BCHM 102A: Quantitative Approaches to Biochemical Systems, 2018

Section 1: Spectroscopic methods (10)
Instructor: Maria-Eirini Pandelia

8/29 Molecules and radiation: The electromagnetic spectrum and ….Ground and Excited States
8/30 Ultraviolet/Visible Absorption spectroscopy
9/3 NO CLASS – Labor Day
9/5 Fluorescence spectroscopy I
9/6 Fluorescence spectroscopy II and FRET
9/10 No CLASS – Rosh Hashanah
9/12 NMR Spectroscopy I
9/13 NMR Spectroscopy II
9/17 EPR Spectroscopy
9/19 NO CLASS – Yom Kippur
9/20 Mössbauer Spectroscopy
9/24 NO CLASS
9/25 A case Study. The case of [Fe-S] clusters (Combining NMR, EPR, Mössbauer, Raman)
9/26 1st Exam

Section 2: Dissection of enzymatic mechanisms (16)
Instructor: Maria-Eirini Pandelia

9/27 Study of Reaction Mechanisms. What is a rate of a chemical reaction? Integrated Rate Equations and Derivation of Rates (*Zero-order, First-order, Second Order and pseudo-order reactions*)
10/1 NO CLASS
10/3 Complex Reactions (Reversible Reactions, Consecutive Reactions A→B→C). Homework Problem: Solve the A→B→C→D
10/4 Computational lab – Kinetic Exercise I (A→B→C Scheme). Non-linear data regression using Kaleidagraph (bring your computer)
10/8 Simple binding equilibria. Derivation of the Michaelis-Menten equation. Briggs and Haldane steady state approximation.
10/10 Meaning of the steady state kinetic parameters, practical exercises.
10/11 Steady-state inhibition (competitive, non-competitive and uncompetitive inhibition)
10/15 Kinetic Exercise II (practical exercise)
10/17 Kinetic Exercise II (solution), upper limit of rate constants and kinetic partitioning.
10/18 Quadratic vs hyperbolic equations. Reversible and irreversible one-step binding. Cooperative

Binding (Hill equation).
10/22 Rapid Equilibrium, two step substrate binding.
10/24 Kinetic Exercise III (practical exercise). Non-linear data regression using Kaleidagraph (bring your computer)
10/25 Single turnover and multiple-turnover experiments; two sides of the same coin.
10/29 Bringing all the kinetic concepts together
10/31 2nd Exam
11/1 NO CLASS BCBP Retreat

Section 3: Stochastic Behavior of Single Molecules (7)
Instructor: Christopher Miller

11/5 Chaos and determinism. Lightbulb statistics
11/7 The pdf, a magic averaging machine
11/8 Pdf for single molecule dwell-times: the exponential distribution
11/12 Single-molecule measurements, connection to conventional kinetics
11/14 Single-channel analysis lab, 1: data collection
11/15 Single-channel analysis lab, 2: data analysis
11/21 NO CLASS (Thanksgiving)
11/22 NO CLASS (Thanksgiving)
11/19 Multistate kinetics and the rule of departure

Section 4: Diffusion and Molecular Transport Processes (6)
Instructor: Jeff Gelles

11/26 Diffusion; Microscopic description. One-dimensional Random walk
11/28 Two and three-dimensional random walks
11/29 Macroscopic Diffusion; Fick's equations are differential equations that describe changes in concentration as a result of molecular motion.
12/3 Diffusion equation and diffusion constants
12/5 How fast can a chemical reaction be? Diffusion limited reaction rate constants and how to obtain them
12/6 Diffusion to capture
12/10 Final Exam

* Last day of classes is 12/11, which is a Tuesday. The format of the class in Mo/Wed/Thu, 11.00-11.50 am.

Course Information

Instructor: Maria-Eirini Pandelia (mepandelia@brandeis.edu) – Rosenstiel 656
M, W, Th, 11-11:50 AM, Volen 106
Teaching Assistant: Chansik Kim (kva0987@brandeis.edu)

What is the course about?

Understanding biological phenomena often comes down to comprehending the structures of the molecules that participate in biochemical processes and the ways that these molecules work and interact. Biochemistry textbooks are packed to the brim with such information, but where does this knowledge come from in the first place? A great deal of our knowledge about biochemical processes comes from just two basic types of laboratory experiments. First, we explore the ***mechanisms*** of biochemical reactions by measuring the rates of various reaction steps. Second, we infer the ***structures*** and behavior of biological molecules from the ways that they interact with electromagnetic radiation. All such experiments involve making and interpreting quantitative chemical and physical measurements on biochemical systems.

This is not a laboratory course, nor will it teach the details of how to use specific techniques. Instead, the course covers *basic principles* that underlie a range of quantitative biochemical experiments and phenomena. Many of these principles arise from physical chemistry (the study of large collections of molecules), and their applications to real systems are worked out via mathematics. The aim here is to equip students with some of the basic attitudes, approaches, and knowledge they will require to read, critically evaluate, and ultimately contribute to original research in macromolecular biochemistry and biophysics.

Another purpose of this course is to gain experience with *mathematical methods* in common use in the quantitative treatment of biochemical problems – linear differential equations in kinetics, concepts of probability, statistics, stochastic processes, fourier series. Students have seen most of these before but usually have not had much practice actually using them. My object here is not to torture students but rather to empower them by teaching a few of these tools and demystifying them so that when they are encountered in the biochemical literature later on, they will be seen as useful friends rather than as obscure tormentors.

Required Preparation

The course requires knowledge of basic biochemistry at the level covered in a good introductory college biochemistry course (e.g., Bchm 100). I will assume that you already are familiar with fundamental chemistry concepts like Gibbs free energy and chemical equilibrium and that you have had at least some previous exposure to basic chemical kinetics. **A *calculus-based introductory physics course is an essential prerequisite.*** You should be *very, very* familiar with the properties of common mathematical functions such as polynomials, logarithms, exponentials, and trig functions. You must also to be able to **solve algebraic equations, differentiate, and integrate with ease** and also to apply univariate calculus to the solution of physical problems stated in words.

Readings

The course uses sections from the following texts:

Kuriyan, J. et al. (2013). *The Molecules of Life*. New York, Garland Press
A pretty good general textbook emphasizing physical-chemical principles underlying biochemical analysis. Paperback, worth owning.

Berg, H. C. (1983). *Random Walks in Biology.* Princeton, N.J., Princeton University Press. (This is a cheap paperback and an absolute gem - really worth owning.)

Fersht A. (1977) Enzyme structure and mechanism, New York, W.H. Freeman and Company (some Chapters will be posted)

Other pdfs of relevant books for the course material will be uploaded in LATTE (or just ask me if you need sth in particular and I can provide it to you).

Some of you may already have these texts, but if you don't, you will not need to buy them, as the relevant sections will be posted on LATTE. You should also have available an introductory biochemistry text in case you need to refresh your memory of some of the background material.

For those of you who feel rusty on your introductory calculus, Chris Miller recommends that you buy a sweet little paperback "*Quick Calculus*" by Kleppner and Ramsey. The book emphasizes methods rather than proofs, and it takes you through many practice problems. I have posted the entire book as a pdf on the LATTE site.

Course Organization

Problem sets and assignments. Much of the material covered in the course cannot really be understood just by listening to me jabber on about it; you have to try it out for yourself. For that reason, the ***problem sets are the most important part of the course***. Along with readings, I will assign problem sets throughout the course. These *must* be turned in at the end of class on the due date. I will grade and return them, but the grades are merely for your information; problem set grades have almost no effect on your grade for the course. I will not look at problem sets turned in after the due date. Do not hesitate to collaborate with other students on the problem sets if you feel that this will help your understanding of the material.

Lectures. See the course schedule for dates of lectures. Class starts promptly at 11:00

Questions. I want to help you understand this quantitative material. Do not hesitate to see me in my office or lab if you have questions about the course, lectures, problems, etc. I do not keep office hours but am always available (just send an e-mail announcement beforehand!).

Exams. There will be three exams. If you miss an exam, you will receive a failing grade, and no makeup exams will be given. In exceptional circumstances in which a student is absent from an exam due to a documentable emergency beyond the student's control, I will give an oral exam at the whiteboard in my office. Any student requiring special academic accommodations in the exams or lectures should make arrangements immediately upon starting the course; see the Brandeis University Bulletin for details.

Computational labs. Several class sessions will be spent doing Matlab exercises, non-linear regression fitting using kaleidagraph. My goal is that you understand how to fit and analyze your data, and how to approach complex reaction mechanisms, without really becoming experts in these software at this point.

Grades. Final grades will be determined on the basis of the exam scores and your class participation.

Four-Credit Course (with three hours of class-time per week)

Success in this 4 credit hour course is based on the expectation that students will spend a minimum of 9 hours of study time per week in preparation for class (readings, papers, discussion sections, preparation for exams, etc.).