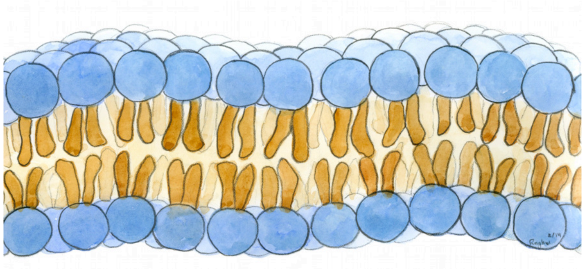

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Dept. of Physics; Univ. of Oregon

Spring 2015

Physics 610 – Introduction to Biophysics

Syllabus

LAST MODIFIED: MARCH 20, 2015

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 networks, guide and constrain life. Biophysics is one of the most vibrant and exciting areas in contemporary science, and in this course, we'll explore various aspects of this sprawling and constantly evolving topic.

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 general approach.

Prerequisites

We'll assume a good knowledge of undergraduate physics, especially statistical mechanics, 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. We will write simple programs throughout the term. Students should know *some* language, or should be able to 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.)

Time

TuTh 10.00am – 11.50am, Willamette 318

Textbook (and other readings)

We'll use *Biological Physics*, by Philip Nelson[1]. 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. I've ordered it for the UO bookstore, but also 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 statistical mechanics. 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.

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

Circuits in the Cell

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

Multicellular organization and pattern formation

How does a collections of cells, in a developing embryo, for example, organize itself into a robust three-dimensional structure? We're beginning to understand how multicellular organisms harness small-scale physical processes, such as diffusion, and large-scale processes, such as folding and buckling, to generate form. We'll take a brief look at this.

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 a genome given only 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, and also a course that I haven't taught before, 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.[2] ") We'll spend quite a bit of time in class problem-solving and discussing various topics. To have fruitful discussions, it will of course be important for people to have read the assigned 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 every week. Some of these will involve computer simulations.
- **Final Project.** We'll have a final project that involves writing a short research proposal, and presenting it to the class. This will involve reading research papers, and then using your skills and imagination to build on this and propose something worth exploring in the future.
- **Quiz.** Since it's useful to have a shared vocabulary of biological terms, and since it's fine not to know any prior to the class, we'll have a short quiz within the first few weeks of the term on biological "components" that you'll learn from the readings. Passing will be required to continue in the course. I'm sure everyone will pass; I'm creating the quiz so that everyone has a concrete milestone to aim for. (Also, I'll help out anyone who doesn't pass, so they can try again.)
- **Exams.** There will not be any exams.
- **Grades.** Homework: 80%, Project: 20%. Scale: [85,100%] = 'A', [70,85) = 'B', [60,70) = 'C', [50,60) = 'D', [0,50) = 'F'

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

Teaching Assistant

Somewhat remarkably, thanks to the peculiarities of university funding arrangements, we'll have a teaching assistant for this course: Tristan Hormel (hormel@uoregon.edu). I'll especially be drafting Tristan to come up with and help implement interesting programming projects.

Office Hours

- RP: TuTh 1:00-2:00pm. I'm happy to change these if they're inconvenient for many people. My office is Willamette 362.
- Tristan: TBA

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 welcome to contact Disability Services in 164 Oregon Hall, 346-1155.