Biophysics: Molecules and Systems

(December 16, 2017)

Instructor: Deniz Sezer
E-mail: dsezer@sabanciuniv.edu
Office: FENS G021
TA: Kadriye Kahraman

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 (Dec 25)	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.
- Goodsell, *The Machinery of Life*, Ch. 2 Molecular Machines.
- Goodsell, *The Machinery of Life*, Ch. 4 Molecules in Cells: *Escherichia coli.*
- Schneider, Sequence logos, machine/channel capacity, Maxwell's demon, and molecular computers: a review of the theory of molecular machines, *Nanotechnology*, **5**, 1–18 (1994) (first two sections only).
- Savageau, Design of molecular control mechanisms and the demand for gene expression, *Proc. Natl. Acad. Sci. USA*, **74**, 5647–5651 (1977).
- Kauffman, *At Home in the Universe*, Ch. 4 Order for Free.
- Elowitz & Leibler, A synthetic oscillatory network of transcriptional regulators, *Nature*, **403**, 335-338 (2000).
- Halford & Marko, How do site-specific DNA-binding proteins find their targets? *Nucleic Acid Research*, **32**, 3040–3052 (2004) (from beginning till end of p. 3042).
- Milo, Phillips, Orme, *Cell Biology by the Numbers*, Taylor & Francis, 2015.

Detailed Course Content:

	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, 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	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	Physics view of binding
Oct 27	Relating the physics and chemistry pictures	HW6: Regulatory logic of the *lac* operon
Nov 2	*lac* repressor binding to DNA	Information necessary to find a binding site
Nov 3	Information content of recognized DNA sequences	HW7: Information content of *lac* operators
Nov 9	Demand theory of gene regulation	Logic gates
Nov 10	Molecular Boolean networks	HW8: Boolean network analysis of repressilator
	III. Diffusion in 1D and 3D	
Nov 16	What powers the motion of transcription factors?	Microscopic view of diffusion along DNA
Nov 17	Time- and length-scales of diffusion	
Nov 23	**Midterm Exam**	
Nov 24	Is 1D diffusion better for finding a site on DNA?	HW9: Passive transport and diffusion coefficient
Nov 30	Mean time to find a target via diffusion in 1D ...	and in 3D
Dec 1	Sliding along and jumping across DNA	HW10: Time to find target in 1D and 3D
Dec 7	Model of random transitions between two states	Two states of ion channels and transporters
Dec 8	Membrane permeation of small molecules	
Dec 14	Macroscopic view of diffusion: Fick's law and ...	continuity equation
Dec 15	Time scales related to the permeability coefficient	(HW11: Diffusion equation)
	IV. Recent research literature	
Dec 21	**Presentations**	**Presentations**
Dec 22	**Presentations**	
Dec 25	**Final Exam**	