MATH564: Mathematical Modeling in the Life Sciences

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Course Info

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This course is intended as a window into the burgeoning field of quantitative biology, a field that both finds new uses for traditional mathematical techniques (e.g., differential equations) and suggests novel approaches (e.g., machine learning). Through specific biological examples, the course will introduce a variety of mathematical modeling techniques and computational programming approaches as specified in the lesson plan below.

Course goals: Students will be exposed to mathematical modeling techniques commonly used in the life sciences, their implementation using a variety of software systems, and standard procedures for analysis and validation. A non-exhaustive list of the mathematical approaches includes: function approximation, differential and difference equations, combinatorics, stochastic calculus, algebraic-integro-differential systems, linear approximation, model reduction.

Title	**MATH564: Mathematical Modeling in the Life Sciences**
Times	TuTh 2:00-3:15PM, Phillips 385
Instructor	Sorin Mitran (mailto:mitran@unc.edu)
Office hours	MoWeFr 9:00-10:30AM and by e-mail appointment (mailto:mitran@unc.edu) , Chapman 451

Title	**MATH564: Mathematical Modeling in the Life Sciences**
Assistant	Carol Sadek (mailto:sadekcw@live.unc.edu)
Office hours	TBA

Honor Code:

- All work is individual. You may discuss various approaches to homework problems with students, instructors, but must draft your answers by yourself
- All exams are closed book

Grading

Required work

- Homework - best 10 of 12 assignments x 6 = 60 points
- Project - 2 phases x 10 = 20 points
- Midterm - 3 problems x 2 points = 6 points
- Final - 7 problems x 2 points = 14 points

Homework is posted every Friday, due the next Friday, and is designed such that each grade point requires 10 minutes to complete, once basic concepts have been understood. Late homework is not accepted. The homework schedule allows flexibility in individual time management by each student.

All homework is organized around practical applications that correspond to the structure of the textbook. Homework exercises are meant to be carried out in conjunction with active reading of the textbook material before further discussion of the material in class.

Students are asked to form research groups of 2-4 individuals for the purpose of drafting a project in mathematical modeling of a problem from the life sciences. Individual work within the project shold be evenly divided and clearly identified.

Examinations will test *understanding* of course concepts, as tested by problems that require insight rather than rote repetition of homework exercises.

Total weekly course effort is:

- 2.5 classroom hours
- 1.5 reading hours
- 1 homework hour
- 1 project hour

for a total of 6 hours per week.

Mapping of point scores to letter grades

Grade	Points	Grade	Points	Grade	Points	Grade	Points

Grade	Points	Grade	Points	Grade	Points	Grade	Points
A+	101-112	B+	86-90	C+	71-75	D+	56-60
A	96-100	B	81-85	C	66-70	D	50-55
A-	91-95	B-	76-80	C-	61-65	F	0-49

Note: Students can obtain a grade of B- (80 points) by correct solution of the homework problems and completion of a project. Higher undergraduate grades require *understanding* of the theoretical concepts of the course, as tested during the midterm and final examinations.

Course policies

- Course attendance is required
- Students are required to bring their CCI-compliant laptops to all classes
- Students are required to read posted lecture notes, sections from textbook, and complete exercises prior to class attendance. These assignments are posted at least one day in advance of class meeting time starting with Week 2.
- Late homework is not accepted.
- Homework is submitted in electronic form through Sakai. Submission by email is not accepted.

Bibliography

Course textbook: *Mathematical Biology: An Introduction with Maple and Matlab* by Ronald Shonkwiler and James Herod. The textbook is available in electronic form at no cost through the UNC library and is also distributed through the course svn site.

Lesson plan

[↑] (./courses/MATH564/#md-page-menu)
The following lecture notes are meant as a synopsis of class discussions. For more details consult the corresponding sections within the textbook. Reading assignments from the textbook are denoted in **bold face**, e.g., **2.1-8 pp.10-81** refers to pages 10 to 81 (inclusive) within subsections 2.1 to 2.8 of the textbook. Recommended exercises to understand the concepts within each lesson are denoted as *2.8.1*, referring to Exercise 1 in Section 2.8 of the textbook.

Remember: Except for the first week, you are expected to read the relevant textbook material before class and do the recommended exercises as a first exposure to the material, so that we can concentrate on solidifying understanding of the concepts in class discussion.

Note: Lesson links (Lesson##.tm, Lesson##.pdf) below become active at 12:00PM on the Monday of the week, and are always available. Depending on lesson content, *Mathematica* notebooks (Lesson##.nb) and class

notes (Notes##.pdf) may also appear, and are posted within a week of class discussion.

Week	Tuesday	Thursday
1		1/11 Class goals, Linear dependence and regression **2.1-3 pp. 1-25** Lesson01.pdf (./courses/MATH564/./lessons/Lesson01.pdf) Lesson01.tm (./courses/MATH564/./lessons/Lesson01.tm) Lesson01.nb (./courses/MATH564/./lessons/Lesson01.nb)
2	1/16 **2.4-6 pp. 36-57** Rates of change Lesson02.pdf (./courses/MATH564/./lessons/Lesson02.pdf) Lesson02.tm (./courses/MATH564/./lessons/Lesson02.tm) Lesson02.nb (./courses/MATH564/./lessons/Lesson02.nb)	1/18 **2.7-8 pp.58-78** Probability Lesson03.pdf (./courses/MATH564/./lessons/Lesson03.pdf) Lesson03.tm (./courses/MATH564/./lessons/Lesson03.tm)
3	1/23 **3.1-5 pp.85-105** Reproduction Lesson04.pdf (./courses/MATH564/./lessons/Lesson04.pdf) Lesson04.tm (./courses/MATH564/./lessons/Lesson04.tm) Lesson04.nb (./courses/MATH564/./lessons/Lesson04.nb)	1/25 Exponential model Lesson05.pdf (./courses/MATH564/./lessons/Lesson05.pdf) Lesson05.tm (./courses/MATH564/./lessons/Lesson05.tm) Lesson05.nb (./courses/MATH564/./lessons/Lesson05.nb)
4	1/30 **4.1-3 pp.107-127** Population growth Lesson06.pdf (./courses/MATH564/./lessons/Lesson06.pdf) Lesson06.tm (./courses/MATH564/./lessons/Lesson06.tm) Lesson06.nb (./courses/MATH564/./lessons/Lesson06.nb)	**4.4 pp. 128-135** 2/1 Multiple species Lesson07.pdf (./courses/MATH564/./lessons/Lesson07.pdf) Lesson07.tm (./courses/MATH564/./lessons/Lesson07.tm) Lesson07.nb (./courses/MATH564/./lessons/Lesson07.nb)
5	2/6 **5.1-3 pp.141-161** Aging Lesson08.pdf (./courses/MATH564/./lessons/Lesson08.pdf) Lesson08.tm (./courses/MATH564/./lessons/Lesson08.tm) Lesson08.nb (./courses/MATH564/./lessons/Lesson08.nb)	2/8 Exercises Lesson09.pdf (./courses/MATH564/./lessons/Lesson09.pdf) Lesson09.tm (./courses/MATH564/./lessons/Lesson09.tm) Lesson09.nb (./courses/MATH564/./lessons/Lesson09.nb)
6	2/13 **6.1-2 pp.163-184** Membranes & diffusion Lesson10.pdf (./courses/MATH564/./lessons/Lesson10.pdf) Lesson10.tm (./courses/MATH564/./lessons/Lesson10.tm) Lesson10.nb (./courses/MATH564/./lessons/Lesson10.nb)	2/15 **6.3-4 pp. 187-197** Transport Lesson11.pdf (./courses/MATH564/./lessons/Lesson11.pdf) Lesson11.tm (./courses/MATH564/./lessons/Lesson11.tm) Lesson11.nb (./courses/MATH564/./lessons/Lesson11.nb)

Week	Tuesday	Thursday
7	2/20 **7.1-4 pp. 201-213** Synapses Lesson12.pdf (./courses/MATH564/./lessons/Lesson12.pdf) Lesson12.tm (./courses/MATH564/./lessons/Lesson12.tm) Lesson12.nb (./courses/MATH564/./lessons/Lesson12.nb)	2/22 **7.5-6 pp. 214-227** Fitzhugh-Nagumo model Lesson10.pdf (./courses/MATH564/./lessons/Lesson13.pdf) Lesson13.tm (./courses/MATH564/./lessons/Lesson13.tm) Lesson13.nb (./courses/MATH564/./lessons/Lesson13.nb)
8	2/27 **8.1-3 pp. 229-258** Biomolecules Lesson14.pdf (./courses/MATH564/./lessons/Lesson14.pdf) Lesson14.tm (./courses/MATH564/./lessons/Lesson14.tm) Lesson14.nb (./courses/MATH564/./lessons/Lesson14.nb)	3/1 **8.4-8.6 pp. 229-280** Biochemistry Lesson15.pdf (./courses/MATH564/./lessons/Lesson15.pdf) Lesson15.tm (./courses/MATH564/./lessons/Lesson15.tm) Lesson15.nb (./courses/MATH564/./lessons/Lesson15.nb)
9	3/6 **9.1-11 pp.283-320** Biotransport Lesson16.pdf (./courses/MATH564/./lessons/Lesson16.pdf) Lesson16.tm (./courses/MATH564/./lessons/Lesson16.tm) Lesson16.nb (./courses/MATH564/./lessons/Lesson16.nb)	3/8 Midterm examination
10	3/20 **10.1-10.4 pp. 323-350** Infection Lesson17.pdf (./courses/MATH564/./lessons/Lesson17.pdf) Lesson17.tm (./courses/MATH564/./lessons/Lesson17.tm) Lesson17.nb (./courses/MATH564/./lessons/Lesson17.nb)	3/22 **10.5-10-6** Mutant infections Lesson18.pdf (./courses/MATH564/./lessons/Lesson18.pdf) Lesson18.tm (./courses/MATH564/./lessons/Lesson18.tm) Lesson18.nb (./courses/MATH564/./lessons/Lesson18.nb)
11	3/27 **11.1-4 pp.371-397** Parasites Lesson19.pdf (./courses/MATH564/./lessons/Lesson19.pdf) Lesson19.tm (./courses/MATH564/./lessons/Lesson10.tm) Lesson19.nb (./courses/MATH564/./lessons/Lesson19.nb)	3/29 **12.1-6 pp.399-415** Cancer Lesson20.pdf (./courses/MATH564/./lessons/Lesson20.pdf) Lesson20.tm (./courses/MATH564/./lessons/Lesson20.tm) Lesson20.nb (./courses/MATH564/./lessons/Lesson20.nb)
12	4/3 **13.1-4 pp.419-439** Genetics Lesson21.pdf (./courses/MATH564/./lessons/Lesson21.pdf) Lesson21.tm (./courses/MATH564/./lessons/Lesson21.tm) Lesson21.nb (./courses/MATH564/./lessons/Lesson21.nb)	4/5 **13.5-7 pp. 440-458** Mutations Lesson22.pdf (./courses/MATH564/./lessons/Lesson22.pdf) Lesson22.tm (./courses/MATH564/./lessons/Lesson22.tm) Lesson22.nb (./courses/MATH564/./lessons/Lesson22.nb)
13	4/10 **14.1-4 pp.461-470** Genomics Lesson23.pdf (./courses/MATH564/./lessons/Lesson23.pdf) Lesson23.tm (./courses/MATH564/./lessons/Lesson23.tm) Lesson23.nb (./courses/MATH564/./lessons/Lesson23.nb)	4/12 **14.5-7 pp. 471-495** BLAST Lesson24.pdf (./courses/MATH564/./lessons/Lesson24.pdf) Lesson24.tm (./courses/MATH564/./lessons/Lesson24.tm) Lesson24.nb (./courses/MATH564/./lessons/Lesson24.nb)

Week	Tuesday	Thursday
14	4/17 **15.1-3 pp.497-519** Phylogeny Lesson25.pdf (./courses/MATH564/./lessons/Lesson25.pdf) Lesson25.tm (./courses/MATH564/./lessons/Lesson25.tm) Lesson25.nb (./courses/MATH564/./lessons/Lesson25.nb)	4/19 **15.4-6 pp. 497-537** Phyogenetic trees Lesson26.pdf (./courses/MATH564/./lessons/Lesson26.pdf) Lesson26.tm (./courses/MATH564/./lessons/Lesson26.tm) Lesson26.nb (./courses/MATH564/./lessons/Lesson26.nb)
15	4/20 Project presentations	4/26 Project presentations

Homework

[↑] (./courses/MATH564/#md-page-menu)

Homework should be started within 24 hours of it being posted. You should attempt upload of your completed assignment well ahead of the deadline, preferably to allow enough time for office hours consultation. The submission deadline and electronic submission procedure of typeset homework are strictly enforced.

Nr.	Issue Date	Due Date	Topic	Problems	Solutions
0	1/19	1/23	Basic mathematical techniques	Homework00.pdf (./courses/MATH564/./homework/Homework00.pdf) Homework00.tm (./courses/MATH564/./homework/Homework00.tm)	
1	1/19	1/26	Reproduction	Homework01.pdf (./courses/MATH564/./homework/Homework01.pdf) Homework01.tm (./courses/MATH564/./homework/Homework01.tm)	
2	1/26	2/2	Environment		
3	2/2	2/9	Aging Populations		
4	2/9	2/16	Random movement		
5	2/16	2/23	Neurophysiology		
6	2/23	3/2	Biochemistry		
7	3/2	3/9	Transport		
8	3/9	3/23	Infection		
9	3/23	3/30	Cancer		
10	3/30	4/6	Genetics		

Nr.	Issue Date	Due Date	Topic	Problems	Solutions
11	4/6	4/13	Genomics		
12	4/13	4/20	Phylogenetics		

Examinations

[↑] (./courses/MATH564/#md-page-menu)

- Midterm examination: 2:00-3:15 PM, Th. Mar. 8
- Final examination: 12:00-3:00 PM, Mo. May 7

Course materials

[↑] (./courses/MATH564/#md-page-menu)

Software

Mathematical insight into life science phenomena usually results from computer implementation of the relevant models. Hence, a basic familiarity with current software systems is gradually built up during the course. The recommended option is to install Virtual Box (https://www.virtualbox.org/wiki/Downloads) and the SciComp@UNC (http://scicomp.web.unc.edu/) Linux environment.

An alternative that requires less disk usage is to install TeXmacs (http://www.texmacs.org/tmweb/download/windows.en.html) and use Octave-online (http://octave-online.net/)

Course examples will mostly use the SciComp@UNC environment.

TeXmacs and Octave

- TeXmacs is a freely available editor with excellent support for mathematical editing. Under OS/X and Linux TeXmacs supports interspersing computation and text editing
- Octave is a freely available system oriented towards linear algebra computations. The language is almost identical to the commercial Matlab system. Octave may be installed locally (https://www.gnu.org/software/octave/download.html), or used online (http://octave-online.net/), and there are many tutorials available online, e.g. on YouTube (https://www.youtube.com/watch?v=X0xLTKRWPgo).

SciComp@UNC Linux environment

Scientific computation is typically carried out in a Un*x environment (e.g. OS/X, various Linux versions). This course uses a customized Linux environment named SciComp@UNC that is installed as a virtual machine on your laptop (assumed to satisfy UNC laptop requirements (http://cci.unc.edu/new-students/minimum-laptop-requirement/). See SciComp@UNC (http://scicomp.web.unc.edu/scicompunc-virtual-machine/).

Here are some basic operations we carry out within the environment:

- Navigating to Homework 1 (https://www.youtube.com/watch?v=t3kx4u3y7i4)

- Basic editing within Homework 1 (https://www.youtube.com/watch?v=5VYFhbK_TiM)

Lecture notes, homework texts and solutions

Course materials (lecture notes, homework, quizzes) are distributed through the subversion utility, available on all major operating systems. In the SciComp@UNC Linux environment the following will check out an initial copy of course materials:

- mkdir ~/courses
- cd ~/courses
- svn co svn://mitran-lab.amath.unc.edu/courses

Under Windows use Tortoise SVN (https://tortoisesvn.net/downloads.html) or SmartSVN (http://www.smartsvn.com/). Under OS/X use [SmartSVN](http://www.smartsvn.com/} (http://www.smartsvn.com/}). Refer to the particular product for instructions on how to carry out the initial checkout of course materials.

In SciComp@UNC Linux you update the course materials before each lecture by:

- cd ~/courses/MATH547
- svn update

Similar procedures exist for svn under Windows or OS/X.