



Prof. Raghuv eer Parthasarathy

Dept. of Physics; University of Oregon

Spring 2026

CRN 35829/35841

PHYSICS 444/544: BIOLOGICAL PHYSICS – SYLLABUS

Instructor Information, Office Hours

Professor Raghuv eer Parthasarathy (Par-tha-sa-ra-thē)

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Office hours: **Week 1 only:** Tuesday March 31, 1:30 – 2:20 pm, Friday April 3, 12:00 – 12:50 pm
All other weeks: Tuesday 2:00 – 2:50 pm, Friday 11:00 – 11:50 am

Teaching assistant: Francesca Ark

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Office hours: Wednesday 10:00 – 10:50 am, Friday 4:00 – 4:50 pm, outside WIL 373

Time and Place

Monday and Wednesday 2:00-3:50 pm, Willamette Hall Room 318

Description and Learning Goals

The living world exhibits a dazzling variety of forms and functions, yet it also shows remarkable universality in its components and mechanisms. Every cell, for example, uses a stiff polymer (DNA) to carry genetic information; every cellular membrane is a two-dimensional liquid; every protein adopts a particular three-dimensional shape while being buffeted by random forces. More subtly, phenomena as different as vision and evolution make use of the statistical variation of physical processes. The field of Biological Physics / Biophysics aims to understand how universal physical principles govern the structure and activity of the living world. This course introduces students to a vibrant area of contemporary science, exploring the mechanical properties of biomaterials, the sensory abilities of cells and organisms, the dynamical properties of information processing networks, and more.

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

- Understand the physical principles that govern ubiquitous biological phenomena such as DNA packaging, bacterial navigation, 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.
- Model and computationally simulate complex dynamical systems.

4xx/5xx Differences

This course is a combined graduate and undergraduate course. As required by university guidelines, the graduate (544) course will require roughly one-third more work than the undergraduate (444) course, which will take the form of additional readings, additional problems on homework assignments and quizzes, and a longer final project.

Prerequisites

Undergraduate (444 students) should have completed a course in statistical mechanics (such as Physics 352) or the equivalent (such as Physical Chemistry) and should have a solid grasp of lower-division physics and calculus. Graduate students should have a good knowledge of undergraduate physics, especially statistical mechanics¹, and a corresponding adeptness with math. **No prior knowledge of biology is required**, though I'll expect everyone to pick up basic biological facts, through readings, early in the term.

Being comfortable with computer programming is a valuable skill in any science. We will write programs throughout the term, and a sizeable part of the homework assignments will involve writing computer simulations. I recommend using Python or MATLAB; both are easy to learn and powerful, and Python is free and very popular. (UO has a site license for MATLAB, so it's effectively free here.) I can provide guidance for those new to programming.² See also the "Homework" item in the "Course structure and grade components" section below, and the "AI (Artificial Intelligence) Policy".

Textbook and other readings

We'll use *Biological Physics*, by Philip Nelson for about half the course (Philip Nelson, *Biological Physics: Energy, Information, Life*, Student Edition, Chiliagon Science, 2020), and I'll require that you read the assigned sections. It's an excellent textbook, written for both undergraduates and graduate students. Feel free to find used copies, share with your friends, etc. Since its initial publication, 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, \$30 paperback), please see: <https://www.physics.upenn.edu/biophys/BPse/> .

¹ Nelson's *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 Here, for example, are some Python exercises I wrote to help students prepare for my Image Analysis class: https://docs.google.com/document/d/1rGo98lf3_Bk1yQyF7lcZVAw5OEFZ-myivWd2gTd0vzAc/edit?usp=sharing

We'll read parts of three other excellent textbooks; I'll supply excerpts. These are: (i) *Biophysics: Searching for Principles* by W. Bialek (Princeton University Press, 2012); (ii) *Physical Biology of the Cell* by R. Phillips, J. Kondev, J. Theriot, and H. Garcia (Garland Science, 2nd edition, 2012); (iii) *Physical Models of Living Systems, Second Edition: Probability, Simulation, Dynamics*, by Philip Nelson (Chilagon Science, 2020). See <https://eightenthelephant.wordpress.com/2013/10/31/readings-in-biophysics-part-i/> for some comments about these books.

I've written a biophysics book intended for the general public in which I provide non-technical descriptions of most of the topics of this course (and much more). You may find it useful: *So Simple a Beginning: How Four Physical Principles Shape Our Living World*, by Raghuveer Parthasarathy (Princeton University Press, 2022). UO's library has the physical book ([Link](#)), and the eBook ([Link](#)).

I'll also assign a variety of 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?

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!

Course structure and grade components

- **Lecture and discussion.** I'll lecture, but not exhaustively. 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. I will ask students questions; it is fine not to know answers, or to respond by asking questions. Powerpoint slides will be posted on Canvas after each class. As will be discussed, the slides are rather minimal and aren't a substitute for taking notes in class.
- **Classroom activity.** I expect active participation in class: asking and answering questions, working with others on problem-solving activities, and engaging with the material. Given the level of the course and its nature as an elective, and based on consistently enjoyable past experiences, I expect that students will be active and engaged without the necessity of assigning a grade to participation; I can revisit this if need be.
- **Contemporary papers.** We'll discuss recent articles, and I may assign students to be "in charge" of them. (This will be folded into the homework grade.)
- **Homework.** We'll have homework assignments roughly every week, probably due on Saturdays. 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. Many of these assignments will involve computer simulations; see also the AI policy below. **Write clearly** and indicate key points and conclusions. Assignments will be graded based on correctness of the results and clarity of explanations. The homework assignments will be challenging and completing them will be crucial for learning the material.
- **Homework presentations.** Part of the overall homework score will include presenting and explaining one's solutions in class. This may include explaining simulation logic or code. Not every student will be called on every week, but on average everyone will have similar presentation expectations.
- **Quizzes.** There will be quizzes approximately weekly. The quizzes will assess key concepts and will revisit homework problems. Each student's lowest quiz score will be dropped from the overall total. There won't be any make-up quizzes; if you miss one, this will be the quiz dropped from your overall grade calculation.
- **Exams.** There will not be any exams.
- **Final Project.** We'll have a final project that involves reading a few related research papers, writing a summary, and giving a presentation to the class that includes a proposal for future experiments to be done. This may include preparatory assignments during the term.

Grade Weights and Overall Scale

Grade weights. Homework: 50%, Quizzes: 25%, Final project: 25%.

Grading scale and criteria.

Scale: A = [90,100%], B = [80,90), C = [70,80), D = [60,70), F = [0,60%).

An “A” indicates demonstration of an excellent understanding of course material and the ability to mathematically calculate, computationally simulate, *and explain* biophysical processes. A “B” indicates good understanding, perhaps lacking in one aspect of calculation, simulation, or explanation. A “C” indicates satisfactory understanding, and likely correlates with incomplete or inadequate submission of course assignments. A “D” indicates significant lack of understanding of many course topics. An “F” indicates consistent lack of understanding of course topics.

AI (Artificial Intelligence) Policy

Homework: Simulations. A significant part of the homework assignments will involve writing computer simulations, with the goal of gaining insights into biophysical phenomena and methods. Contemporary artificial intelligence tools are useful programming assistants, and you may use these. I elaborate on this process in a separate document, “Guidelines for AI-assisted programming,” but in brief: The homework assignments will require that you clearly articulate the logic of your programming task; you must be able to understand and explain the code that is generated; you must be able to test that the code is doing what you intend it to do. Students may be asked to explain their code in class. Note that you will find it impossible to assess or trust AI-generated code without a basic grasp of programming.

Homework: Other exercises. You may **not** use artificial intelligence tools for non-programming parts of the homework assignments. If you are stuck, do these things, in any order: (i) sleep, and the answers may come to you, and they will become embedded in your understanding; (ii) talk to classmates; (iii) come to my or the teaching assistant’s office hours.

Final Project. You may **not** use artificial intelligence tools. Such tools can certainly summarize research articles, but reading these summaries will not solidify your understanding of the articles to the same extent as generating the summaries yourself.

Canvas

We’ll use Canvas to distribute materials, post links, submit assignments, etc. <https://canvas.uoregon.edu/> . If you have questions about accessing and using Canvas, visit the [Canvas support page](#).

Absences

We follow the university’s policies, described at <https://provost.uoregon.edu/course-attendance-and-engagement-policy>. Please note the “reason neutral” policy: instructors “shall not ask for reasons for

absences and shall not distinguish between ‘excused’ and ‘unexcused’ absences.” Attendance is not mandatory but succeeding in the class without consistent attendance will be very difficult.

How to do well in the course

Plan ahead and start early! This applies to everything in the course – homework, reading assignments, and general studying. **Make use of resources.** If you have questions about anything, come to office hours! Communication by email is also welcome, though it’s often more effective to chat in person.

*Also: **Sleep!** Many studies show that sleeping helps memory and understanding.*

University Policies

There are many university policies that are important and useful, focused in many cases on helping students deal with adversity. Please see <https://teaching.uoregon.edu/university-course-policies>