PHYS 1376, Introduction to Biological Physics (3 cr.)

Tuesday and Thursday, 11 am – 12:15 pm

No recitation

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This course is designed for students who are interested in studying life phenomena from a physics perspective. Consistent with this approach, the subjects are organized based on physical concepts that unit a given class of biological phenomena. Important concepts include, for example, different energy forms and their transformations; Newton's laws of motion for solid and soft bodies; electrostatics and molecular interactions, physics of reversible and irreversible processes; information processing and transmission; and the law of exponentials.

The course does not assume extensive prior knowledge on the part of students, though a background in both calculus and elementary physics is required. By taking this class, I wish to help students develop a rational way of thinking of complex biological phenomena and be able to perform back-of-the-envelope estimates for simple biophysical processes.

Homework assignments will be given regularly, and there will be two midterm in-class exams and one take-home final. Your grade will be calculated based your homework (30%), the midterm (20%x2), and the final (30%).

The following is a tentative schedule for the materials covered during the term.

Week 1: An Introduction:

1. The building blocks of biological systems: nucleic acids, amino acids, phospholipids, carbohydrates, and the complex structures they form
2. Typical length and time scales associated with biological processes
3. Model organisms

Week 2: Simple Statistics:

1. Counting statistics
2. Probability functions
3. Random walks in physics and biology

Week 3: Powerful Physical Techniques:

1. Single molecule Imaging
2. Atomic force microscopy
3. Optical Tweezers

Week 4: Forces in Biological Systems:

1. Solid body mechanics
2. Soft body mechanics

3. Motion in fluids

Week 5: Molecular Interactions:

1. Collision of hard spheres
2. Electrostatic Interactions
3. Effects of dielectrics
4. Hydrophobic vs. hydrophilic interactions
5. Membrane potentials

Week 6: Energy and Free Energy:

1. Concepts of entropy
2. Thermodynamic forces
3. Relations with living systems (diffusion, transport, gene expression, etc.)

Week 7: Energy Flow:

1. Photosynthesis and carbon utility
2. The role of oxygen

Week 8: Enzyme Kinetics:

1. Law of mass action
2. Two-state models in physics and biology
3. Reactions without cooperativity
4. Reactions with cooperativity
5. Applications to ion channels, chemoreceptors, and motor proteins

Week 9: Information Flow I:

1. Central dogma of biology
2. From environments to behaviors

Week 10: Information Flow II:

1. On error rates
2. Proof reading and error correction
3. Other strategies of overcoming noises

Week 11: Neurobiology:

1. Membrane permeability, ion channels, and ionic pumps.
2. Action potential and the Hodgkin-Huxley model.

Week 12: System Biology:

1. Models of gene expression
2. Models of biological networks (metabolic, chemotaxis, etc.)
3. Oscillations in biological systems.

Week 13: Law of Exponentials:

1. Population dynamics
2. Stable and unstable fix points
3. What are the implications

I have put on reserve, in the Engineering Library, the following three books that serve as references. (i) “Physical Biology of the Cell” by Rob Phillips, Jane Kondev, Julie Theriot, and Nigel Orme. This is an accessible book with many interesting examples, and is the one I used the most. If you like challenges, read (ii) “Biophysics: Searching for Principles” by William Bialek, and (iii) “Biological Physics: Energy, Information, Life” by Philip Nelson. The latter two are excellent books but demand more mathematics.

Disability Statement – If you have a disability for which you are or may be requesting an accommodation, you are encouraged to contact both your instructor and Disability Resources and Services (DRS), 140 William Pitt Union, (412) 648-7890, drsrecep@pitt.edu, (412)228-5347for P3 ASL users, as early as possible in the term. DRS will verify your disability and determine reasonable accommodations for this course.