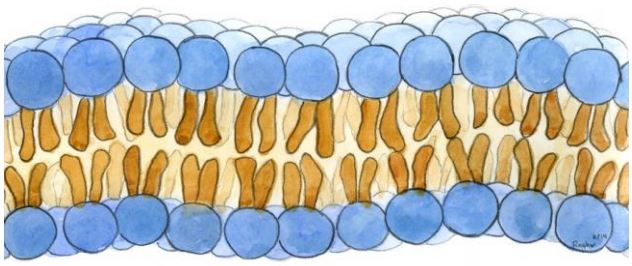

Prof. Raghuveer Parthasarathy
Dept. of Physics; University of Oregon
Fall 2023

PHYSICS 410/510: BIOLOGICAL PHYSICS – *SYLLABUS*

Instructor Information

Professor Raghuveer Parthasarathy (**Par**-tha-**sa**-ra-thē)

Email: raghu@uoregon.edu
Office: Willamette 362
Office hours: To be determined

Time and Place

Tuesday and Thursday 12:00 - 1:50 pm, Willamette Hall Room 350

Description and Learning Goals

The living world exhibits a dazzling variety of form and function, yet 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 (510) course will require roughly one-third more work than the undergraduate (410) course, which will take the form of additional readings, additional problems on homework assignments, and a presentation in addition to a written document for the final project.

Prerequisites

Undergraduate (410 students) should have completed a course in statistical mechanics (such as Physics 352/353) 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 mechanics[1], 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 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.) I can provide guidance and tutorials for those new to programming.

Textbook and other readings

We'll use *Biological Physics*, by Philip Nelson for much of the course (Philip Nelson, *Biological Physics: Energy, Information, Life*, Student Edition, Chiliagon Science, 2020), and you should consider this book **required.** 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, $27 paper), please see: https://www.physics.upenn.edu/biophys/BPse/ .

We'll read parts of two 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* (Chiliagon Science, 2020). See https://eighteenthelephant.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 that gives non-technical descriptions of most of the topics of this course (and much more); you may find it interesting: *So Simple a Beginning: How Four Physical Principles Shape Our Living World*, by Raghuveer Parthasarathy (Princeton University Press, 2022).

---

[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.

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

- **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 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 to not know answers, or to respond with more questions.
- **Classroom behavior.** 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.
- **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. **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 the crucial for learning the material.
- **ChatGPT policy.** [This is tentative, and may change] It's fine to use ChatGPT to help you write code for homework assignments. The key goal of the programming assignments is to learn to model biophysical phenomena and to gain insights into the models, not to learn coding for its own sake. That said, you will find it impossible to assess or trust ChatGPT's code or, more importantly, to know what to ask it for without a basic grasp of the logic and syntax of programming.
- **Quizzes.** There be approximately six quizzes during the term. We'll use these to assess understanding of key points without the heavy weight of exams. The quizzes will also 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 and either writing a summary (undergraduates) or giving a presentation to the class (graduate students) that includes a proposal for future experiments to be done.
- **Grade weights.** Homework: 65%, Quizzes: 20%, Final project: 15%.
- **Grading scale and criteria.** Scale: A = [89,100%], B = [79,89), C = [69,79), D = [59,69), F = [0,59%). An "A" indicates demonstration of an excellent understanding of course material

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

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. An A+ may be awarded, based on exemplary final project work involving original exploration of biophysical topics.

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. Canvas and Technology Support also is available by phone or live chat: 541-346-4357 | livehelp.uoregon.edu

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

Some of this text is quoted from https://provost.uoregon.edu/standard-university-syllabus-language:

Academic Disruption due to Campus Emergency

In the event of a campus emergency that disrupts academic activities, course requirements, deadlines, and grading percentages are subject to change. Information about changes in this course will be communicated as soon as possible by email, and on Canvas. If we are not able to meet face-to-face, students should immediately log onto Canvas and read any announcements and/or access alternative assignments. Students are also expected to continue coursework as outlined in this syllabus or other instructions on Canvas.

Academic Integrity

The University Student Conduct Code (available at conduct.uoregon.edu) defines academic misconduct. Students are prohibited from committing or attempting to commit any act that constitutes academic misconduct. By way of example, students should not give or receive (or attempt to give or receive) unauthorized help on assignments or examinations without express permission from the instructor. Students should properly acknowledge and document all sources of information (e.g. quotations, paraphrases, ideas) and use only the sources and resources authorized by the instructor. If there is any question about whether an act constitutes academic misconduct, it is the students' obligation to clarify the question with the instructor before committing or attempting to commit the act. Additional information about a common form of academic misconduct, plagiarism, is available at https://researchguides.uoregon.edu/citing-plagiarism .

I will report misconduct to the Office of Student Conduct and Community Standards—consequences can include failure in the course.

Access and Accommodations

The University of Oregon and I are dedicated to fostering inclusive, equitable, and accessible learning environments for all students. The Accessible Education Center (AEC) assists students with disabilities in reducing barriers in the educational experience. You may be eligible for accommodations for a variety of disabilities – apparent disabilities, such as a mobility or physical disability, or non-apparent disabilities, such as chronic illnesses or psychological disabilities. If you have or think you have a disability and experience academic barriers, please contact the Accessible Education Center (Location: 360 Oregon Hall; 541-346-1155; uoaec@uoregon.edu) to discuss appropriate accommodations or support. The details of your disability will be kept confidential with the AEC and you are not expected to share this information with others. However, I invite you to discuss any approved accommodations or access needs at any time with me.

Inclement Weather

It is generally expected that class will meet unless the University is officially closed for inclement weather. If it becomes necessary to cancel class while the University remains open, this will be announced on Canvas and by email. Updates on inclement weather and closure are also communicated in other ways described here: https://hr.uoregon.edu/about-hr/campus-notifications/inclement-weather/inclement-weather-immediate-updates

Reporting Obligations

I am a designated reporter. For information about my reporting obligations as an employee, please see Employee Reporting Obligations on the Office of Investigations and Civil Rights Compliance (OICRC) website. Students experiencing sex or gender-based discrimination, harassment or violence should call the 24-7 hotline 541-346-SAFE [7244] or visit safe.uoregon.edu for help. Students experiencing all forms of prohibited discrimination or harassment may contact the Dean of Students Office at 5411-346-3216 or the non-confidential Title IX Coordinator/OICRC at 541-346-3123. Additional resources are available at investigations.uoregon.edu/how-get-support. I am also a mandatory reporter of child abuse. Please find more information at Mandatory Reporting of Child Abuse and Neglect.

Mental Health and Wellness

Life at college can be very complicated. Students often feel overwhelmed or stressed, experience anxiety or depression, struggle with relationships, or just need help navigating challenges in their life. If you're facing such challenges, you don't need to handle them on your own--there's help and support on campus. As your instructor if I believe you may need additional support, I will express my concerns, the reasons for them, and refer you to resources that might be helpful. It is not my intention to know the details of what might be bothering you, but simply to let you know I care and that help is available. Getting help is a courageous thing to do—for yourself and those you care about.

University Health Services help students cope with difficult emotions and life stressors. If you need general resources on coping with stress or want to talk with another student who has been in the same place as you, visit the Duck Nest (located in the EMU on the ground floor) and get help from one of the specially trained Peer Wellness Advocates. Find out more at health.uoregon.edu/ducknest.

University Counseling Services (UCS) has a team of dedicated staff members to support you with your concerns, many of whom can provide identity-based support. All clinical services are free and confidential. Find out more at counseling.uoregon.edu or by calling 541-346-3227 (anytime UCS is closed, the After-Hours Support and Crisis Line is available by calling this same number).

Basic Needs

Any student who has difficulty affording groceries or accessing sufficient food to eat every day, or who lacks a safe and stable place to live and believes this may affect their performance in the course is urged to contact the Dean of Students Office (346-3216, 164 Oregon Hall) for support.

This UO webpage includes resources for food, housing, healthcare, childcare, transportation, technology, finances, and legal support: https://blogs.uoregon.edu/basicneeds/food/

Accommodation for Religious Observances

The university makes reasonable accommodations, upon request, for students who are unable to attend a class for religious obligations or observance reasons, in accordance with the university discrimination policy which says "Any student who, because of religious beliefs, is unable to attend classes on a particular day shall be excused from attendance requirements and from any examination or other assignment on that day. The student shall make up the examination or other assignment missed because of the absence." To request accommodations for this course for religious observance, visit the Office of the Registrar's website (https://registrar.uoregon.edu/calendars/religious-observances) and complete and submit to the instructor the "Student Religious Accommodation Request" form prior to the end of the second week of the term.