Fundamentals in computational neuroscience models (NSBV BC 2xxx)

Office hours: Tuesday 2-4pm (or by appointment), Office: TBD, phone: TBD, email: ggutierr@barnard.edu

Prerequisites: NSBV BC1001 Introduction to Neuroscience, OR Introduction to Cellular and Molecular Biology (BIO BC 1502), OR permission of instructor.

Course description: Computational neuroscience is an exciting, constantly evolving subfield in neuroscience that brings together theories and ideas from many different areas in STEM such as physics, chemistry, math, computer science, and psychology. Through the exploration of computational models of neuronal and neural network activity, students will be introduced to a handful of quantitative STEM concepts that intersect with neuroscience. Before beginning this course students are expected to know about the action potential and synaptic transmission (see prerequisites). In this course, we will connect those neurobiological phenomena to quantitative STEM concepts and then to computational models in Matlab.
This course is designed for students who want to take their first steps towards mathematical and computational models of the brain. Students interested in the computational track for the Neuroscience major should consider taking this course.

Course Objectives: Students will learn about and work with several of the foundational computational neuroscience models relating to single neuron and neural network activity that underlie behavior. Students will be exposed to the mathematical and scientific principles behind those models, and will develop the confidence to pursue a deeper exploration of those topics. Specifically, students will learn to:

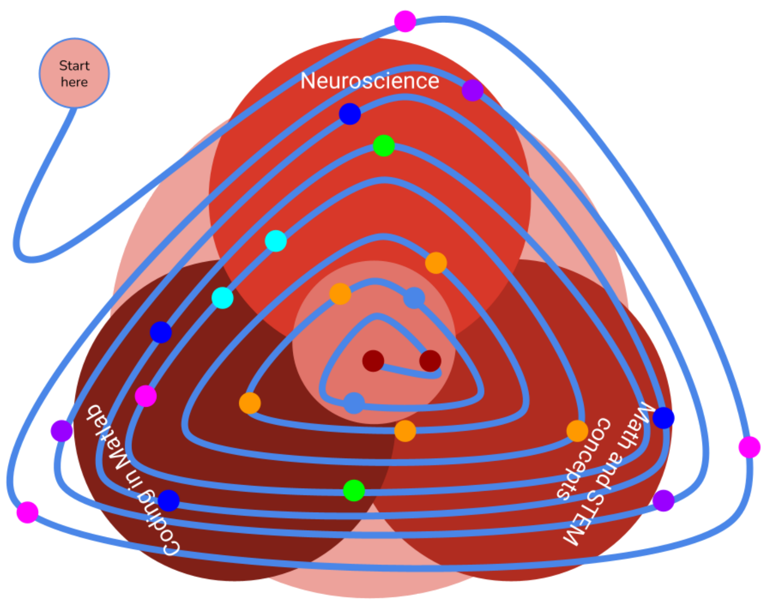
- Make connections from the action potential and synaptic transmission to quantitative/fundamental theories from other STEM disciplines (physics, chemistry, neuroscience, biology, computer science, psychology, etc).
- Identify the scope of a neuroscience model and determine what it can and cannot tell us.
- Compare models and select an appropriate model for a given scientific question from among the models covered in this course.

- Implement computational neuroscience models of neurons and neural networks using Matlab.

Grading:

Grade type	**Percent of final grade**
Exam (after background module to test understanding of concepts)	30%
Quizzes and HW/prob set (These will consist of 1-2 questions and will be given at the start of lecture to provide accountability for having done the reading and come to class prepared and to prime students for the lecture. No make-ups allowed.)	10%
Project (build your own conductance-based neuron model)	30%
Final Exam (similar format to first exam but will test core concepts outlined in learning outcomes. The exam questions will echo the quiz questions somewhat.)	30%

Course Organization: (graphic syllabus)



Schedule by week:

Week	topic	description	readings/hw
1	Course overview	Birds-eye view of comp neuro models and the subset we will explore in this course.	read syllabus and textbook sections 1.1, 1.2
	Neuroscience review	review action potential and synaptic transmission	textbook sections 1.1, 1.2
2	Pocket calculus I	introduce differential equations and what they show us.	Textbook sections 1.4
	Pocket calculus II	tricks for how to “dissect” any equation.	write/draw reflection on a concept covered today and what math stories/devices you’ve made for yourself to

			understand it, textbook section 1.5
3	Matlab basics I	Tutorial work sessions covering some coding principles	tutorial Matlab practice
	Matlab basics II	Tutorial work sessions covering some coding principles	Tutorial practice
4	Spikes	Lecture about what is encoded in spiking activity in neurons	Textbook section 1.3
	E&M principles of closed circuit	Ohm’s law	textbook section 1.3, 2.1-2.3
5	leaky integrate-and-fire neuron	Basic model of spiking neuron	textbook section 1.4
	leaky integrate-and-fire neuron (continued)	Basic model of spiking neuron	textbook section 1.6 and 7.1-2
6	Exam day		
	Hodgkin-Huxley model	Introduction to neuroscientific discoveries to led to HH model	textbook section 4.1
7	Hodgkin-Huxley model	Exploring the dynamics of the steady state HH equations without code	textbook section 1.6
	Hodgkin-Huxley model	Working with the code for the steady state HH model	textbook section 4.2 up to 4.2.3
8	Hodgkin-Huxley model	Another day of working with HH	Conductances worksheet (provided)

		model code. This time we add in the gating variables	
	STG circuit	Lecture about STG circuit	textbook section 7.3
9	STG circuit	Model selection. I'll introduce several new models that could be used to model an STG neuron.	Project: invent your own conductance-based model neuron with conductances of your own choosing.
	working with functions in Matlab	Basics about functions	Matlab tutorial
10	working with functions in Matlab	Using functions for STG model	Matlab tutorial
	Synaptic connections	Review of synaptic connectivity types	textbook section 5.5
11	Synaptic connections	Connect 2 STG model neurons	Gap junction worksheet (provided)
	Synaptic connections	Connect 3 to 5 STG neurons	Cartoon network Worksheet (provided)
12	Neural network connectivity and the connectivity matrix.	Introduction to general Neural networks and the connectivity matrix.	Textbook section 5.5
	Synaptic plasticity	Overview of synaptic plasticity	Textbook section 5.1-3
13	Hebbian plasticity and learning	Lecture about how a psychology theory informed a neurobiological model.	reading on Hebbian plasticity and its origins in cognitive neuroscience
	Hebbian plasticity and learning	walking through the	Worksheet

		math, comparing to synaptic depression/facilitation, etc.	(provided)
14	Pattern completion	Lecture about machine learning origins	Textbook sections 8.1 and 8.2
	Pattern completion	Working through the model concepts and equations	Textbook sections 8.1 and 8.2
	Finals week		

Textbook and course materials:

An Introductory course in Computational Neuroscience (MIT Press)

Author: Paul Miller

ISBN: 9780262038256

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Hardcover: $50, rent e-book: $25

Matlab tutorials provided by professor (website links and digital jupyter notebooks)

Worksheets provided by professor

Barnard Policies:

Honor Code

Approved by the student body in 1912 and updated in 2016, the Code states:

We, the students of Barnard College, resolve to uphold the honor of the College by engaging with integrity in all of our academic pursuits. We affirm that academic integrity is the honorable creation and presentation of our own work. We acknowledge that it is our responsibility to seek clarification of proper forms of collaboration and use of academic resources in all assignments or exams. We consider academic integrity to include the proper use and care for all print, electronic, or other academic resources. We will respect the rights of others to engage *in pursuit of learning in order to uphold our commitment to honor. We pledge to do all that is in our power to create a spirit of honesty and honor for its own sake.*

The Barnard Honor Code includes relevant language for the proper use of electronic class material.

"*We consider academic integrity to include the proper use and care for all print, electronic, or other academic resources.. "*

To be clear, this means that recorded class content — from lectures, labs, seminars, office hours and discussion groups — is the intellectual property of your professor and your fellow students, and should not be distributed or shared outside of class.

Accommodations:

If you believe you may encounter barriers to the academic environment due to a documented disability or emerging health challenges, please feel free to contact the Center for Accessibility Resources & Disability Services (CARDS). Any student with approved academic accommodations is encouraged to contact me during office hours or via email. If you have questions regarding registering a disability or receiving accommodations for the semester, please contact CARDS at (212) 854-4634, cards@barnard.edu, or learn more at barnard.edu/disabilityservices. CARDS is located in 101 Altschul Hall.

Health and Wellness

Furman Counseling Center

The Rosemary Furman Counseling Center offers health and wellness resources even when you are not on campus. Appointments with a counselor can be scheduled on their website: https://barnard.edu/rosemary-furman-counseling-center. They are also holding listening sessions related to changes to the Fall 2020 semester (these sessions do not have a therapeutic focus). They also list several emergency services that you can use.

General Resources

It is important for undergraduates to recognize and identify the different pressures, burdens, and stressors you may be facing, whether personal, emotional, physical, financial, mental, or academic. We as a community urge you to make yourself--your own health, sanity, and wellness--your priority throughout this term and your career here. Sleep, exercise, and eating well can all be a part of a healthy regimen to cope with stress. Resources exist to support you in several sectors of your life, and we encourage you to make use of them. Should you have any questions about navigating these resources, please visit these sites:

- http://barnard.edu/primarycare
- http://barnard.edu/counseling
- http://barnard.edu/wellwoman/about
- Stressbusters Support Network

Center for Accessibility Resources & Disability Services (CARDS)

If you believe you may encounter barriers to the academic environment due to a documented disability or emerging health challenges, please feel free to contact me and/or the Center for Accessibility Resources & Disability Services (CARDS). Any student with approved academic accommodations is encouraged to contact me during office hours or via email. If you have questions regarding registering a disability or receiving accommodations for the semester, please contact CARDS at (212) 854-4634, cards@barnard.edu, or learn more at barnard.edu/disabilityservices. CARDS is located in 101 Altschul Hall.

Affordable access to course texts and materials

All students deserve to be able to study and make use of course texts and materials regardless of cost. Barnard librarians have partnered with students, faculty, and staff to find ways to increase student access to textbooks. By the first day of advance registration for each term, faculty will have provided information about required texts for each course on CourseWorks (including ISBN or author, title, publisher, copyright date, and price), which can be viewed by students. A number of cost-free or low-cost methods for accessing some types of courses texts are detailed on the Barnard Library Textbook Affordability guide (library.barnard.edu/textbook-affordability). Undergraduate students who identify as first-generation and/or low-income students may check out items from the FLIP lending libraries in the Barnard Library (library.barnard.edu/flip) and in Butler Library for an entire semester. Students may also consult with their professors, the Dean of Studies, and the Financial Aid Office about additional affordable alternatives for having access to course texts. Visit the guide and talk to your professors and your librarian for more details.