

Biology 226: Mathematical Methods for Quantitative Biology Syllabus
TuTh – 4:45PM – 6:00PM via Zoom

Credit Hours: 3. This will be a 3 hour credit course with 3 hours of lecture each week.

Instructor:

Brian K. Taylor

Assistant Professor of Biology

Email: brian.taylor@unc.edu

Website: <http://taylorlab.web.unc.edu/>

Course Website: https://sakai.unc.edu/portal/site/biol226_fall_2020

Office: Coker Building – Room 301

Office Hours: Tuesday/Thursday – 1:30PM – 3:00PM, and by appointment, all through Zoom

Teaching Assistant:

Juan Shi

Graduate Student: Department of Mathematics

Email: juans@live.unc.edu

Office Hours: Wednesdays – 1:30PM – 2:30PM, and by appointment, all through Zoom

Target Audience: Biology majors who are interested in quantitative biology, mathematical modeling, and computer simulation. Mathematics, physics, chemistry, and computer science majors who are interested in biological applications of mathematics.

Course Prerequisites: One of MATH 231/283 and one of BIO 201/202, or equivalents

Course Goals and Key Learning Objectives:

- Write down mathematical models to describe molecular, cellular, and organismal processes.
- Solve the mathematical models numerically or analytically and evaluate them against experimental data.
- Become proficient in the use of MATLAB for biological applications, both in terms of writing programs and using software packages.

Course Requirements:

Students will be expected to review assigned readings from the course packet, lecture notes, and other materials posted on webassign before each class. Comprehension of the material covered in lectures will be evaluated from in-class assignments and homeworks that will involve writing down mathematical models, solving them numerically or analytically, and evaluating them against experimental data. Two midterms and a final exam will also be used to evaluate comprehension and will be based upon material in the homework assignments.

Grades: Graded work will consist of in-class activities to be turned in over webassign (5%), weekly Matlab computing assignments (10%), weekly homework assignments (10%), two midterms (20% each), and a final exam (35%). The weekly and in class assignments are designed to be short assignments to keep you on track. MATLAB computing assignments will be applications relevant to medicine and the life sciences. Lectures and written homework will also cover a range of applications relevant to the medicine and the life sciences.

Help/Camaraderie: While all submitted work must ultimately be your own, I want to encourage you to help each other, and ask each other questions on assignments. This course should be a community where we all help to increase each other's comprehension and understanding of the material, and just plain have fun! Therefore, if you agree with a classmate to help and/or receive help on a particular assignment via webassign, that exchange will be recorded. At the end of the semester, I will take the total number of times you received/gave help, compare that to the number of times possible (i.e., assignments given), and convert that to a maximum of 2 percentage points that will be added to your grade after the final grade has

Syllabus Changes: The professor reserves the right to make changes to the syllabus, including project due dates and test dates. These changes will be announced as early as possible.

Biology 226: Mathematical Methods for Quantitative Biology Syllabus
TuTh – 4:45PM – 6:00PM via Zoom

been computed. **To get credit, you must both separately indicate the party that provided help, and the party that received it. If one party states that they gave/received help and the other does not, neither gets the extra credit for that assignment.**

Assignment Redos: If you don't like your grade on an assignment, if you **come and talk to me about what you did wrong**, you may resubmit a corrected version of the assignment **within one week of when the grade is posted**. If you do this, and the assignment is correct (i.e., flawless), you will be given back half of the points that you lost **up to an 85%**. For example, if you get a 50/100 on an assignment, talk to me about it to understand what you did wrong, and resubmit something perfect, you will get back 25 points, so you now have a 75/100. **THIS DOES NOT APPLY TO EXAMS**

Course Policies:

Late Homework Policy: 10% will be deducted the first hour the assignment is late, and then 20% will be deducted each day unless the student can provide a written excuse with documentation for valid reasons (illness, family emergency, religious observance, university sponsored travel, etc.) A student should present his or her explanation for any absences in writing in advance if the reason for the absence could be foreseen, or within 5 days of the due date of the assignment if the reason could not be foreseen. The lowest Matlab, weekly homework, and in-class activity scores will be replaced with the score to compensate for late or missed homeworks without a university approved excuse.

Makeup Exam Policy: Make up exams will only be provided for documented and valid reasons (illness, family emergency, religious observance, university sponsored travel, etc.) As before, a student should present his or her explanation for any absences in writing in advance if the reason for the absence could be foreseen, or within 5 days of the exam if the reason could not be foreseen. If an exam is missed for any other reason, no makeup will be given and the final exam will be counted for 55% of the grade.

Honor Code Statement: "It is expected that each student will conduct him or herself within the guidelines of the Honor System. All academic work should be done with the highest level of honesty and integrity that this University demands." In particular, all tests and quizzes should be taken without texts without consultation with other student's work, except as indicated. Students are encouraged to work together on all homework assignments.

Calculators: Hand-held calculators and computers may be used in all work including examinations; however cell phones may not be used as calculators.

Final Exam: The course final exam is given in compliance with UNC final exam regulations and according to the UNC Final Exam calendar.

Attendance: Attendance will not be figured into your grade directly. However, attending class, either live as the lectures are done, or asynchronously on your own time, is highly recommended *as there may be things that are stated in class that are not posted* (e.g., concepts around the lecture material). For me to write every single thing out, I think I would have to write something 100x longer than War and Peace (~1,200 pages), and I'm sure that none of you want to read that. You will be responsible for any in-class activities that may be assigned during your absence. While attendance will not be taken, I DO monitor who comes to class on a regular basis. Unless you contact me and work something out prior, exams **MUST BE TAKEN UNDER THE SPECIFIED RULES**. If you can't make it to class, or have circumstances that are preventing you from attending synchronously or asynchronously, let me know and let's talk about it – I might be able to help!

Contact with Dr. Taylor: I STRONGLY encourage you to use my office hours, e-mail me, and talk to me about the class, career advice, or things in life that are affecting your ability to perform in the class. It

Syllabus Changes: The professor reserves to right to make changes to the syllabus, including project due dates and test dates. These changes will be announced as early as possible.

Biology 226: Mathematical Methods for Quantitative Biology Syllabus
TuTh – 4:45PM – 6:00PM via Zoom

will help you do better in the class, maybe help you figure out future plans, help smooth out life, and I just like to hear and learn (yes, learn) from all of you! I think that this IS ESPECIALLY TRUE DURING THE PANDEMIC. That being said, this class is not my only responsibility. Just as you all have other classes to balance on top of your personal lives, I have other personal and professional responsibilities to balance. While I want to be available and responsive to you, I cannot be available all the time. If you have a question about something, I ENCOURAGE you to ask. However, if you e-mail me after 7:00PM, you may not receive a response until the following day. Please keep this in mind, especially if you are sending an e-mail about an assignment the night before it is due.

Code: If asked to turn in or submit code, ASSUME THAT I WILL PUT IT IN MATLAB AND RUN IT! If your code does not run, but you acknowledge this along with what might be wrong in your writeup, partial credit will be given. If your code does not run, and you make no acknowledgement that your code does not run, the question under consideration WILL RECEIVE ZERO CREDIT. Bottom line: Make sure your code works, or acknowledge that it doesn't, and why you think it might be broken. Making mistakes is OK! But, we have to acknowledge them.

Course Resources:

Suggested Text: F.C. Hoppensteadt and C.S. Peskin. Modeling and Simulation in Medicine and the Life Sciences. Second Edition, New York: Springer-Verlag, 2002.

Sakai Resources: Supplemental reading, lecture notes, and problem sets will be posted to www.unc.edu/sakai throughout the semester.

MATLAB: Instructions for obtaining Matlab

1) Go to the following website and scroll down to the Matlab link:

<http://software.sites.unc.edu/software/>

Select “Get Software” under Matlab. Select “Student Ordering” and login using your Onyen,

If you return to <http://software.sites.unc.edu/software/>, and select the Matlab link, you will find the installation instructions. Note that you will need the Activation key available on this website to install Matlab.

2) Another way to do this is to go to the Mathworks site:

<http://www.mathworks.com/products/matlab/tryit.html>

Select “Download licensed products,” and then select the “create an account” link to create a mathworks account. Once you have this, login on the Mathworks site. You can then download the most recent version of Matlab to your computer over the internet. You will need the Activation key on the <http://software.sites.unc.edu/software/> site listed above.

Webassign: Homework will be assigned and submitted through webassign. Please create an account using your onyen as the username at <http://www.webassign.net>.

<u>Instructor</u>	<u>Section</u>	<u>Class Key</u>
Brian K. Taylor	BIOL 226	unc 0293 4814

Grading Scale: A letter grade will be based on the following APPROXIMATE scale: A= 95-100%, A- = 90-94%, B+ = 86-90%, B = 81-85%, B- = 80-81%, C+= 78-80%, C = 71-77%, D= 60-70%, F= less than 60%.

Syllabus Changes: The professor reserves to right to make changes to the syllabus, including project due dates and test dates. These changes will be announced as early as possible.

Biology 226: Mathematical Methods for Quantitative Biology Syllabus
TuTh – 4:45PM – 6:00PM via Zoom

Calendar: A calendar with all due dates is being maintained on weassign and Sakai. The important dates are as follows. Changes to these dates will be announced as soon as possible.

Midterm 1: Thursday: September 17 (tentative)
Midterm 2: Tuesday: October 22 (tentative)
Final: TBA (Wasn't listed when I wrote this!)

Time Table:

I. Weeks 1-2: Introduction to Mathematical Modeling, Markov Processes, and Random Walks

- A. Introduction to Mathematical Modeling
- B. Random walks
- C. Markov processes
 - i. Markov matrices
 - ii. Steady states
- D. Applications
 - i. Markov vs. Markov case study
 - ii. Movement of insects
 - iii. Brownian motion

II. Weeks 3-4: Diffusive Processes

- A. Deriving the diffusion/heat equation from random walk of molecules.
- B. The process of diffusion
 - i. Diffusion across a membrane
 - ii. Diffusion of a drop on a substrate
 - iii. Modeling organism movement as a diffusive process

III. Weeks 5-6: Robotics and its Applications to Medicine and Biomechanics

- A. Uses of Robotics in Medicine and Biomechanics
- B. Representations of a point in multiple coordinate systems - Kinematics

IV. Weeks 7-9: Regulatory networks

(from Tyson et al. Sniffers, buzzers, toggles and blinkers: dynamics of regulatory and signaling pathways in the cell. *Current Opinion in Cell Biology* 2003, 15:221–231)

- A. Models of protein synthesis and degradation
 - 1. Linear signal-response curves
 - 2. Hyperbolic signal-response curves
- B. Feedback models
 - 1. Positive feedback and irreversible switches
 - 2. Negative feedback: homeostasis and oscillations
- C. Complex networks
 - 1. Cell control cycle

V. Weeks 10-11: Electrical Properties of Cell Membranes

- A. Osmotic Pressure
- B. The movement of ions across membranes
- C. Interaction of Electrical and Osmotic Effects
- D. The Hodgkin Huxley equations
 - 1. Computer simulations of action potentials
- E. The Fitz-Hugh Nagumo equations

Syllabus Changes: The professor reserves the right to make changes to the syllabus, including project due dates and test dates. These changes will be announced as early as possible.

Biology 226: Mathematical Methods for Quantitative Biology Syllabus
TuTh – 4:45PM – 6:00PM via Zoom

VI. Week 12: Reaction Diffusion Processes

- A. Fitz-Hugh Nagumo equations with space
- B. Reaction Diffusion equations and pattern formation

VII. Weeks 13-14: Muscle Mechanics (Hoppensteadt and Peskin, Chapter 5)

- A. Length-Tension relationship
- B. The Force-Velocity Curve
- C. A microscale model of crossbridge attachment
 - 1. Computer simulation of attachment and detachment.

Other topics that may be covered as time permits

Genetic Algorithms

- A. Introduction to evolutionary algorithms and biomorphs
- B. Genetic algorithms
 - 1. Mathematical representations of mutation and crossover
 - 2. Fitness functions
 - 3. Simulating evolution

Noisy Regulatory Networks (D. T. Gillespie. Exact Stochastic Simulation of Coupled Chemical Reactions. The Journal of Physical Chemistry, Vol. 81, No. 25, 1977.)

- A. Stochastic Formulation of Biochemical Kinetics
- B. Examples
 - 1. Radioactive decay
 - 2. Coupled reactions
 - 3. The Lotka Reactions
- C. Computer simulations

Syllabus Changes: The professor reserves the right to make changes to the syllabus, including project due dates and test dates. These changes will be announced as early as possible.