Biology 492/592 – Introductory Mathematical Biology
Fall, 2007

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Course Goals: we will devote ourselves to studying the theory and practice of mathematical biology, which can be defined as the application of mathematical theory and tools to modeling biological systems. Lectures will provide you with the mathematical skills required to utilize the mathematical biology literature, while in lab you will develop the MATLAB programming skills necessary to create programs with which you can analyze models from the research literature as well as run simulations with models you produce yourself.

Grading: grades will be based on homeworks (60%), paper discussions (10%), and presentation of the results of a small-group modeling project involving a topic of the students' choosing (30%).

Homeworks: most homeworks will be of the standard problem-solving variety, designed to develop your modeling skills and ensure that you know how to use the mathematical tools we'll be giving you in lecture and lab. However, in some cases you will write the code for a model presented in a paper from the mathematical biology research literature, and use your code to help you critically evaluate the paper. In any case, you should show your work, and when a question requires you to produce spreadsheets or MATLAB scripts, please submit those along with your solutions. You may work together with your classmates to solve the homework problems, but you must turn in your own independent version of the completed homework.

Paper discussions: We don't have time to spend discussing papers in lecture or lab, so we're going to use an alternative approach. I will divide the class into 3- or 4-person teams, and assign each team to be responsible for one of the papers in turn. Each person in the class will read the paper for him- or herself and submit to me and to the team that has been assigned responsibility for that particular paper the following:

- the assumption(s) – explicit and implicit – made by the author(s) in developing their model.
- two strong points of the paper.
- two weak points of the paper.
- a 'next step' – i.e., sensitivity analysis, the next feature that you feel should be added to the model, a new system to which the model might be applied, etc.

The responsible team will then use these lists as the basis for a two- or three-paragraph consensus summary of the paper that will be submitted to me. I will then make the summary available to all by posting it on the course web site. The grade for this will be based primarily on effort and completion. Expect a total of 6-8 papers over the course of the semester.

Small-group modeling project: For this, you will team with two or three of your classmates to research a topic of mutual interest, and use the results of your research as the basis for a model that you will develop and analyze using a program that you write in MATLAB (or other programming language, if you prefer) This project may be directly related to your dissertation or undergraduate honors research, but should not be a simple re-hash of something you're already done. Along with your computer code, you will submit a flow chart and pseudocode for your model. These will be made available to the other students in the course.

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Week	Lecture Topics	Lab Topics
1	Course introduction; review of calculus, including Taylor Series; introduction to modeling.	Introduction to MATLAB.
2	Modeling of biological systems.	Single-function plots in MATLAB.
3	Linear difference equation models – general solutions for linear homogeneous first- and second-order difference equations.	Subplots with MATLAB.
4	Linear difference equations – systems of linear difference equations; qualitative behavior of solutions;	Programming with MATLAB – program control; **if**, **for**, and **while** loops.
5	Leslie Matrix; the eigenvalue problem; the Perron-Frobenius theorem; delay difference equations and the Cheyne-Stokes model of respiratory control.	More program control; **if…else**, **switch** statements; multidimensional arrays; three-dimensional plotting with MATLAB.
6	Nonlinear difference equations – introduction; finding steady states.	MATLAB implementation of the discrete logistic equation; delay difference equations; functions in MATLAB.
7	Nonlinear difference equations – perturbation analysis; linearization & stability of steady states; Ricker plots.	More MATLAB programming with functions; calling a function from another program.
8	Systems of difference equations and population dynamics of two interacting populations – stability and sensitivity analysis; bifurcation theory.	Difference equations – Nicholson-Bailey model of host-parasitoid population dynamics; bifurcations, period-*n* solutions, limit cycles, attractors.
9	Continuous models – linear ordinary differential equations (ODEs); chemostat model, dimensional analysis, nondimensionalization.	Difference equations – Allee effect on population dynamics. **Fowler & Ruxton, 2002**
10	Continuous models – linear ODEs; direction fields, phase plots, stability analysis.	Introduction to scientific computing – Taylor series approximation of functions; rounding and truncation errors; numerical solution of ODEs.
11	Continuous models – systems of linear ODEs; stability analysis; the Jacobian.	Qualitative solution of ordinary differential equations, linear ODEs – **dfield7**.
12	Continuous models – nonlinear ODEs; the chemostat revisited – stability analysis of systems of nonlinear ODEs.	Qualitative solution of systems of linear ODEs – **pplane7**; predator-prey models.
13	Continuous models – nonlinear ODEs – phase planes, nullclines, steady states, and orbits; bifurcation theory; Lotka-Volterra predator-prey and competition models.	MATLAB's ODE solvers; stiff vs. non-stiff ODEs; delay differential equations.
14	Limit cycles in biological systems.	2D bifurcations – nonlinear ODEs I.
15	Student presentations.	2D bifurcations – nonlinear ODEs II.
16	Student presentations.	Catastrophe theory and spruce budworm population dynamics.