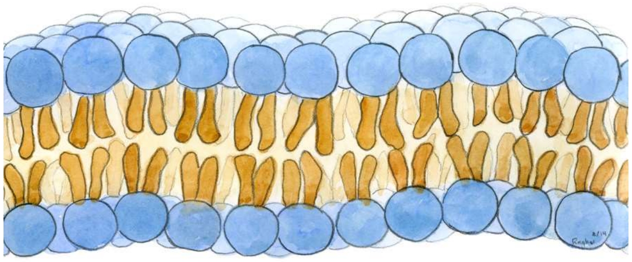

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Dept. of Physics; Univ. of Oregon
Fall 2020

Physics 610: Introduction to Biophysics – *Syllabus*

Please Note: As you know, this course will be "remote." I nonetheless intend it to be enjoyable and engaging for all of us. Your feedback is especially important; I may modify aspects of the course structure as we go along, based on what we feel is going well or needs adjustment. Please don't hesitate to contact me!

In this syllabus, I've indicated with "*NOTE*" items that are new or significantly altered from previous years due to the remote format or other logistical constraints.

Time and Place

Monday and Wednesday 10:15-11:45 am, via Zoom at
https://uoregon.zoom.us/j/99822834081?pwd=bDBTbDRac1hMU2Mzb3d6bTZhYW5XZz09
Meeting ID: 998 2283 4081 **Passcode:** 6s644s
Please note: We can move to other times if more convenient.
NOTE: There are no classes at UO on Monday, September 28 in observance of Yom Kippur

Goals

The living world exhibits an enormous diversity of form and function, yet also shows remarkable uniformity in its mechanisms and molecular components. Every cell, for example, uses a stiff polymer (DNA) to carry genetic information; every cellular membrane is a two-dimensional liquid; every protein adopts some shape while being buffeted by random forces. Biophysics aims to understand how physical properties guide and constrain life, whether the mechanical properties of biomaterials or the dynamical properties of information processing networks. Biophysics is one of the most vibrant areas in contemporary science, and 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 govern the function of important biological phenomena such as DNA packaging, bacterial motion, membrane deformation, and gene regulation.
- 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, early in the term.

Being comfortable with computer programming is an invaluable skill in any science. We will write simple programs throughout the term, and a sizeable part of the homework problems will involve writing computer simulations. 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.)

Textbook and other readings

We'll use *Biological Physics*, by Philip Nelson[2] for much of the course. 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. Feel free to find used copies, share with your friends, etc.! In a neat development, the author got the rights to the book back from the publisher, since he was annoyed by the high price they were charging! For details and information on how to get the book ($10 eBook, $27 paper), please see: https://www.physics.upenn.edu/biophys/BPse/ .

I'll supplement this 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.

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[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.

[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.

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?

COOL THINGS EVERYONE SHOULD BE AWARE OF
We live in an age in which we can shine a laser at neurons in a live animal to stimulate it, paste genes into any organism we wish, and read the genetic information in a single cell. It would be tragic to be ignorant of these almost magical things, and they contain nice physics as well!

Office Hours

- Tuesday 1:00-1:50pm and Friday 12:30-1:20pm. I'm happy to change these if they're inconvenient! *NOTE:* Office hours will be at the course Zoom link, but I am also happy to have in person office hours, likely outdoors in small groups, if requested and if possible.

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. *NOTE:* The class has always been quite lively, and I hope that this will continue despite the online format. To help ensure this: (i) everyone should keep their video on, as much as possible. (ii) Mute your audio when you are not actively contributing, but be ready to unmute. (iii) Feel free to interrupt with questions or comments – it's difficult for me to keep track of the chat window or the "raised hand" button, and so feel free to speak up. (iv) I will ask students questions; it is fine to not know answers, or to respond with more questions. (v)

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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

I may change aspects of the course structure as we go along, if I feel that this would be beneficial to the class.

- **Other Zoom issues.** *NOTE:* We will record the class sessions, for the benefit of any students with technical or other difficulties. For technical help and troubleshooting with Zoom, visit the UO Service Portal: https://service.uoregon.edu/TDClient/2030/Portal/KB/ArticleDet?ID=101392 .
- **Contemporary papers**. We'll discuss recent articles, 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. Students are encouraged to talk to each other about how to approach the problems, and to compare answers, but I recommend (i) first staring at the assignment alone, and (ii) making sure that the final output is your own. With programming especially, it is useful to talk to classmates. Especially because there is no grader for this course, please **write clearly,** and indicate key points and conclusions. *NOTE:* Assignments must be submitted electronically as PDFs, but can be scanned, handwritten pages. (There are plenty of phone apps that convert camera images to PDFs, e.g. TinyScanner.)
- **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 (November 30-December 4, 2020).
- **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%)

Canvas

- We'll use Canvas to distribute materials, post links, submit assignments, etc. https://canvas.uoregon.edu/

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.