**Biology 226: Mathematical Methods for Quantitative Biology** **Syllabus**

**TuTh – 3:30PM – 4:45PM in Stone Center 0210**

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:

Office: Coker Building – Room 301A

Office Hours: Tuesday/Thursday 1:00 PM – 2:30 PM

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

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.

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. Therefore, if you agree with a classmate to help and/or receive help on a particular assignment via webassign, that exchange will be recorded. To get credit, you must both separately indicate the party that provided help, and the party that received it. 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 been computed.

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. 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:* Sign-in sheets will be circulated during each class, but attendance will not be figured into your grade directly. However, attending class is highly recommended. You will be responsible for any in-class activities that may be assigned during your absence.

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](http://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>.

**Instructor Section Class Key**

**Brian K. Taylor BIOL 226, section 001 unc 9974 3469**

*Calendar:* A calendar with all due dates is being maintained on webassign. The important dates are as follows:

Midterm 1: Thursday, 2/19/19

Midterm 2: Thursday, 3/28/19

Final: Tuesday, April 30, 4PM – 7PM

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: 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

III. Weeks 5-6: 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

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

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.

VIII. Weeks 15: Noisy Regulatory Networks (D. T. Gillespie. Exact Stochastic Simulation of Coupled Chemical Reactions. The Journal of Physical Chemistry, Vol. 8 1, No. 25, 1977.

A. Stochastic Formulation of Biochemical Kinetics

B. Examples

1. Radioactive decay

2. Couple reactions

3. The Lotka Reactions

C. Computer simulations

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.