

ECE-609/BME-603 Engineering Analysis of Living Cells

Instructor: Prof. Liang-Liang Xie (EIT-4173, ext.33697, llxie@uwaterloo.ca)

Description:

This course introduces a quantitative understanding of cell biology at the molecular level. Guided with real experimental data, biological processes and systems are modeled using fundamental physical principles and engineering analytic techniques, including free-energy minimization, statistical mechanics, electrostatics, diffusive dynamics, random walk models, complex networks, regression models, feedback system analysis, Turing reaction-diffusion equations. Various complicated biological phenomena will be shown to be explicable with the same simple underlying principles.

Objective:

At the end of the course, students should be able to:

1. Appreciate the power of physical modeling and engineering analysis in understanding biological data;
2. Realize numerous seemingly unrelated biological phenomena can be explained with the same fundamental physical principles;
3. Model biological processes with basic physical principles and engineering techniques, and if necessary, add finer details, to achieve a better match with experimental data.

Textbook:

Phillips, Kondev, Theriot, and Garcia, *Physical Biology of the Cell*, 2nd Ed., 2013.

References:

U. Alon, *An Introduction to Systems Biology: Design Principles of Biological Circuits*, 2nd Ed., 2019.

Sanguinetti and Huynh-Thu, *Gene Regulatory Networks: Methods and Protocols*, 2019.

Grading: Homework Assignments (50%) + Final Exam (50%)

Homework Assignments

Homework assignments and solutions will be posted on LEARN.

Main Topics:

1. Introduction to cell biology and the need of quantitative understanding
2. Simple numbers with quick estimation: the model organism *E. coli* as a basic unit of measure

3. Mechanical and chemical equilibrium in the living cell: the central role of energy and free-energy minimizers
4. The analytical engine of statistical mechanics, with applications to gene expression and osmotic pressure
5. Two-state systems: from ion channels to cooperative binding
6. The chemistry of water and the charge on DNA and proteins: electrostatics for salty solutions
7. A statistical view of biological dynamics: diffusion in the cell; active versus passive transport
8. Gene regulation networks: signals, dynamics, inference and control
9. Biological patterns: order in space and time, Turing reaction-diffusion equations

Academic integrity, grievance, discipline, appeals and note for students with disabilities: see www.uwaterloo.ca/accountability/documents/courseoutlinestmts.pdf. The text for this web site is listed below.

Academic integrity: In order to maintain a culture of academic integrity, members of the University of Waterloo community are expected to promote honesty, trust, fairness, respect and responsibility.

[Check www.uwaterloo.ca/academicintegrity/ for more information.]

Grievance: A student who believes that a decision affecting some aspect of his/her university life has been unfair or unreasonable may have grounds for initiating a grievance. Read Policy 70, Student Petitions and Grievances, Section 4, www.adm.uwaterloo.ca/infosec/Policies/policy70.htm. When in doubt please be certain to contact the departments administrative assistant who will provide further assistance.

Discipline: A student is expected to know what constitutes academic integrity [check www.uwaterloo.ca/academicintegrity/] to avoid committing an academic offence, and to take responsibility for his/her actions. A student who is unsure whether an action constitutes an offence, or who needs help in learning how to avoid offences (e.g., plagiarism, cheating) or about rules for group work/collaboration should seek guidance from the course instructor, academic advisor, or the undergraduate Associate Dean. For information on categories of offences and types of penalties, students should refer to Policy 71, Student Discipline, www.adm.uwaterloo.ca/infosec/Policies/policy71.htm. For typical penalties check Guidelines for the Assessment of Penalties, www.adm.uwaterloo.ca/infosec/guidelines/penaltyguidelines.htm.

Appeals: A decision made or penalty imposed under Policy 70 (Student Petitions and Grievances) (other than a petition) or Policy 71 (Student Discipline) may be appealed if there is a ground. A student who believes he/she has a ground for an appeal should refer to Policy 72 (Student Appeals)
www.adm.uwaterloo.ca/infosec/Policies/policy72.htm.

Note for students with disabilities: The Office for persons with Disabilities (OPD), located in Needles Hall, Room 1132, collaborates with all academic departments to arrange appropriate accommodations for students with disabilities without compromising the academic integrity of the curriculum. If you require academic accommodations to lessen the impact of your disability, please register with the OPD at the beginning of each academic term.