

# BIO 466 Biophysics: Molecules and Systems - Fall 2014

(December 27, 2014)

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**Lectures:** Mon 14:40-16:30 FENS L055  
Wed 15:40-16:30 FENS L067

**TA:** Tuğçe Oruç

**Course Description:** The objective of this course is to introduce students to concepts and techniques in theoretical molecular 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 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:

Participation	5 %
Homework	15 %
Exam 1 (Nov 3)	25 %
Exam 2 (Dec 8)	25 %
Final exam	30 %

## Textbook:

**PBoC.** Phillips, Kondev, Theriot & Garcia, *Physical Biology of the Cell*, 2<sup>nd</sup> edn., Garland Science, 2012.

**Detailed Course Content:** (See next page.)

From cells to molecules (Bio-physics)

Sep 15	General information about the course	Introduction to the molecules of life
Sep 17	Molecular interactions	
Sep 22	DNA and protein structure	Multiplicity and entropy
Sep 24	Hydrophobic effect and protein folding	<a href="#">HW1: Genomes and DNA structure</a>
Control and optimization of protein production		
Sep 29	Bacterial growth and lactose utilization	Cost-benefit analysis of protein expression
Oct 1	Statistical mechanics of binding to DNA	<a href="#">HW2: Self-assembly of lipids: a lattice model</a>
Oct 6	Spring Break	
Oct 8		
Oct 13	Regulation of transcription	Demand theory of gene regulation
Oct 15	Boolean logic gates from molecules	<a href="#">HW3: Regulatory logic of lac operon</a>
Binding to DNA: chemistry, physics and information		
Oct 20	Molecular Boolean networks	Statistical mechanics of ligand binding
Oct 22	Information content of DNA binding sites	<a href="#">HW4: Boolean network analysis of repressilator</a>
Oct 27	Information needed to find DNA binding site	Review
Oct 29	National Holiday	
Nov 3	First Exam	
Nov 5	Solution of exam questions (toggle switch)	<a href="#">HW5: Information content of operator sequences</a>
Moving along DNA and inside the cell		
Nov 10	Microscopic view of diffusion along DNA	Diffusion in 3D
Nov 12	Sliding along and jumping across DNA	<a href="#">HW6: Passive transport and diffusion coefficient</a>
Nov 17	Mean time to find a target via diffusion in 1D	...and in 3D
Nov 19	First law of thermodynamics	<a href="#">HW7: Time to find target in 1D and 3D</a>
Thermodynamics and mechanosensitive ion channels		
Nov 24	Second law of thermodynamics	Microscopic model of heat flow
Nov 26	Helmholtz and Gibbs free energies	<a href="#">HW8: Temperature of a two-level system</a>
Dec 1	Mechanosensitive ion channels	Hydrophobic mismatch and channel gating
Dec 3	From thermodynamics to statistical mechanics	
Dec 8	Second Exam	
Dec 10	Pressure unfolding of proteins	
Diffusion and getting into the cell		
Dec 15	Fick's law and continuity equation	Macroscopic view of diffusion
Dec 17	Permeation of molecules through membrane	<a href="#">HW9: Diffusion equation</a>
Dec 22	Nernst equation and membrane potential	Electrical signals in neurons
Dec 24	Structures of voltage-gated ion channels	
Dec 30	Final Exam	

**Reading list:**

End of the week of Sep 24

- Goodsell, *The Machinery of Life*, Ch. 2 Molecular Machines.
- Goodsell, *The Machinery of Life*, Ch. 4 Molecules in Cells: *Escherichia coli*.
- PBoC, Ch. 1 Why: Biology by the Numbers.
- PBoC, Sec. 2.1 An Ode to *E. coli*.
- PBoC, Sec. 3.1 The Hierarchy of Temporal Scales.
- PBoC, Sec. 3.2 Procedural Time.
- PBoC, Sec. 3.3 Relative Time.

End of the week of Oct 15

- Kirschner & Gerhart, *The Plausibility of Life*, pp. 112–121.

- Dekel & Alon, Optimality and evolutionary tuning of the expression level of a protein, *Nature*, **436**:588-592 (2005).
- PBoC, Sec. 4.4 A Tale of Two Cells: *E. coli* as a Model System.
- PBoC, beginning of Sec. 5.5 Structures as Free Energy Minimizers and Sec. 5.5.1 Entropy and Hydrophobicity.
- PBoC, beginning of Sec. 6.1 The Analytical Engine of Statistical Mechanics and Sec. 6.1.1 A First Look at Ligand-Receptor Binding.
- PBoC, Sec. 6.1.2 The Statistical Mechanics of Gene Expression: RNA Polymerase and the Promoter.
- PBoC, Sec. 19.2 Genetic Networks: Doing the Right Thing at the Right Time (up to page 742).

#### End of the week of Oct 29

- Kauffman, *At Home in the Universe*, Ch. 4 Order for Free.
- Kauffman, *At Home in the Universe*, Ch. 5 The Mystery of Ontogeny.
- Elowitz & Leibler, A synthetic oscillatory network of transcriptional regulators, *Nature*, **403**:335-338 (2000). (Homework 4)
- PBoC, Sec. 6.4.1 A Second Look at Ligand-Receptor Binding.
- PBoC, Sec. 18.1 Biological Information.
- PBoC, beginning of Sec. 18.2 Sequence Alignment and Homology (up to page 688).
- 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).

#### End of the week of Nov 19

- PBoC, Sec. 13.1 Diffusion in the Cell.
- PBoC, Sec. 13.2.1 Diffusion by Summing Over Microtrajectories.
- Halford & Marko, How do site-specific DNA-binding proteins find their targets? *Nucleic Acid Research*, **32**:3040-3052 (2004) (read from beginning to end of p. 3042).
- Bruinsma, Physics of protein-DNA interaction, *Physica A*, **313**:211-237 (2002) (read Sec. 2.2.3 only, pp. 234-236).

#### End of the week of Dec 3

- PBoC, Sec. 5.2 Biological Systems as Minimizers.
- PBoC, Sec. 5.3 The Mathematics of Superlatives.
- PBoC, Sec. 5.4 Configurational Energy.
- PBoC, Sec. 5.5 Structures as Free Energy Minimizers.
- PBoC, Sec. 6.1.3 Classic Derivation of the Boltzmann Distribution.
- PBoC, Sec. 11.5 The Active Membrane (read the discussion but do not expect to understand the math).

#### End of the week of Dec 24

- Roche, . . . , & Royer, Cavities determine the pressure unfolding of proteins, *Proc. Natl. Acad. Sci. USA*, **109**:6945-6950 (2012).
- PBoC, Sec. 3.4.2 Beating the Diffusive Speed Limit (pp. 108-113).
- PBoC, Sec. 5.1.1 The Interplay of Deterministic and Thermal Forces (pp. 168-170).
- PBoC, Sec. 13.1 Diffusion in the Cell (pp. 481-487).
- PBoC, Sec. 13.2 Concentration Fields and Diffusive Dynamics (up to page 495).
- PBoC, Sec. 13.2.2 Solutions and Properties of Diffusion Equation.
- PBoC, Sec. 17.1 The Role of Electricity in Cells.
- PBoC, Sec. 17.2 The Charge State of the Cell.