PHY 382. Physics of Cells

Fall 2023

Dimitrios Vavylonis
Department of Physics
415 Lewis Lab
vavylonis@lehigh.edu

Time and Location: Tuesdays and Thursdays 9:20-10:35 (ET) Lewis Lab 316

First Class: August 29. Last Class: December 7.
University Holidays (no class): November 7, 23

Office hours: To be determined

Description

This course focuses on the physical principles underlying the organization of living cells, which spans several orders of magnitude in length and time. It provides an introduction to biological physics and relevant concepts of soft-matter physics. Each topic provides a review of relevant experimental and mathematical/computational methods.

Course Contents

1. Introduction to physical biology of the cell: numbers, length and time scales. The molecules of life.
2. Rate equations and kinetics of association and dissociation. Mechanical and Chemical Equilibrium. Cooperativity. Electrostatics in solution.
3. Diffusion and random walks. Introduction to polymer physics. Computer simulations of flexible chains.
4. The cell nucleus. Chromatin organization.
5. Cytoskeleton and molecular motors. Mechanical properties. Polymerization kinetics. Transport and force generation. Computer simulations of cytoskeletal systems.
6. Cellular membranes: mechanics, organization, and transport.
7. Liquid-liquid phase separation. Membraneless organelles.
8. Pattern formation in the cell. Symmetry breaking and reaction-diffusion mechanisms.
9. Fluid dynamics and coarse-grained descriptions of active cellular matter.
10. Cell signaling and sensing. Chemotaxis. Robustness and adaptability.
11. Selected examples of multicellular systems. Biological networks. Introduction to topics in systems biology.

Initial Competences

Some exposure to thermal/statistical physics. Knowledge of multivariable calculus and stochastic processes. Prior exposure to biology or biochemistry is helpful but not required.

Final Competences

1. Perform order of magnitude estimates in cell biophysics.
2. Comprehend and develop quantitative, physics-based models that captures the essential behavior of biological systems.
3. Apply physical and mathematical principles to model how cells regulate their function, internal organization and shape, process information, sense and adapt to their environment.

Grading

The final grade will be based on:

1. Homework (35%). Assignments must be submitted on the assigned due date. Prior permission from the instructor is required for late submissions.
2. Quiz (15%).
3. Active participation in class (10%).
4. Course Project (40 %).

Reading

Reading material will be provided in notes and slides together with selected material from the following textbooks.
1. Robert Phillips, Jane Kondev, and Julie Theriot, *Physical Biology of the Cell*, Second Edition (Garland Science, New York, 2012).
2. Jonathon Howard, *Mechanics of motor proteins and the cytoskeleton* (Sinauer Associates, Publishers, Sunderland, Mass., 2001).
3. Philip Nelson, *Biological physics : energy, information, life* Student ed. (Chiliagon Science, 2020).

Other recommended books:
1. Philip Nelson, *Physical models of living systems* (W.H. Freeman, New York, 2015).
2. Bruce Alberts et al. , *Molecular biology of the cell*, 7th ed. (Norton, 2022).
3. Uri Alon, *An introduction to systems biology*, 2nd ed. (Chapman & Hall/CRC, 2019).
4. Howard C. Berg, *Random walks in biology*, expanded ed., (Princeton University Press, Princeton, N.J., 1993).

Slack, Zoom, and Course Site

We will use Slack for course announcements, questions, links, ideas, and group activities. Students are expected to check it regularly and submit any course-related communication to me or to other students there. Please use slack instead of email; if you send me a course-related email, I will not respond back in slack.

LL 316 is a multimedia classroom so we will use zoom to record all lectures. The zoom link will be provided in slack. All Lehigh students are expected to participate in person, though zoom will help in cases such as conference travel or illness.

This summer, we co-organized a summer school in biological physics in Crete, Greece (https://biophysics.materials.uoc.gr/). Some students who participated in this summer school may join this course as guests from Europe on zoom.

Homework will be submitted and graded on Course Site.

Course Project

The course project will involve a 10-15 min presentation to the class as well as a written final report of 3000-4500 words (including text in figure legends but excluding citation references). The topic of the project could be related to anything covered in the course, upon instructor approval. The topic will ideally be related to your area of interest. A typical outline of a written report will be:

1. Statement of the project topic and overview
2. Review of current understanding, outstanding questions
3. Quantitative approach/analysis in the form of equations, plots, or computer simulations
4. Interpretation, Discussion

University Policies

Accommodations for Students with Disabilities:
Lehigh University is committed to maintaining an equitable and inclusive community and welcomes students with disabilities into all of the University's educational programs. In order to receive consideration for reasonable accommodations, a student with a disability must contact Disability Support Services (DSS), provide documentation, and participate in an interactive review process. If the documentation supports a request for reasonable accommodations, DSS will provide students with a Letter of Accommodations. Students who are approved for accommodations at Lehigh should share this letter and discuss their accommodations and learning needs with instructors as early in the semester as possible. For more information or to request services, please contact Disability Support Services in person in Williams Hall, Suite 301, via phone at 610-758-4152, via email at indss@lehigh.edu, or online at https://studentaffairs.lehigh.edu/disabilities.

Bias, Discrimination, Harassment, Retaliation, and Sexual Misconduct:
Lehigh University upholds The Principles of Our Equitable Community and is committed to providing an educational, working, co-curricular, social, and living environment for all students that is free from harassment and discrimination on the basis of age, color, disability, gender identity or expression, genetic information, marital or familial status, national or ethnic origin, race, religion, sex, sexual orientation, or veteran status.
Harassment and discrimination, including sexual harassment and misconduct, not only disrupts this commitment and violates our principles, but may also violate University policy and applicable laws.
Lehigh University and its faculty are committed to providing an environment that is free from bias, discrimination, harassment, retaliation, and sexual misconduct (including sexual harassment, sexual assault, stalking, dating violence, domestic violence, and sexual exploitation). If you have experienced, witnessed, or become aware of any of these behaviors, you are strongly encouraged to report the incident to the Lehigh University Police Department (LUPD) at 610-758-4200 or to the Equal Opportunity Compliance Coordinator/Title IX Coordinator (EOCC) at 610-758-3535 or at eocc@lehigh.edu.
If you would prefer to submit your report electronically, two online reporting forms are available and may be submitted to report the incident:
Gender Violence Incident Notification Form: https://cf.lehigh.edu/gves/auth/gvreport/
Discrimination, Harassment, Retaliation, or Bias Incident Reporting Form:
https://cm.maxient.com/reportingform.php?LehighUniv&layout_id=30
Please note that, while the University options to respond may be limited, the online reporting forms may be submitted anonymously. Every effort will be made to address concerns reported anonymously.
You can access support and resources even if you do not want to take any further action following the submission of a report.