The Mathematics of Life
Biol 224H

SYLLABUS

Course goals:
This course enriches the foundational material from BIOL 201, 202 and 205 by studying classic applications of math to many of the same topics. By revealing the mathematical underpinnings of much of the material in the majors' core, this course will introduce students to quantitative approaches and research directions across Biology.

One of the goals is to make a mathematical approach to these topics as accessible as possible. To accomplish this, we will use a number of techniques to remove some of the anxiety that many students experience when dealing with mathematical problems. These include making the material accessible by approaching the mathematical formulations from intuitive biological principles, eliminating time constraints in problem solving as much as possible, working in groups, and encouraging lots of questions. No advanced mathematical knowledge is required beyond the first semester of calculus. The mathematical techniques we use will predominantly consist of algebra, but will also include some calculus, linear algebra and probability. There will be plenty of opportunities for refreshers and tutorials in class if you have forgotten or need an introduction to some of the mathematical techniques!

This course must be taken along with a corequisite lab, Biol 224HL

Credit hours:
3 lecture hours per week

Meeting time and place:
T, Th 9:30-10:45am
GSB 1377

Instructors:
Dr. Maria Servedio
Phone: 843-2692, Email: servedio@email.unc.edu, Office: GSB 2258
Office hours: In the 1st half of the semester, Wed 1-2 or by appointment; In the 2nd half of the semester: by appointment only.
Dr. Servedio has been studying questions in Behavioral Ecology and Evolution since she was an undergraduate (though she completed her undergraduate thesis in a functional morphology lab). In grad school she turned to mathematical models to study mate choice copying, speciation, and the evolution of warning coloration. Her work at UNC has focused on sexual selection and speciation, and the effects of learning on both of these processes.

Dr. Todd Vision
Phone: 962.4479, Email: tjv@bio.unc.edu, Office: GSB 3155
Office hours: In the 2nd half of the semester, Mon and Tue 2-3pm or by appointment. To ensure availability within regular office hours, book times at https://tjv.youcanbook.me/.

Dr. Vision dipped his toes into programming and statistics starting as an undergraduate doing research in plant ecology. He did his graduate work in quantitative and population genetics of natural plant populations and discovered while a postdoc at the beginning of the genomics era that he had inadvertently become a bioinformaticist (bioinformatician?). At UNC, he has developed data analysis methods for studying the evolution of genomes, phenotypes, and the genetic basis of complex traits.

Readings:
When readings relevant to specific topics are assigned, they will be posted to Sakai.

There is no required textbook, but we encourage you to consult the following book for reference: *Introduction to Mathematics for Life Scientists*, by Edward Batschelet (Springer, 3rd edition). If you wish to purchase a paper copy, new and used copies of the relatively inexpensive paperback "Study Edition" are available online from a variety of sources. UNC Libraries also provides online and PDF download access to an electronic copy.

The following non-required texts will be placed on reserve at the House Undergraduate Library (24 hour loan period).

- Alberts B *et al.* (2013) *Essential Cell Biology*, 4th ed. *Covers material in BIOL205.*
- Bergstrom CT, Dugatkin LA (2015) Evolution, 2nd ed. *Covers material in BIOL201*.
- Otto SP, Day T (2007) A Biologist's Guide to Mathematical Modeling in Ecology and Evolution. *Includes excellent primers on mathematical topics.*
- Sanders MF, Bowman JL (2015) Genetic Analysis: An Integrated Approach, 2nd ed. *Covers material in BIOL202.*

Grading:
The lecture and lab contain nine joint homework assignments in which the students will explore biological problems using mathematical and programming techniques. Each assignment includes both 1) a portion that addresses the biological interpretation of these exercises – how these procedures address the particular biological question of interest and how their results should be interpreted – as covered in the lecture portion of the class, and 2) the implementation of mathematical and programming exercises using Mathematica or Matlab, as covered in the lab. The grades from these portions count towards the lecture and lab respectively.

The projects, in which students address large scale, creative biological problems, are similarly broken into model development/interpretation portions (lecture) and coding implementation portions (lab).

9 lab/homework assignments - interpretation portion: 40%
2 Group projects - model development, presentation, and write-up: 60%

Final exam period:

As stated above, one goal in making this section accessible and removing math anxiety is removing stressful time constraints during problem solving, which a final exam would introduce. The second group project write-up will be submitted in lieu of a final exam.

Homework:
While in lab, you will be using Matlab or Mathematica to work on problems. Each problem with have a portion in which you explain the biological implications of your solutions. These portions of the homework assignments will count towards your Biol 224H lecture grade.

Course Policies:
Homework assignments must be turned in to Sakai by class time on Tuesdays and the key for each assignment will be posted at the same time. Homework turned in late, but before the key posted, will incur a 25% penalty on the final grade. Homework turned in after the key is posted, but before the final exam, will incur a 50% penalty on the final grade.

Students assign an initial grade to their own homework assignment using the key, and can correct any error (explaining the logic of the correction) to earn back up to half of the missed points, at the discretion of the instructor. The initial grading of each assignment by the student is due on Thursdays at the start of the next lab period. Graded files turned in after that will not be eligible to earn back points from corrections. Graded files that are turned in more than one week late (without prior permission) will receive a 50% penalty.

Honor code:
Students are encouraged to work together on homework assignments, but must submit independent write-ups. Students are not allowed to use keys for the homework assignments from previous years. Violations of this policy will have honor code consequences.

Projects:
There will be two group projects during the semester on topics of your choosing. Groups will consist of 2-3 students. Each group will submit a brief proposal for approval, and then have approximately one month to complete their project. The projects will be presented in-class, evaluated by one instructor with peer input, and each group will then submit their final write-up (see schedule below for specific due dates). The model development, presentation, and write-up portions of the group project will count towards the Biol 224H lecture grade.

Note:
The instructors reserve the right to make changes to this syllabus.

Schedule:

Week	Date	Activity	Reading
1	Thurs 1/10	Welcome	

		Basics of Biological Modeling Basics of Evolution	
2	Tues 1/15	Natural selection and Equilibria Discuss Orr 2009	Orr 2009
	Thurs 1/17	Natural selection and Stability Types of Models	
3	Tues 1/22	Mutation and Migration	
	Thurs 1/24	Natural selection at two loci Genotypes and allele frequencies	
4	Tues 1/29	Sexual selection Discuss Kirkpatrick 1982 *Group projects: Finalize groups*	Kirkpatrick 1982
	Thurs 1/31	Modeling exercise	
5	Tues 2/5	Types of models Quantitative Genetic Model example *Due: Group project abstracts (in class)*	Lande 1981
	Thurs 2/7	Project Workday 1 Finalize topic and build initial equations	
6	Tues 2/12	Natural and sexual selection Discuss Chunco et al 2007	Chunco et al. 2007
	Thurs 2/14	Probability trees Brood parasitism example	Servedio and Lande 2003
7	Tues 2/19	Stochasticity	
	Thurs 2/21	Host-parasitoid model	
8	Tues 2/26	Cultural evolution	Feldman and Laland 1986, Aoki 1984
	Thurs 2/28	Class Structure models Sea turtle exercise	
9	Tues 3/5	Deterministic chaos	May 1987
	Thurs 3/7	Synchronized oscillations	Strogatz & Stewart 1993
	Break		
10	Tues 3/19	Markov chains	Deonier et al. 2007 Ch. 2.6
	Thurs 3/21	Application: protein sequences	Krogh 1987
11	Tues 3/26	Pattern formation	Murray 1998
	Thurs 3/28	Application: lizard scales	Manukyan et al 2017
12	Tues 4/2	Agent-based models	Gelfand 2013
	Thurs 4/4	Application: cell division	
13	Tues 4/9	Flocking	Reynolds 1987

	Thurs 4/11	Project workday 3	
14	Tues 4/16	Randomness	Batschelet Ch 13
	Thurs 4/18	Application: the Luria-Delbruck experiment	Luria-Delbruck 1943
15	Tues 4/23	Scaling and allometry	Schmidt-Nielsen 1975
	Thurs 4/25	Application: a universal 3/4 rule?	West and Brown 2005
	Fri 5/3 8am	*Final papers due*	