Physical Biology of the Cell

This course offers an introduction to molecular and cell biology from a physical biology perspective. Emphasis is placed on applying simple quantitative models to understand complex biological processes. Experimental, theoretical and computational tools for investigating cellular phenomena are incorporated throughout the course.

Course number: BIOL 219-001 / BIEN 219-001

Credits: 4

Pre-requisites: 1-year of college calculus, chemistry and physics; BIOL 112

Co-requisites: MATH 222

Lectures: MWF 12:35 – 1:25 pm EDT

Tutorials: M 8:35 – 9:25 am or 6:30 – 7:20 pm EDT. Students are required to attend one tutorial a week, but are free to choose which time slot. Tutorials will be held on Zoom and recordings will be posted on myCourses.

Course materials: *Biological Physics*, 2nd edition by Nelson
Molecular Biology of the Cell, 6th edition by Alberts et al.
eTextbooks can be purchased or rented from Amazon.
Slides, videos and class recordings will be posted on myCourses.

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Evaluation: Final grades will be based on quizzes (40%), problem sets (30%) and case studies (30%).

Assessments

Quizzes. There will be six quizzes, administered through myCourses, containing a mix of multiple-choice and short-answer questions. Your lowest quiz mark will be dropped.

Problem Sets. There will be three problem sets, involving calculations, model predictions and interpretation of experimental data.

Case Studies. There will be two case studies in which you will analyze primary data, apply mathematical models and draw conclusions. You are encouraged to discuss these cases with classmates, but your final submission must represent your own work.

There will be no exams in this course.

Tutorials

Attendance at tutorial is *mandatory*. This is an opportunity for you to work through problems with your classmates and TAs.

Academic integrity

McGill University values academic integrity. Therefore, all students must understand the meaning and consequences of cheating, plagiarism and other academic offenses under the Code of Student Conduct and Disciplinary Procedures (see Keeping it Honest for more information).

Language policy

In accord with McGill University's Charter of Students' Rights, students in this course have the right to submit in English or in French any written work that is to be graded.

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Students with disabilities

As instructors of this course, we endeavor to provide an inclusive learning environment. However, if you experience barriers to learning in this course, do not hesitate to discuss them with us and the Office for Students with Disabilities.

Learning Objectives

Course content is organized into seven learning modules:

1. Overview of physical biology
2. Protein structure and function
3. Information storage and flow
4. Molecular self-assembly and transport
5. Cell cycle control
6. Cell signaling and polarity
7. Neuroscience

Within each module, you will learn to:

- Describe specific examples of basic cellular processes (ex. chemical kinetics, gene expression, mechanobiology, cell cycle control, signaling networks)
- Distill complex cellular processes down to their essential components
- Examine the properties of these minimal systems and identify general principles
- Apply simple mathematical models to understand molecular and cellular behavior
- Manipulate theoretical models to make testable predictions
- Use quantitative analysis to interpret experimental data
- Recognize the advantages and limitations of various experimental systems

Course Schedule

Date	Topic	Instructor	Reading	Tutorial	Assessment
Module 1: Overview of physical biology					
Sep 2	Physical biology	Weber	Cohen 2004		
Sep 4	Energy	Hendricks	Nelson, Ch 1		
Sep 7	Length and time scales	Hendricks	Nelson, Ch 2	Python	
Sep 9	Diffusion	Hendricks	Nelson, Ch 3, 4		
Sep 11	Diffusion, equipartition	Hendricks	Nelson, Ch 3, 4		Quiz 1
Module 2: Protein structure and function					
Sep 14	Protein structure	Weber	Alberts, p 109-127	Diffusion	
Sep 16	Protein folding	Weber	Kuryan, Ch 5		
Sep 18	Binding, enzyme catalysis	Hendricks	Nelson, Ch 10		
Sep 21	Protein regulation	Hendricks	Nelson, Ch 9	Chimera	
Sep 23	Allostery	Hendricks	Nelson, Ch 9.6		
Module 3: Information storage and flow					
Sep 25	Nucleic acid structure	Weber	Alberts, p 176-180		Quiz 2

Sep 28	Genomes	Weber	Alberts, p 29, 180-191	Enzyme kinetics	
Sep 30	DNA replication	Weber	Alberts, p 240-266		
Oct 2	Prokaryotic transcription	Weber	Alberts, p 302-309		Problem Set 1
Oct 5	Regulation of transcription	Weber	Alberts, p 374-384	Transcription	
Oct 7	Eukaryotic transcription	Weber	Alberts, p 310-315, 384-392		
Oct 9	Case study 1 Q&A	Weber	-		Quiz 3
Oct 12	THANKSGIVING	-		No tutorial	
Oct 14	mRNA processing	Weber	Alberts, p 316-327		
Oct 16	Translation	Weber	Alberts, p 334-349; Schmeing 2009		Case study 1
Module 4: Molecular self-assembly and transport					
Oct 19	Cytoplasm	Weber	Luby-Phelps 2013	FRAP	
Oct 21	Phase separation	Weber	Brangwynne 2015		
Oct 23	Membranes	Hendricks	Nelson, Ch 8		Quiz 4
Oct 26	Polymerization	Hendricks	Alberts, Ch 16	Polymerization	
Oct 28	Molecular motors	Hendricks	Nelson, Ch 10		
Module 5: Cell cycle control					
Oct 30	CDK oscillator	Vogel	Alberts, Ch 17		Problem Set 2
Nov 2	G1 phase	Vogel	Alberts, Ch 17	Oscillator	
Nov 4	S phase	Vogel	Alberts, Ch 17		
Nov 6	Mitosis	Vogel	Alberts, Ch 17		Quiz 5
Nov 9	Checkpoints I	Vogel	Alberts, Ch 17	???	
Nov 11	Checkpoints II	Vogel	Alberts, Ch 17		
Module 6: Cell signaling and polarity					
Nov 13	Cell morphology	Vogel	Alberts, Ch 15		
Nov 16	Intracellular signaling	Vogel	Alberts, Ch 15	Polarity	
Nov 18	Asymmetric division	Vogel	Alberts, Ch 21		
Nov 20	Cell fate	Vogel	Alberts, Ch 21		Quiz 6
Nov 23	Intercellular signaling	Vogel	Alberts, Ch 21	???	
Module 7: Neuroscience					
Nov 25	Neurons	Watt	Nelson, Ch 12		
Nov 27	Neurotransmitters	Watt	Nelson, Ch 12		Problem Set 3
Nov 30	Circuits	Watt	Nelson, Ch 12		
Dec 2	Optogenetics	Watt		Hodgkin-Huxley	
Dec 3	Case study 2 Q&A	Weber	-		
TBD	-	-			Case study 2