Course Syllabus

PHYS 337 – Contemporary Problems in Physics: Biophysics
Spring 2014

Instructor: Ben Vollmayr-Lee

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Office Hours: Mon 1–2, Tue 4–5, Wed 2–3, Thu 11–12 and 4–5

Textbook: R. Phillips, J. Kondev, J. Theriot, and H. Garcia, Physical Biology of the Cell, 2nd Ed.

Course Web Page: http://www.eg.bucknell.edu/∼bvollmay/phys337

Course Description

Biophysics is a new, exciting, and rapidly growing branch of physics. At the same time, it is not very well defined: there is an extremely wide range of topics where quantitative models based on physics principles are being applied to biological data. There are not standard textbooks. In fact, there are only two textbooks written at the undergraduate level. This messy, muddy, murky situation is exactly what hot new fields look like. We will dive in and try to capture some of the essentials of how physics concepts, particularly the focus on energy and entropy and quantitative modeling, can be fruitfully applied to problems of biology.

Our emphasis will be on the cell, which is the "atom" of biology. We know matter is made up of just a few types of atoms; that sometimes these atoms go it alone (a gas), and sometimes they team up to form liquids or solids. We know all atoms have common building blocks (electrons, protons, neutrons). So it is with cells, which can be solo, like bacteria or yeast, or can team up to form organisms like us. In all cases, the cells are made up of four types of macromolecules: proteins, nucleic acids, lipids, and carbohydrates. All proteins in all cells are made up of the same set of 20 amino acids. So, just as the atom is a reasonable focus for the fundamentals of matter, the cell is the focus for the fundamentals of life.

The topics we will study include first an introduction to the ingredients of cells and the characteristic length and time scales. Next we will develop quantitative tools for mechanical and chemical equilibrium and the methods of statistical mechanics, in particular the Boltzmann factor, and use them to describe binding and unbinding transitions. Then we will cover the math of random walks and what they imply for macromolecule structure; the statistical mechanics of charged fluids, to describe the salty environment of cells; the free energies for beams and membranes that define cellular structure; the transport properties of diffusion and hydrodynamics within the cell; and the chemical rate equations that govern many processes.

Course Structure

The course material is drawn from the texts and the lectures. Assigned reading will be given roughly a week ahead, and the reading for a lecture should be done *before* coming to lecture. Class time will be used to expand on the reading and to work through examples. This will be done via a combination of lectures and in-class exercises.

- **Homework** — A homework set will be assigned weekly and will be due at the beginning of class on Fridays. You are encouraged to work together on the homework sets, though you must write up the problems yourself.

  No late homework will be accepted! This is because the solution sets will already have been distributed, and because the goal is for you to be working on the problems while we are discussing the material.

- **Journals** — You are required to submit a journal entry for two of the three reading assignments each week. You may choose which two. These journals serve the purpose of encouraging you to do the reading and giving me a useful guide as to what we should spend lecture time on, i.e., letting me know what's already clear and what's confusing from the reading. Because I will need to read these before class, they are due before 8:00 am on the day of class.

  To submit your journal entry, log in to your PHYS 337 account, which is accessible via the course web page. Your journal entry should demonstrate that you've done the reading and can contain any or all of the following:

  - a summary,
  - parts you found confusing,
  - parts you found clear,
  - parts you particularly liked or disliked, or
  - general comments about the course.

  These will be scored on a 2 point scale: 0 if there is no evidence that you've done the reading, 1 if there is some evidence you did the reading, but not a lot of thought put into it, and 2 if your entry reflects you've done the reading and put a reasonable effort into it.

- **Exams** — There will be three midterm exams. The dates for these is given in the Course Schedule below.

Grading

- Problem sets: 20%
- Journals: 10%
- 3 Midterm exams: 45% combined
- Final exam: 25%

Course Schedule

This is an approximate schedule, subject to revision as we go through the course. The exam dates are fixed.

Dates	Topics	Text
Jan 15–17	Intro to Biophysics I	Ch 1–2
Jan 20–27	Intro to Biophysics II	Ch 3–4
Jan 29–Feb 5	Mechanical and Chemical Equilibrium	Ch 5
Feb 7	Catchup and review	
Mon, Feb 10	**Exam 1 due** (take-home)	
Feb 12	Guest lecture: JiaJia Dong	
Feb 14–19	Statistical Mechanics	Ch 6
Feb 21–26	Two-State Systems	Ch 7
Feb 28–Mar 5	Random Walks & Macromolecules	Ch 8
Mar 7, Mar 17–19	Electrostatics of Ionic Solutions	Ch 9
Mar 21	Catchup and review	
Mon, Mar 24	**Exam 2** (in-class)	
Mar 26–31	Beam Theory	Ch 10
Apr 2–7	Membranes	Ch 11
Apr 9–11	Hydrodynamics for the Small	Ch 12
Apr 14–16	Diffusion	Ch 13
Apr 18	Catchup and review	
Mon, Apr 21	**Exam 3** (in-class)	
Apr 23–28	Rate Equations	Ch 15
Mon, May 5	**Final Exam**	

Travel Dates

Unfortunately, I will be away for five class periods due to conference travel. For three of these classes, we will try using technology to create a remote classroom. The schedule is as follows

- Monday, February 10 — Take-home exam due. No class.
- Wednesday, February 12 — Guest lecture: JiaJia Dong.
- Friday, February 14 — Remote classroom.
- Monday, March 3 — Remote classroom.
- Monday, March 5 — Remote classroom.

Honor Code

As a student and citizen of the Bucknell University community:

1. I will not lie, cheat, or steal in my academic endeavors.
2. I will forthrightly oppose each and every instance of academic dishonesty.
3. I will let my conscience guide my decision to communicate directly with any person or persons I believe to have been dishonest in academic work.
4. I will let my conscience guide my decision on reporting breaches of academic integrity to the appropriate faculty or deans.