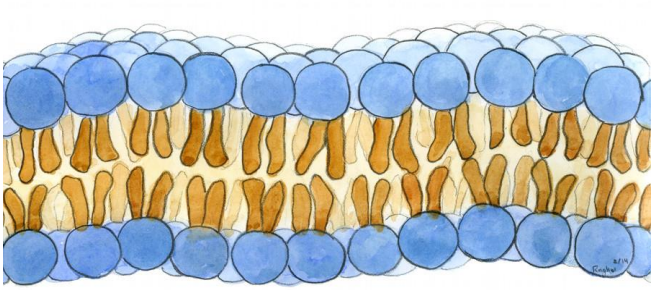

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Dept. of Physics; Univ. of Oregon

Spring 2019

Physics 610: Introduction to Biophysics – *Syllabus*

Goals

The living world exhibits an enormous diversity of forms and functions, yet also shows remarkable uniformity in its mechanisms and molecular components. Every cell, for example, uses a particular stiff linear polymer (DNA) to carry its genetic information; every cellular membrane is a two-dimensional liquid; every protein is buffeted by random forces and must obey the dictates of statistics mechanics. It is the aim of biophysics to understand how physical properties, whether the mechanical properties of biomaterials or the dynamical properties of information processing networks, guide and constrain life. Biophysics is one of the most vibrant, exciting, and even fun areas in contemporary science, and in this course, we'll explore various aspects of this sprawling and constantly evolving field.

By the end of the course, students will be able to:

- Understand the physical principles that relate to the function of important biological phenomena such as DNA packing, bacterial motion, membrane deformations, and signaling circuits.
- Apply statistical and statistical-mechanical ideas to a wide variety of complex systems.
- Read contemporary papers in biophysics and follow the aims and approaches.

Prerequisites

We'll assume a good knowledge of undergraduate physics, especially statistical mechanics[1], and a corresponding adeptness with math. No prior knowledge of biology is required, though I'll expect everyone to pick up some basic biological facts, through readings, in the early part of the term.

Being comfortable with computer programming is an invaluable skill in any science. <u>We will write simple programs throughout the term, and a sizeable part of the homework problems will involve writing computer simulations.</u> Students should know *some* language, or should be able to very quickly pick one up. We'll provide examples in MATLAB; I recommend MATLAB or Python; both are easy to learn and powerful, and Python is free. (UO has a site license for MATLAB, so it's effectively free here.)

[1] The *Biological Physics* book noted below has an excellent review / summary of statistical mechanics in its early chapters. You may wish to read this ahead of time.

Time and Place

TuTh 10:00-11:50 am in Willamette 350. There will likely be class periods that need to be rescheduled, due to travel and other conflicts.

Textbook (and other readings)

We'll use *Biological Physics*, by Philip Nelson[2]. It's an excellent textbook – a bit simple, since it's intended for both undergraduates and graduate students, but very well organized and well written. Sadly, it's pricy. Feel free to find used copies, share with your friends, etc.!

I'll supplement this book, and build off of Nelson, with other readings including contemporary research articles. There's no shortage of recent papers that are accessible and that illuminate fundamental concepts.

Topics

INTRODUCTION; PHYSICS, STATISTICS, AND SIGHT

What are the fundamental limits on vision, and how close does biology come to reaching them? (A brief look.)

COMPONENTS OF BIOLOGICAL SYSTEMS

What are the components of biological systems? What are the length, time, and energy scales that we'll care about? How can we organize a large list of "parts?"

PROBABILITY AND HEREDITY (A QUICK LOOK)

We'll review concepts in probability and statistics. We'll discuss a classic example of how a quantitative understanding of probability revealed how inheritance and mutation are related.

RANDOM WALKS

We can make sense of a remarkable array of biophysical processes, from the diffusion of molecules to the swimming strategies of bacteria to the conformations of biomolecules, by understanding the properties of random walks.

LIFE AT LOW REYNOLDS NUMBER

We'll figure out why bacteria swim, and why they don't swim like whales.

ENTROPY, ENERGY, AND ELECTROSTATICS

We'll see how entropy governs electrostatics in water, the "melting" of DNA, phase transitions in membranes, and more.

MECHANICS IN THE CELL

We'll look more at the mechanical properties of DNA, membranes, and other cellular components, and also learn how we can measure them.

CIRCUITS IN THE CELL

Cells sense their environment and perform computations using data they collect. How can cells build switches, memory elements, and oscillators? What physical principles govern these circuits?

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[2] See https://eighteenthelephant.wordpress.com/2013/10/31/readings-in-biophysics-part-i/ for some comments, including thoughts on two other excellent biophysics books.

COOL THINGS EVERYONE SHOULD BE AWARE OF

We live in an age in which we can shine a laser at particular neurons in a live animal to stimulate it, paste genes into a wide array of organisms, and sequence the genome of a single cell. It would be tragic to be ignorant of these sorts of almost magical things, and they contain some nice physics as well!

Course structure

Since this is a graduate course, the structure described below may change as we meander through the term – your feedback is welcome!

- **In class.** I'll lecture, but not exhaustively. (As many of you know, I'm a convert to "active learning.[3] ") We'll spend quite a bit of time in class on discussions and problem-solving. To have fruitful discussions, it is important for people to have read the pre-class readings.
- **Contemporary papers**. We'll discuss recent articles at least one per week, and I may assign people or groups to be "in charge" of them.
- **Homework.** We'll have homework assignments roughly every week. Many of these will involve computer simulations.
- **Final Project.** We'll have a final project that involves reading a few related papers (perhaps from the same group) and presenting them to the class along with either a deeper discussion of the methods used, or a proposal for worthwhile future experiments to be done. I'll elaborate on this later in the term, and there will be "preliminary assignments" due before the overall project is due. The presentations will likely be in Week 10 (June 4-8).
- **Exams.** There will not be any exams.
- **Grades.** Homework: 80%, Final project: 20%. Scale: A = [87,100%], B = [74,87), C = [61,74), D = [50,61), F = [0,50%)

Teaching Assistant

There will be a grader for this course, Kentaro Hoeger. (He took this class in 2015, and works in Tristan Ursell's lab.)

Office Hours

- RP: Tentatively Tu 1:00-2:00pm, Fr 1:00-2:00pm,. I'm happy to change these if they're inconvenient! My office is Willamette 362.

Students with disabilities

If aspects of the instruction or design of this course result in barriers to your inclusion, please notify me as soon as possible. You are also encouraged to contact the Accessible Education Center: (541) 346-1155, uoaec@uoregon.edu, which provides a variety of useful guidance and services.

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[3] http://www.changemag.org/Archives/Back%20Issues/September-October%202007/full-scientific-approach.html, http://www.pnas.org/content/111/23/8410.abstract