The 2005 Herman R. Branson Summer Mini Course in Biophysics
Case Studies in the Physics of Life

Organizer
The Biophysical Society and The National Society of Black Physicists

Venue
Boston University

Time
June 12 – July 17, 2005

Course Design

The objective of the course is to introduce disadvantaged students from under-resourced colleges and universities to the excitement of biophysical research and thus to the possibility of a career in biophysics. While an introduction to the intellectual content of biophysics is certainly a desired outcome, the most important outcome will be students whose confidence has grown, whose interests in research have been aroused and focused, and whose horizons have been broadened. The course is targeted to rising junior or senior undergraduate students in the quantitative sciences, mathematics, and biology. Participants should have a good introduction to physics and the calculus needed to master this, as well as some background in biology and chemistry. We expect students from diverse backgrounds and will organize study groups to maximize the benefits from this diversity. This cohort may well include majors in physics, computer science, chemistry, biology, or biochemistry.

Course registration will be limited to 12 students. Prospective students will apply for admission, with applications being reviewed by a representative of the Biophysical Society, the NSBP, and by the two course instructors. The students will be provided with a syllabus, an appropriate text, and lecture notes. A library of reference books will be available on site. Notes used in the lectures will be provided to the students. Students will be organized on the first day into study groups in which they will work on problems (2-3 per week), literature reading for discussion (1 per week), and laboratories (one per weak).

The course will consist of a series of 25 lectures (1½ hours each) on nine major topics that will be held every weekday over the three weeks of the course. Lectures will be given by Dr. Bernard Chasan, Emeritus Professor of the Physics Department, Boston University, and by the on-site instructor, Mark Jack, Assistant Professor of Physics at Florida A&M University. Lectures will be supplemented by seminars or discussions that relate each topic to issues of current societal or biomedical interest. Seminars will be presented by leading biophysicists to put each topic in the context of the modern research that defines that topic. These seminars will be taped for use in future offerings of the course. The seminars by leading biophysicists give a modern context to the lecture material, but, more importantly, they introduce the students to ordinary people just like themselves, but who are biophysicists. Time outside of lectures, seminars, and discussions will be used by students to work in study groups of 3-4 students on problems, reading assignments, and laboratory assignments.

In addition, group reports on research projects will be presented orally by each group on the final day of the course. A workshop on group work and on giving oral presentations will be held early in the first week, with instructors meeting with group to help identify topics by the end of the first week. The instructors will meet with groups each week to mentor this project. A dress rehearsal of each group presentation will be held in week four.

Evaluation of Student Performance

Student performance will be judged based on 1] group assignments, 2] brief quizzes held each Friday afternoon of the course, 4] participation in class and paper discussions, and 3] the final oral presentation. Grades will be assigned on a High Pass (H), and Pass (P) basis. Performance at a lower level will receive no grade. Students receiving either an H or P grade will receive a certificate from the Biophysical Society recognizing their successful completion of the course. We will seek to negotiate with each participating institution for students who receive a P or H to receive academic credit for a one semester course at their home institution.

Course Evaluation

The course will be professionally evaluated by an educational psychologist from Temple University (Liz Russell–McKenzie, MS, PhD candidate) through surveys and interviews of each student. Ms. Russell-McKenzie will conduct follow-up interviews with each of the students after six months, one year, and each year thereafter until they graduate.

Scholarships

Funds are requested for 12 students to participate each summer. The application deadline is February 25, 2005 to allow plenty of time to connect successful applicants with research apprenticeships. Scholarships will include funds for travel to and return from the institution, room, registration fees, and a small living allowance.

Apprentice Research Positions

Students receiving scholarships will be matched with opportunities for apprentice research positions to commence immediately following completion of the summer course. These positions will be at Research 1 universities having graduate training programs in biophysics and being geographically near the student's home institution. These research apprentices will be arranged directly between the student and directors of biophysics training programs or Biophysical Society members with NIH funding who can support the students as apprentices during the school year through grant supplements.

Course Outline

The **course outline** is given below:

1. Life and Its Physical Basis: 2 lectures
    a. What is life? An attempt at definition.
    Life and energy. What is energy and why do organisms need it? Where do they get it?
    Discussion: How much energy do you expend in climbing up a mountain? How much energy is needed to pull RNA into a viral capsid?
    b. Energy type and the second law of thermodynamics
    Discussion: Nature is a crap-shoot: the Boltzmann distribution and the second law.
    Computer Lab: Simple mathematical tools in biophysics.

2. The Cell: A Survey and Preview: 2 lectures
    a. The cell as a basic unit of life's organization.
    The components: membranes, cytoskeleton, organelles.

The central role of macromolecules: proteins, nucleic acid, carbohydrates.
Lab: Heats of dissolution in a bomb calorimeter.
b. The cell interior as a tough neighborhood: Brownian motion and viscosity and their influence on particle motion in the cell.
Discussion: Research Topics for final project.

3. Proteins: structure and function: 5 lectures
a. From linear polymer to functioning molecular machine: the role of weak interactions.
The structural organization within proteins: primary, secondary, tertiary, and quartinary levels of organization; Varieties of proteins: globular and fibrous.
Discussion: A historical perspective: Basic "secondary" structures defined by Pauling, Corey, & Branson
b. The stability of proteins as measured by free energy and denaturation. Motions within proteins.
Lab: Polystyrene beads on a microscope grid: The nature of random motions.
c. Speeding things up: how enzymes work.
d. Proteins as binding machines: measurement of binding and thermodynamic analysis.
Discussion: myoglobin and hemoglobin at work.

4. The Cell Membrane: 4 lectures
a. The lipid bilayer: self assembly at work.
Lab: Liposomes as self-assembling sacks to trap and deliver drugs.
b. Controlling traffic: membrane proteins and transport in and out of the cell, passive *versus* active transport, fusion and exocytotic release.
Discussion: Why did nature put so many lipids in a membrane?
c. Bioenergetics: bacteriorhodopsin, photosynthesis, the role of ATP and the structure of the ATP synthase.
d. The chemiosmotic model.
Lab: Diffusion through a semi-permeable membrane, osmotic force.

5. Motility: 3 lectures
a. The role of the cytoskeleton in cell motion
b. Distributing the goods: the role of motors within the cell.
c. Muscle: many actin- myosin motors at work.
Discussion: how biological motors work: general principles.

6. The Neuron: 4 lectures
a. Generation and propagation of the action potential: experimental observations and the Hodgkin-Huxley analysis.
b. The role of channels and pumps.
c. The biophysics of the synapse.
d. Two cases: muscle and retina.
Discussion and Computer lab: neural networks in vivo and in the computer.

7. Nucleic Acid and Genetic Information: 5 lectures
a. Why a double helix?
b. How structure stores information
c. The replication process.
d. From DNA to RNA to protein.
e. How DNA is packed in the cell nucleus

Discussion: Supercoiling.

Class days will in general be organized as follows:

9AM-11AM lecture
11:15AM-12:30PM Seminars or Discussions
12:30PM-2:00PM lunch break, meet with seminar speakers
2-3PM Assign or review problems; quizzes
3-6PM Labs, group work on lab reports, field trips to local labs, or work with mentors on final projects.
6-7:30PM: Dinner
After 7:30PM and weekends: Two weekend day trips to coast; otherwise free time for group or individual study.

Course Content

This is not a syllabus implying an order of presentation, but rather a list of topics. The order of presentation will depend on opportunities available at the site and on the schedules of the seminar speakers who can be lined up from the membership of the Biophysical Society and faculty of NIH-supported biophysics programs with which we have established a collaborative relationship.

1. Review of Essential Physical Principles and Laws

2. Life and physics

3. Common themes for all organisms: The cell as the basic unit of machinesw.

4. The structure and function of proteins

5. Enzymes and Other Machines

6. The cell membrane

7. Neurons and neuronal system

8. Motility. 2 lectures

9. Nucleic Acid and Genetic Information.