1 Course Overview and Curriculum Content

This course examines fundamental models that arise in biology and their analysis through modern scientific computing. It covers discrete and continuous-time dynamics, in deterministic and stochastic settings, with application from molecular biology to neuroscience to population dynamics; statistical analysis of experimental data; and simple R programming from scratch.

The topics to be covered are:

A new approach to population dynamics (or "bathtub models" or "balancing checkbooks", if you like) based on individual's random behavior which gives rise to a deterministic dynamics at the population level.

Introduction to mathematical modeling, two kinds of models, population balance equation, Darwin's law of natural selection in a nutshell.

Chemicals as molecular populations, chemical and enzyme kinetics, Michaelis-Menten equation, Euler's method and Runge-Kutta method for solving ordinary differential equations (Sec. 5.7).

Revisit radioactive decay process and exponential decay and growth, Poisson process, birth-and-death process.

Structured population dynamics and matrix methods. [Chapter 2]

Cellular biochemical dynamics and gene expression. [Chapter 4]

Dynamical systems, nonlinear ordinary differential equation for a single species, concepts of fixed points, linear stability, and bifurcations. [Chapter 5]

Infectious disease dynamics [Chapter 6]

Membane electrophysiology [Chapter 3]

Discrete-time linear and nonlinear population dynamics, Fibonacci sequence and linear difference equation, and logistic dynamics of an insect population.

2 Required Texts, Readings, Films, Websites, etc.

Required Text:

"Dynamic Models in Biology" by S. P. Ellner and J. Guckenheimer (Princeton, 2006). Available at University bookstore.

"Lab Manual: An Introduction to R for Dynamic Models in Biology" S. P. Ellner and J. Guckenheimer (2011) – Free download from:
`https://people.cam.cornell.edu/~dmb/DynamicModelsLabsInR.pdf`

"An Introduction to R" by R Core Team (2013). – Open Access. Free download on the course website.

Reference Text:
"Chemical Biophysics: Quantitative Analysis of Cellular Systems" by Daniel A. Beard and Hong Qian (Cambridge Univ. Press, 2008).
"Mathematical Biology: I. An Introduction" by James D. Murray (3rd edition, Springer, 2007).
"Matlab: A Practical Introduction to Programming and Problem Solving" by Stormy Attaway (Butterworth-Heinemann 2013).

3 Computational Software Packages

R is the official course language. It is in the public domain, and it also contains a significant amount of statistical tools:
`http://www.r-project.org/`
No prior programming experience is assumed.
If you prefer to use MATLAB, that is fine with me.
There are supplementary materials for the textbook by Ellner and Guckenheimer. They are required and can be found at
`http://people.cam.cornell.edu/~dmb/DMBsupplements.html`
We shall also learn to use XPPAUT:
`http://www.math.pitt.edu/~bard/xpp/xpp.html`
Please check out the Homework # 1 immediately, on the course website, to install a copy of R on your computer.

4 Learning Goals/Objectives

Although the subject matter of biological dynamics can be made difficult, we will attempt to present the course material in as simple a manner as possible. Model development, and how to connect biological problems to mathematical equations, will be emphasized. We will let students know clearly what they need to learn and what can be skipped.

All students should leave the class knowing several concrete examples of mathematical models for biological systems and processes. The stronger students might in fact learned to generalize the approaches presented in the class and be able to development models on their own for other biological problems.

Homeworks are used to reinforce class lectures, but not as a way to introduce new material not covered in class. They serve two purpose: (1) To reinforce the skills in analyzing ordinary differential equations; and (2) to get their own "hand wet" by working on models developed in the class.

5 Project and Presentation

Each student group will give two 6-10min in-class presentations of a paper that applies the modeling and computational techniques we have learned in the course (case study). These studies will be developed into final projects.

Two presentations: **Wed. February 26**, in class (literature review and proposal), **Wed. March 12**, in class (final presentation)

Final term papers are due on **Wed. March 19**.

Please download the "Project and Presentation Guidelines" from course website and read it carefully. Replacing MATLAB with R.

You can also find a list of possible topics on the course website.

6 Evaluation and Grading

There are no exams for this class.

6-7 homework assignments consist total 50% of the final grade. All homework will be graded. A final project in the form of a group presentation, 20%, and a group term paper, 30%.

The term paper will be about 12 pages in length. It should be written with the style of a scientific research paper: Introduction, Problem formulation and Models, Solution to Mathematical Models, Discussion, and References. Grading scheme of the term paper is based on the following five criteria, 20% each:

(1) Stylistics, i.e., spelling, grammar, referenecs, and handling of equations.
(2) Clarity of thoughts, writing, and implications.
(3) Originality and novelty and/or thoroughness of review.
(4) Accuracy of the mathematics and validity of the science.
(5) Mathematics, i.e., depth, explanations, exposition, and appropriateness.

7 Course Schedule

Twice a week, 80 mins per class. Monday and Wednesday 4:30-5:50pm, Communications Building (CMU) 228.

8 Important Dates

Frist day of class, Monday January 6.
No class on Monday January 20, Martin Luther King Day.
No class on Monday February 17, Presidents Day.
Wed. February 26, in class presentation on literature review and plan.

Wed. March 12, in class final presentation.
Last day of class, Wednesday March 12.
Term paper due, Wednesday March 19.