Biophysics: Molecules and Systems

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Lectures: Thu 12:40-2:30 FENS L058
Fri 10:40-11:30 FENS L063

Course Description:
The objective of this course is to introduce students to concepts and techniques in theoretical biophysics. As an introductory course it is designed to be accessible to a wide audience with diverse background. In particular, the course aims to provide engineering and physical science students with first exposure to modern molecular and cell biology. At the same time, it aims to equip biology students with a formal language and analytical tools for quantitative analysis of biological problems.

Evaluation:

Homework	20 %
Midterm exam (Nov 23)	30 %
Oral presentation and written report	20 %
Final exam	30 %

In the second half of the semester, students will be expected to choose a biophysical question to examine using the recent research literature. They will present their work in class during the last week of the semester and will submit a short written report of their findings by the end of the exam period.

References:

- Phillips, Kondev, Theriot, Garcia, *Physical Biology of the Cell*, 2$^{\text{nd}}$ edn., Garland Science, 2012.
- Milo, Phillips, Orme, *Cell Biology by the Numbers*, Taylor & Francis, 2015.

Detailed Course Content:
(See next page.)

I. Cells and molecules

Sep 21	General information about the course	How big is a cell?
Sep 22	How long is a genome?	HW1: Information content of a genome
Sep 28	How much information is in a genome?	What keeps the DNA strands together?
Sep 29	Simple model of a folding protein	HW2: Energy of a hydrogen bond
Oct 5	Entropy as information and Boltzmann factor	Role of water in protein folding
Oct 6	Models of cell population growth	HW3: Self-assembly of lipids

II. Transcritpion and its regulation

Oct 12	*Escherichia coli* eats glucose and lactose	Quantifying the cost and benefit of making a protein
Oct 13	Transcription, RNA polymerase, promoter	HW4: Cost-benefit analysis of protein expression
Oct 19	Model of RNA polymerase binding to DNA	Regulation of transcription (activator)
Oct 20	Regulation of transcription (repressor)	HW5: Activator makes the promoter stronger
Oct 26	Binding and the dissociation constant	*lac* repressor binding to DNA
Oct 27	Information content of recognized DNA sequences	HW6: Binding of *lac* repressor to its operators
Nov 2	Transcription regulation: activator and repressor	Demand theory of gene regulation
Nov 3	Logic gates	HW7: Regulatory logic of the *lac* operon
Nov 9	Molecular Boolean networks	
Nov 10		HW8: Boolean network analysis of repressilator

IV. Diffusion

Nov 16	Membrane permeation of small molecules	
Nov 17	Macroscopic view of diffusion	HW9: Passive transport and diffusion coefficient
Nov 23	**Midterm Exam**	
Nov 24	Drug molecules crossing the membrane	
Nov 30	Microscopic view of diffusion along DNA	Diffusion in 1D and 3D
Dec 1	Is 1D diffusion better for finding a site on DNA?	HW10: Diffusion equation
Dec 7	Mean time to find a target via diffusion in 1D …	and in 3D
Dec 8	Sliding along and jumping across DNA	HW11: Time to find target in 1D and 3D

IV. A look at recent research problems

Dec 14	Systems view of cell metabolism …	and growth
Dec 15		
Dec 21	**Presentations**	**Presentations**
Dec 22	**Presentations**	
Dec ?	**Final Exam**	