BIOL 4800 – Modeling Biological Systems
Fall 2018

Prof. Paul Nerenberg

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Office Hours (in BIOS 167): Mo 2:30-4 pm, Tu 11 am-12 pm, Th 10:30-12 pm, We and Fr by appt.

Lectures: TuTh 1:40-2:55 pm in KH C2096

Prerequisites: Minimum grade of C in MATH 2050 or in both MATH 2150 and MATH 2550.

Course Overview

Nearly every field of science now depends on mathematical modeling to generate insights into how complex systems behave. Biology is no exception to this trend, and the use of mathematical modeling techniques is now common place in fields ranging from systems biology to ecology. Knowing how to select, solve, and analyze mathematical models are therefore vital skills for biologists in the 21st century (and indeed for many other professions as well!). To that end, this course provides a broad introduction to mathematical modeling as it applies to biological systems, including many of the "greatest hits" of the past few decades. In addition, we will also learn about various statistical methods for estimating the parameters relevant to these models, with a particular focus on Bayesian parameter estimation (which is generally not covered in our biostatistics courses). In addition to analytic problem solving, you will get a great deal of hands-on experience using R to perform both mathematical modeling and parameter estimation.

Course Learning Objectives

By the end of this course, students should be able to:

1. Analytically solve and characterize basic mathematical models of biological systems.
2. Develop original computer programs and/or use pre-existing software libraries to numerically solve and characterize complex mathematical models of biological systems.
3. Develop original computer programs and/or use pre-existing software libraries to perform desired statistical analyses of their data.
4. Understand the rationale behind scientific study designs and choices of mathematical models and/or statistical analyses that appear in recent scientific literature.

Course Materials and Resources

Textbook: There is no required textbook for the course. Below are several suggestions for additional references that you may find helpful throughout the term:

- "A Biologist's Guide to Mathematical Modeling in Ecology and Evolution" by Sarah P. Otto and Troy Day.
- "Mathematical Modeling in Systems Biology" by Brian P. Ingalls. Preprint version available from the author at: https://www.math.uwaterloo.ca/~bingalls/MMSB/Notes.pdf
- "Statistical Data Analysis" by Glen Cowan.
- "Bayesian Data Analysis" by Andrew Gelman et al.

Course website: Each student is expected to have access to Moodle through the MyCalStateLA portal. The course site on Moodle will be your primary resource for acquiring information, turning in problem sets and take-home exams, and accessing other required materials for this course. All course materials will be available on Moodle, and all course announcements will be posted there as well.

Software: If you have your own laptop, you may find it useful to install R. R is an open-source software package that can be downloaded here: http://cran.stat.ucla.edu. You should also install RStudio Desktop, a graphical interface and workspace for R, which can be obtained here: https://www.rstudio.com/products/rstudio/download/.

Lecture Expectations

The course lectures will be fairly interactive, and each day I will give group problems and/or short coding projects for everyone to think about and work on collaboratively. You will benefit the most from these active learning activities if you give them your full attention and come to class having done the assigned reading. While I encourage – and sometimes will require – you to use the computers in the classroom, please do not let them become a distraction.

Grading Policy, Course Activities, and Assignments

Your course grade is designed to reflect the level of your problem solving skills and your demonstrated proficiency with the course material. As such, your course grade will be determined by your performances on problem sets, exams, and a final project assignment:

Activity	Number	Percentage of course grade
Problem sets	6	30%
In-class exams	2	25%
Take-home exams	2	25%
Final project	1	20%
Total		**100%**

Once your various grades are combined, the nominal ranges for your overall course grade will be:

A = 92-100%	A- = 88-91%	B+ = 84-87%	B = 80-83%
B- = 76-79%	C+ = 72-75%	C = 68-71%	C- = 64-67%
D+ = 60-63%	D = 56-59%	D- = 52-55%	F = 0-51%

These ranges may be adjusted down (but never up!) at my discretion.

Problem sets: There will be 6 (mostly computational) problem sets that both reinforce and expand on what we discuss during lectures. These problem sets provide an opportunity to apply your knowledge and gain valuable experience with R. All of the problem sets will be distributed via Moodle and should be uploaded there as well. *Late problem sets will not be accepted without my prior permission.*

In-class exams: There will be two in-class exams with a variety of question types that emphasize conceptual thinking based on the course content. *Make-up exams will be given only for absences with valid, documented excuses.*

Take-home exams: There will be two take-home exams paired with the in-class exams described above. These exams will emphasize R programming as it applies to mathematical modeling and data analysis (parameter estimation). *Late exams will not be accepted without my prior permission.*

Final project: An important aspect of this course is to become comfortable implementing and exploring the behavior of mathematical models. As a mini-capstone project, you will select a research article involving mathematical modeling, implement the authors' model(s), and replicate at least one key finding presented in that article. You will write a brief report and give a 15-20 minute oral presentation to the class about your project. [I will provide plenty of feedback along the way!] More details about this final project will be given as the semester progresses.

Getting Help

This is a challenging (and exciting!) upper-level course in mathematical biology and will likely require 7-10 hours per week of outside effort in addition to normal class hours. If you find that you need help:

(1) Please stop by to see me! I have multiple days/times (see page 1) for formal office hours, but you should feel free to stop by my office anytime. If my door is closed, I am away, busy, or in my group's computational lab (BIOS 167). If my office door (or the door in BIOS 167) is open, then I am available. You can also e-mail me with questions or to schedule a meeting ahead of time.

(2) Get in touch with your classmates. For those on the receiving end of such requests, helping someone else learn the material is without a doubt the best way to tell if you have mastered it yourself. You may find that by explaining the material to someone else also helps deepen your understanding of it.

University Policies

Student Handbook

Information on student rights and responsibilities, academic honesty, standards of conduct, etc., can be found online in the University Catalog (http://ecatalog.calstatela.edu) under Procedures and Regulations. Students are expected to abide by the University's Academic Honesty Policy, and those who violate this policy will be subject to disciplinary action, potentially receiving a failing grade in the course for a single violation. *Students are expected to do independent work on all exams and quizzes.* Collaboration with proper attribution is encouraged on lab assignments, but your write-ups should be done independently. Simply copying another student's work is (always) considered plagiarism.

Americans with Disabilities Act (ADA)

Reasonable accommodation will be provided to any student who is registered with the Office of Students with Disabilities (OSD) and requests needed accommodation. It is the responsibility of the student to initiate any request for accommodation in the course; OSD does *not* notify faculty unless the student requests it for that course. OSD can be reached in-person at the Administration Building (Room 127), on the web at http://web.calstatela.edu/univ/osd, or by phone at 323-343-3140.

Mental and Physical Health

With both academic and personal challenges, college can be stressful experience. Diminished mental and physical health, including significant stress, mood changes, excessive anxiety, or problems with eating or sleeping can interfere with academic performance. The source of symptoms may be strictly related to your coursework; if so, please speak with me. However, problems with relationships, family worries, loss, or a personal struggle or crisis can also contribute to decreased academic performance. Please remember that help is always available. Cal State LA provides resources for Counseling and Psychological Services (http://www.calstatela.edu/studenthealthcenter/caps) to support the academic success of students.

Course Schedule

Note: This schedule is *very* approximate and will likely evolve throughout the semester. Any changes to the schedule will be announced during lecture and posted online to Moodle; it is your responsibility to remain informed of any announced changes.

Week	Day/Date	Lecture Topic	Assignments
1	Tu – 8/21	Course introduction; the "why" of mathematical modeling	
	Th – 8/23	How to construct mathematical models	
2	Tu – 8/28	Single variable difference equations	
	Th – 8/30	Computational exploration: introduction to R	
3	Tu – 9/4	Linear differential equations of one variable	Problem Set 1 due in-class on 9/4
	Th – 9/6	Computational exploration: differential equations of one variable	
4	Tu – 9/11	Linear algebra review; systems of differential equations	
	Th – 9/13	Systems of differential equations (cont.)	
5	Tu – 9/18	Computational exploration: systems of differential equations	Problem Set 2 due in-class on 9/18
	Th – 9/20	Exploring model stability and behavior	
6	Tu – 9/25	Exploring model stability and behavior (cont.)	
	Th – 9/27	"Greatest hits" of mathematical models for biology	
7	Tu – 10/2	"Greatest hits" (cont.)	Problem Set 3 due in-class on 10/2
	Th – 10/4	"Greatest hits" (cont.)	
8	Tu – 10/9	**IN-CLASS EXAM #1**	**TAKE-HOME EXAM #1** due in-class on 10/11
	Th – 10/11	Introduction to parameter estimation and probability	
9	Tu – 10/16	Probability and calculus review	
	Th – 10/18	Common probability distributions	
10	Tu – 10/23	Maximum likelihood estimation	
	Th – 10/25	Maximum likelihood estimation (cont.)	
11	Tu – 10/30	EM algorithm	Problem Set 4 due in-class on 10/30
	Th – 11/1	EM algorithm (cont.)	
12	Tu – 11/6	Bayesian parameter estimation	
	Th – 11/8	Bayesian parameter estimation (cont.)	
13	Tu – 11/13	Bayesian parameter estimation (cont.)	Problem Set 5 due in-class on 11/13
	Th – 11/15	Bayesian parameter estimation (cont.)	
	Week incl. 11/20+22	***No lectures this week – Thanksgiving Break***	
14	Tu – 11/27	Model selection and hypothesis testing	Problem Set 6 due in-class on 11/27
	Th – 11/29	Model selection and hypothesis testing (cont.)	
15	Tu – 12/4	**IN-CLASS EXAM #2**	**TAKE-HOME EXAM #2** due in-class on 12/6
	Th – 12/6	Final project collaborative time	
16	Th – 12/13	**FINAL PROJECT PRESENTATIONS (12–2 pm in this room)**	