division of Health Sciences and Technology who are interested in a detailed quantitative and analytic understanding of biological and physiological phenomena. In addition to the blackboard lecture presentations, students will be provided with typed notes on the topics covered.

The principal discipline which will underlie and unify the analysis in this course is statistical mechanics and thermodynamics. We shall provide at the first lecture a complete set of notes reviewing those elements of statistical mechanics and thermodynamics with emphasis on those most useful in applications to biological phenomena. In order to increase the time available for biophysical topics, we urge the student to read these notes on their own. When a particular element of statistical mechanics or thermodynamics is needed for the development of a biological topic, a review of that element will be provided in lecture and further explained in recitation sections. Each of the topics covered in the course will be provided to students in the form of typewritten text which are to be the basis of a new textbook in Biological Physics.

The topics to be discussed during the term are as follows:

I. Review of Statistical Mechanics and Thermodynamics

Concept of entropy, microcanonical ensemble, fundamental equations of thermodynamics, the chemical potential. The thermodynamic potentials: equations of state, phase equilibria, Clapeyron equation, multicomponent systems, phase equilibria, aqueous solution of biological molecules, osmotic pressure, Poisson Boltzmann equation. Reactions and reaction equilibria, pH and pH control-buffers. Random walk and diffusion. Ligand binding to macromolecules - the binding polynomials. Wyman linkage relations between interacting ligands.

II. Proteins as Stores and Transporters: The Respiratory Proteins

Experimental data on the binding of ligands to hemoglobin. Oxygen dissociation curve, effect of pH, effect of organic phosphates, effect of CO2. Heterotropic and homotropic interaction, cooperativity, allosteric control, linkage between heterotropic ligands. Statistical thermodynamics of binding of ligands to distinct sites on multisubunit proteins: The Pauling, and the Monod-Wyman-Changeaux models of homotropic interactions in hemoglobin. Allosteric model for heterotropic interaction in hemoglobin. Theory of the Bohr effect - pH as a modulator of oxygen binding to hemoglobin.

III. Biological Physics of the Eye and Vision

Basic anatomy, physiology and pathophysiology of the visual system. Cornea, ciliary body, aqueous humour dynamics, iris, ciliary muscles and the lens. History of the development of spectacles. Theory of transparency of the eye: normal and pathological corneas. Scattering of light from the normal and cataractous lens. Discovery of high molecular weight protein aggregates. Observation of Brownian movement of lens proteins. The method of optical mixing spectroscopy. Liquid-liquid and solid-liquid phase transition in concentrated protein solution. Protein condensation diseases. Threshold detection of light at low and high light levels. Light detection as signal to noise discrimination. The molecular basis of phototransduction. The role of rhodopsin, transducin (G protein), phosphodiesterase and cyclic GMP as a cascade for the transduction of light into an electrical response. The theory of the gain and kinetics of the G protein cascade.

IV. Theory of Action Potentials, Simplified Neural Network Models, and Neural Basis of Short Term Memory

V. Random Walks and Diffusion in Biological Systems

VI. Feedback, Control and Homeostasis in Physiological Systems

General role of feedback and control on a molecular level (metabolic pathways) and an organ level (physiological control loops). The human respiratory system and basic model of CO2 control. The system, the controller, the concept of open and closed loop gain. Transient behavior of CO2 proportional control system. Time delays and instability in control. Control during exercise and at high altitudes. Control of blood glucose and the theory of control of enzyme activity at the molecular level.