

PHY 372/472. Cellular Physics of Membranes and the Cytoskeleton

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Time and Location: MWF 10:10-11:00 Lewis Lab 511

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Description

The filaments and motor proteins of the cytoskeleton organize into networks that provide cells with shape, generate mechanical forces and movement by polymerization and motor-based sliding. The plasma membrane is a fluid surface which is responsive to environmental and biochemical signals. It defines the boundaries of the cell, internal compartments, and organelles. Changes of cell shape and intracellular organization require coordination of the cytoskeleton and membranes. This course is an introduction to the physical principles relevant to this organization, which spans several orders of magnitude in length and time.

Course Contents

The following topics will cover aspects that relate to membranes and the cytoskeleton in parallel:

1. Brownian motion in the cell. Viscous, inertial and other forces. Diffusion in the cell and diffusion in external potential. Biopolymers as random walks.
2. Biomolecular association and dissociation. Rate equations and microscopic reversibility. The diffusion-controlled limit.
3. Cytoskeletal polymerization kinetics. Actin and microtubule assembly and disassembly, ATP/GTP hydrolysis. Dynamic instability. Nucleation and growth kinetics. Bacterial cytoskeleton.
4. Transport and force generation by the cytoskeleton. Thermal ratchets. Molecular motors: myosin, kinesin, dynein. Thermodynamics of conversion of chemical energy into force and pattern. Force generation by polymerization and the Brownian ratchet. *Listeria* motility.
5. Amphiphiles, varieties of lipid molecules and their effect on lipid membrane physical properties.

6. Biological functions of membranes in the cell. Cell anatomy. Bending, diffusion, fusion and fission, bursting.
7. Membrane phase separation. Free energy, entropy vs. chemical potential. The phase rule, phase diagrams, tie lines. Diffusion of domains and of proteins in membranes.
8. Critical fluctuations: critical vs. off-critical phase transitions, lipid critical fluctuations, anaesthesia, immune signaling, protein clustering.
9. Physical measurements of membrane properties: viscosity, inter-leaflet friction, bending modulus. Membrane protein structures and lipid-protein interactions.

Initial Competences

Undergraduate students (372): Introductory physics, basic thermal physics, Calculus I-III.
Graduate students (472): At least one prior course in thermal/statistical physics, good knowledge of multivariable calculus and stochastic processes
Prior exposure to biology or biochemistry is helpful but not required.

Final Competences

1. Solve problems in cell biophysics by applying the concepts and techniques covered in lectures.
2. Demonstrate their ability to read critically, analyze, and form questions about primary sources, both experimental and theoretical works, through participation in class discussions.
3. Clearly communicate the content of primary sources to their peers, in both written and presentation format.

Grading

Each student will work on a topic close to his/her background and interests. The topic will be decided after discussion with the instructor. The project will consist of a 10-page written report and a short oral presentation. The homework/project degree of difficulty will be adjusted accordingly for students taking the course at the 300 and 400 levels.

The final grade will be based on:

1. **Course project (50%).**
2. **Homework (30%).** Assignments must be submitted on the assigned due date. Prior permission from the instructor is required for late submissions.
3. **Active participation in class (20%).**

Textbook

- [1] Robert Phillips, Jane Kondev, and Julie Theriot, *Physical Biology of the Cell* (Garland Science, New York, 2009).

Recommended Textbooks

- [1] Jonathon Howard, *Mechanics of motor proteins and the cytoskeleton* (Sinauer Associates, Publishers, Sunderland, Mass., 2001).
- [2] Howard C. Berg, *Random walks in biology*, expanded ed., (Princeton University Press, Princeton, N.J., 1993).
- [3] Philip Nelson, *Biological physics : energy, information, life* (W.H. Freeman, New York, 2007, Updated edition).
- [4] Bruce Alberts, Alexander Johnson, Julian Lewis, David Morgan, Martin Raff, Keith Roberts, Peter Walter, *Molecular biology of the cell*, 6th ed., (Garland Science, New York, 2014).

Accommodations for Students with Disabilities: If you have a disability for which you are or may be requesting accommodations, please contact both your instructor and the Office of Academic Support Services, University Center 212 (610-758-4152) as early as possible in the semester. You must have documentation from the Academic Support Services office before accommodations can be granted.

The Principles of Our Equitable Community:

Lehigh University endorses The Principles of Our Equitable Community (http://www.lehigh.edu/inprv/initiatives/PrinciplesEquity_Sheet_v2.032212.pdf). We expect each member of this class to acknowledge and practice these Principles. Respect for each other and for differing viewpoints is a vital component of the learning environment inside and outside the classroom.

The University strongly encourages (and, depending upon the circumstances, may require) students, faculty, staff or visitors who experience or witness harassment or discrimination, or have information about harassment or discrimination in University programs or activities, to immediately report such conduct.

Reports or inquiries should be made to: Karen A. Salvemini, Equal Opportunity Compliance Coordinator, Alumni Memorial Building / 610.758.3535 / eocc@lehigh.edu

In the event that the conduct involves the Equal Opportunity Compliance Coordinator, reports should be made to: Judy A. Zavalydriga, Human Resources Investigator, 428 Brodhead Avenue / 610.758.3897 / jaz308@lehigh.edu

Resources for students:

Counseling office:

Counseling and Psychological Services

36 University Drive

Johnson Hall, 4th Floor

Bethlehem, PA 18015

Phone: (610) 758-3880

Fax: (610) 758-6207

Hours: M-F, 8:00 AM - 5:00 PM

<http://studentaffairs.lehigh.edu/content/counseling-psychological-services-ucps>

Gender violence:

University Center C112 and C108

Phone: 610-758-1303

Fax: 610-758-6164

E-mail: ingves@lehigh.edu

<http://studentaffairs.lehigh.edu/content/gender-violence-education-support>