Mathematical Biology (BIOL 4755/BIOL 8803) Spring 2015
aka "Introduction to Systems Biology: Design Principles of Biological Circuits"

Course Syllabus

Professor: Dr. Joshua Weitz

Contact information:

Dr. Joshua Weitz
Office: Cherry Emerson 219
Phone: 404-385-6169
Email: jsweitz@gatech.edu
Web: http://ecotheory.biology.gatech.edu
Office hours: M 2-3:00pm

Lectures: Monday, Wednesday, Friday, 3:05-3:55 PM in ES&T L1125

Textbooks:

Required:

Uri Alon (abbreviated A), An Introduction to Systems Biology: Design Principles of Biological Circuits. Chapman & Hall/CRC, 2007.

Suggested reading:

Mark Ptashne and Alexander Gann (abbreviated P). Genes and Signals. Cold Spring Harbor Laboratory Press, 2002.

Steven Strogatz (abbreviated S). Introduction to Nonlinear Dynamics. Addison-Wesley, 1994.

Kim Sneppen (abbreviated K). Models of Life. Cambridge University Press, 2014.

Special readings to be posted on http://tsquare.gatech.edu

Course Topics: Mathematics of gene regulation; transcriptional network dynamics; structure of transcription networks; network motifs; robustness; applications including chemotaxis, development, kinetic proofreading and optimal circuit design.

Prerequisites: The equivalent of BIOL 2400 or (BIOL 1510 AND MATH 2403). Students should be comfortable with basic mathematical concepts of simple probability, statistics, and integration/differentiation & basic biological concepts of how a cell works. Introductory material on the biology and mathematics of systems biology will be introduced as needed.

Overview

Advanced introduction to systems biology and the quantitative analysis of how cells work: from gene regulation to complex networks to examples of chemotaxis, kinetic proofreading, and collective behaviors. The textbook, An Introduction to Systems Biology, is accessible to math, science, and engineering, majors. The aim will be to develop quantitative toolkits to analyze the complex mechanisms behind the regulation, design, and operation of biological circuits.

Computer programming will be done in Matlab, though no prior experience with Matlab is necessary for the course.

Course format

Three hours each week are scheduled for the class. Class time will be divided among traditional lectures and group problem-solving exercises or discussions. A component of the course will involve students formulating and solving problems in small cooperative groups of three to four members.

Some class days will be devoted to in-class modeling exercises. These days will be announced at least one day prior to class. You are encouraged to bring laptop computers to class to work on these problems.

The reading listed for each week should be done *prior* to the first lecture of the week. The course is tightly tied to Alon's book, and you will get more out of and contribute more to in-class discussions if you are up to date with the reading.

Software: Implementation of homework requires use of (i) mathematic analysis; and (ii) Matlab.

Grading Scheme:

45% homework
15% midterm
15% final presentation
15% final paper
10% class participation

Final project: Final projects will be developed over the course of the semester. Final presentations are *tentatively*, scheduled for the week of April 20-24 Final papers will be due on April 24^{h}. More information will be available later in the term.

Homework: All homework should be done individually. Setting up study groups to discuss problems is okay, however, each student is responsible for solving and writing up their own solutions and explanations.

Midterm: In-class exam to last 50 minutes, tentative date is February 25.

Attendance: Regular attendance in lectures is expected – most lectures will include some component of group work and problem solving. Exceptions will be accepted for valid, documented reasons only, including: (1) official representation of the Institute; and (2) medical emergencies.

Academic Integrity: Students are reminded of the obligations and expectations associated with the Georgia Tech Academic Honor Code and Student Code of Conduct, available online at:
http://www.deanofstudents.gatech.edu/integrity/policies/honor_code.php
http://www.deanofstudents.gatech.edu/codeofconduct.
Any violations must be reported to directly to the Dean of Students.

Additional Resources:

- Tsquare — http://tsquare.gatech.edu
- Tech Tutoring — http://www.undergradstudies.gatech.edu/supportTutoring.htm

Updates: This syllabus is subject to modification. Any changes will be announced in class and posted on the course website.

Lecture Schedule:
Note that special lectures and events, including exams & break, are noted in **bold.**

I. Introduction to Systems Biology - Overview
Readings: Matlab handout, Molecular biology cheat sheet, S.1 & S.2, K.1
January 5, 7 & 9
January 5 Course logistics; course overview
January 7: Molecular biology fundamentals
January 9: Introduction to Matlab

II. Basic concepts of transcription networks
Readings: A.2 & (either P.1 or K.2)
January 12, 14 & 16 (HW1 out)

III. Autoregulation: a network motif
Readings: A.3
January 19 MLK Holiday
Jan 21 & 23 (HW1 due; HW 2 out)

IV. The feed forward loop network motif
Readings: A.4
January 26, 28 & 30 (HW2 due; HW3 out)

V. Global structure of transcription networks
Readings: A.5
February 2, 4 & 6 (HW 3 due; HW 4 out)

VI. Chemotaxis
Readings: A.7 & handouts
February 9, 11 & 13 (HW4 due; HW 5 out)

VII. Network motifs in development
Readings, A.6
February 16, 18 & 20 (HW 5 due)

VIII. Evaluation & final project development
Readings: Handouts
February 23, 25 & 27
Midterm review, February 23
Midterm, February 25
Final project idea critique, February 27

IX. Resources in the analysis of biological circuits (experimental techniques, data manipulation methods, and dynamical inference)
Readings: Handouts TBA
March 2, 4 & 6 (Abstract of project proposal due; Midterm returned)

X. Sensitivity analysis
Readings: Gutenkunst RN, Waterfall JJ, Casey FP, Brown KS, Myers CR, et al. (2007) Universally sloppy parameter sensitivities in systems biology models. PLoS Comput Biol 3(10): e189. doi:10.1371/journal.pcbi.0030189
March 9, 11 & 13
March 13 – In-class MATLAB analysis, JSW away at a conference

Spring break, March 16-20

XI. Noise in biological networks
Readings: Eldar and Elowitz, Nature 467: 167 (2010); doi:10.1038/nature09326
March 23, 25 & 27

XII. Decision circuits in phage lambda
Readings: K.6
March 30, April 1 & 3

XIII. Evolution and optimization in systems biology
Readings: Alon Chapter 10
April 6, 8 and 10
April 10 Project lab day

XIV. Final project preparation week
April 13, 15, 17 – **All project lab days**

XV. Final project presentations
Readings: A.12
April 20: Presentations I (3-4pm)
April 22: Presentations II (3-4pm)
April 24: Presentations II (3-4pm)

Final paper due by April 24, 3pm in lieu of exam