Biology 590: Introduction to Computational Neuroscience
Tuesday/Thursday 3:30PM – 4:45PM Stone Center – Room 209

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/x/rwctj2
Office: Coker Building – Room 301A
Office Hours: Tuesday/Thursday 1:30 PM – 3:00 PM, Wednesday 1:00 PM – 3:00 PM, By appointment

Description: This course covers various mathematical tools and techniques for modeling the various elements and phenomena that comprise the nervous system and brain (e.g., how does one simulate a single neuron vs. population of neurons firing).

Target Audience: Biology, Quantitative Biology, and Neuroscience majors who are interested in how quantitative biology and mathematical approaches are used to understand the nervous system and advance the frontier of neuroscience. Mathematics, Physics, Chemistry, Computer Science, and all other majors who are interested in biological applications of mathematics and computing. Biomedical Engineering and Applied Physical Sciences majors who want to learn about computational approaches to understanding the nervous system for applications such as device development.

Course Prerequisites: One of MATH 231/283 and one of BIO 201/202, and one of BIOL 226, COMP 116, or instructor permission regarding programming abilities. You should have experience with AND feel comfortable working with and solving problems using computer code.

Course Goals and Key Learning Objectives:

- Broadly understand what computational neuroscience is, and why and how it is used in different disciplines
- Write down, implement, and explain mathematical models of neuronal processes.
- Solve the mathematical models numerically or analytically
- Become proficient in the use of computing and mathematics (particularly using MATLAB and other tools) for problem solving, and modeling

Course Philosophy:
There is way too much information in this field to cover all of computational neuroscience in a single class. In addition, there are multiple ways that the material could be approached, and using a given approach will likely cover some important things, but leave out others. My goal is to give you an understanding of basic neural mechanics, dynamical systems, and the application of dynamical systems to modeling neural mechanics. By doing this, you should leave this class with a foundation that you can use to pursue and understand future studies.

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

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.

Grades: Graded work will consist of assignments (10%), two midterms (30% each), and a final exam (30%). Unless otherwise stated, exams are closed book/closed notes. Assignments and in class activities are designed to help you practice the concepts covered in class, and are meant to be challenging, but not onerous or burdensome. A key will be posted for all assignments, but *only a fraction of each assignment will be graded.* Therefore, it is strongly encouraged that you put forth a full effort on all problems. The exams will pull heavily from the assignments, and the assignments are meant to convey the concepts and skills that are important to have, so it is in your best interest to do the assignments, as this could make things much easier on the exams.

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. Therefore, if you agree with a classmate to help and/or receive help on a particular assignment, 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 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 will recieve the extra credit for that assignment.*

Assignment Redos: If you don't like your grade on an assignment, and 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, perfect, nothing wrong), 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. The time requirement is strictly enforced. *THIS DOES NOT APPLY TO EXAMS*

Course Policies:
Late Assignment Policy: Assignments given online *are due at the posted deadline.* Assignments due in class *are due within the first 5 minutes of the class period. Late assignments will not be accepted* unless the student can provide a written excuse with documentation for valid reasons/extenuating circumstances (illness, family emergency, religious observance, university sponsored travel, etc.). EXTENSIONS WILL NOT BE GIVEN without extenuating circumstances. A student should present his or her explanation for any absences in writing *no later than 24 hours* in advance of the assignment due date if the reason for the absence could be foreseen. The explanation should be presented within 5 days of the due date of the assignment if the reason could not be foreseen. Additionally, the lowest assignment score will be dropped, effectively providing one "freebie" assignment that can be missed without penalty.

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 60% 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.

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Calculators: Hand-held calculators and computers may be used to assist you in computations, and showing your work. 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 is highly recommended *as there may be things that are stated in class that are not posted* (e.g., class cancellations, concepts around the lecture material). 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 IN CLASS. IF YOU DO NOT SHOW UP FOR AN EXAM, AND YOU HAVE NOT CONTACTED ME REGARDING THE ABSENSE, ZERO POINTS WILL BE ASSIGNED FOR THE EXAM.*

Contact with Dr. Taylor: I STRONGLY encourage you to use my office hours, e-mail me, and come talk to me about the class, career advice, or things in life that are affecting your ability to perform in the class. It will help you do better in the class, figure out future plans, and smooth out life. Also, I just like to hear and learn (yes, learn) from all of you! 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 after 7:00PM or over the weekend, 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 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:
This course loosely follows the following suggested texts:

- Trappenberg, T. P. (2010). Fundamentals of Computational Neuroscience. New York, Oxford University Press.
- Izhikevich, E.M. (2007). Dynamical Systems in Neuroscience. Cambridge, MIT Press
- Wilson, H. (1999). Spikes, Decisions and Actions: The Dynamical Foundations of Neuroscience, Oxford University Press. (Freely available online at http://cvr.yorku.ca/webpages/wilson.htm)
- Additional posted readings

If you happen to find another text that is useful for you, please let me know. It may end up getting integrated into the course in this year or another year!

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/

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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.

MATLAB/CODING NOTE: If there is another language you are more familiar with (e.g., python), you are more than welcome to use that. However, if you use another language, it may be harder for me to help you if you run into problems as I may not have facility or familiarity with the nuts and bolts of your language. I can help with overall things like loop concepts and flow control, but I may not know the specific syntax of your language.

Grading Scale: A letter grade will be based on the following APPROXIMATE scale: A= 90-100%, B= 80-90%, C= 70-80%, D= 60-70%, F= less than 60%. Plus/minus may be employed for students who are on the border of a grade change

Calendar: A calendar with all due dates and assignments is being maintained on Sakai. Computer assignments should be submitted on SAKAI. Hand assignments should be submitted in class. The important dates are as follows:

Midterm 1:	February 20 (TENTATIVE)
Midterm 2:	March 26 (TENTATIVE)
Final:	Tuesday, April 28, 2020 (HARD DEADLINE)

Course Topics and Approximate Time Table:

I. Course mechanics and philosophy (Week 1)
II. Introductory Neuroscience (Weeks 2-3)
    a. Why computational neuroscience?
    b. Firing an action potential
    c. Basic models/Overview
        i. Deriving the Hodgkin Huxley Equations
III. Mathematical Background Based on Neural Applications and Examples (Weeks 4-8)
    a. Mathematical Primer
    b. Differential Equations and Dynamical Systems
        i. One dimension
        ii. Two + dimensions
    c. Stability
    d. Phase Portraits
    e. Bifurcations/Types
    f. Numerical Techniques
        i. Euler’s Method
        ii. Runge Kutta*

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iii. MATLAB ODE solvers

IV. Types of models (Weeks 9-11)
   a. Single Cell Models
   b. Population Models

V. Artificial Neural Networks/Machine Learning (11-14)

VI. Associators & Synaptic Plasticity*

VII. Cortical Organization*

VIII. Cortical Feature Maps & Competitive Population Coding*

IX. Recurrent Associative Networks & Episodic Memory*

X. Modular Networks, Motor Control, Reinforcement Learning*

XI. The Cognitive Brain*

*Topics will be covered based on course progress

Student Support

Counseling and Psychological Services: CAPS is strongly committed to addressing the mental health needs of a diverse student body through timely access to consultation and connection to clinically appropriate services, whether for short or long-term needs. Go to their website: https://caps.unc.edu or visit their facilities on the third floor of the Campus Health Services building for a walk-in evaluation to learn more."

Accessibility Resources & Service: UNC-Chapel Hill facilitates the implementation of reasonable accommodations for students with learning disabilities, physical disabilities, mental health struggles, chronic medical conditions, temporary disability, or pregnancy complications, all of which can impair student success. See the ARS website for contact and registration information: https://ars.unc.edu/about-ars/contact-us "

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