NEUROBIO 735: Quantitative Neurobiology

21 January, 2021

> Through lectures and hands-on problem solving, this course will provide students with a working, practicable background in coding in Python, and theoretical and computational neuroscience. The material will be oriented strongly towards the needs of working neurobiologists, and will require considerable independent work.

Meeting Dates and Location:

January 21 – April 23
3:00-4:30 PM
Online via Zoom

Course directors:

John Pearson	john.pearson@duke.edu
Nicolas Brunel	nb170@phy.duke.edu

Teaching Assistants:

Robin Blazing	robin.blazing@duke.edu
Liz O'Gorman	elizabeth.ogorman@duke.edu

Overview

The goal of the course is to give you a sampler of techniques and ideas in quantitative neurobiology, which we consider to encompass computation, data analysis, modeling, and theory. The course is divided into three main sections (with a final week for project presentations):

1. **Introduction to programming (1/21 – 2/11):** There are several good options here, but we'll be using Python. More on details below, but *we will not assume prior programming experience.*
2. **Analyzing neural data (2/16 – 3/18):** The goal here is to get you comfortable using programming to explore, visualize, analyze, and model several types of data generated by neuroscience experiments.
3. **Models of neurons and neural circuits (3/23 – 4/15):** Here, we'll introduce some of the main models used in computational neuroscience, and their relationship to experimental data. In parallel,

students will start working on a project, which will consist in building and simulating a neural system of interest.

4. **Final project presentations (4/20 – 4/22):** Students will present their final projects.

Logistics

Getting together

Class will be **remote**. We will send you details for how to access class meetings, which will take place on Zoom.

Computing

Unlike past years, we will provide you with a Python computing environment you can access from your browser. There are two main reasons for this: First, it's going to be harder than in previous years to debug everyone's individual setup; this way, we know what setup you have and that it works. Second, we can all share the same directory structure, have datasets preloaded in known locations, and do a few other things that will reduce friction. You can access this by going to https://vm-manage.oit.duke.edu/containers and authenticating with Shibboleth as usual.

We will focus on using JupyterLab. This includes Jupyter Notebooks, which are covered in the *Python Data Science Handbook*, but we will also cover the basics of navigating this in our first class.

Outside of class

In-class assignments are supposed to be that. After class is done, we will post solutions so you can compare your answers. Outside of class, you are responsible for doing any of the recommended and assigned reading.

You are also responsible for checking the class website. All class materials will be posted there, as well as changes and corrections to homework assignments.

Getting help

Please make use of the TAs and their office hours. We, your instructors, are also glad to help. If something is confusing with the assignments, the fault is probably ours, and you're probably not alone. If you alert us early, we can probably fix it.

Assignments and Grading

For the middle portion of the class, we will have both in-class work and assignments. You are allowed to work collaboratively on homework, but your write-ups must be done independently. Please also note everyone you worked with when turning in your assignments.

Solutions should be submitted as saved Jupyter Notebooks on your remote file system. We'll tell you where to put these and how to name them.

Solutions are due before class on Tuesdays (3pm EST). Given how difficult a period this is, we can work with you if something unexpected occurs, but *we need to know in advance*. Please help us help you. We can't release solutions until we have everyone's assignments turned in.

Final projects. During this third phase of the course, in addition to the lectures on models in computational neuroscience, you will work on a project that will consist in the numerical simulation of a model of a specific neural system. The first step will consist in defining the project itself. The project should consist in the simulation of a particular neural system you are interested in (possibly, but not necessarily, related to your current research project). We will help you in defining a project that can be realistically done in 5 weeks.

As a starting point, you will be asked to send us (i.e. all four instructors and TAs of the course) a proposal for the research project. It should specify the neural system you are planning to model (i.e. a specific type of neuron, or a network of neurons in a particular brain structure), and the question you are planning to investigate. The deadline for sending the proposal is 2/25. Then, you will receive feedback on this proposal to help you converge on something that is doable during the last phase of the course. The work on the project itself will take place during the second half of March and the first half of April. Finally, you will present your results during the week of April 20.

Grading is on a pass/fail basis.

Phase I: Beginning Python

For the first several weeks of class, we'll be offering a crash course in basic Python covering *A Whirlwind Tour of Python*, transitioning to the *Python Data Science Handbook*. This will be basic and focused on students who have limited programming background. **This is purely optional.** Those of you who are already comfortable with programming do not need to attend, though you will be responsible for the material. I will also be working with the TAs to set up additional

help during this period for those who would like it.

Date	Topic	Reading
1/21	Housekeeping, accessing computing, advanced Googling	WWTP Chs. 1–6
1/26	What can Python do?	WWTP Chs. 7–8
1/28	Data structures	WWTP Chs. 9–12
2/2	Patterns, iteration, duck typing	PDSH Ch. 1
2/4	NumPy and arrays	PDSH Ch. 2
2/9	Dataframes	PDSH Ch. 3
2/11	Plotting	PDSH Ch. 4

Phase II: Data Analysis

This second phase of the course will cover five weeks and will focus on analyzing real neuroscience data sets.

I will not be lecturing. At least, not much. Most of what we'll cover isn't really learned effectively that way, so we'll use our class time to complete programming and data analysis exercises that build on the basic Python knowledge you gained by reading *A Whirlwind Tour of Python*.

Each week, we'll do two sessions of in-class assignments, for which you'll be encouraged to work with a partner. The weeks are organized around both data and programming themes, and the in-class assignments often build on one another. After class is done for the day, we'll post links to solutions. Typically, we'll be walking you through an example analysis, with the goal of setting you up for the homework.

Date	Topic
2/16	Point process data I
2/18	Point process data II
2/23	Tabular data I
2/25	Tabular data II
3/2	Image data I
3/4	Image data II
3/9	Debugging I
3/11	Debugging II
3/16	Fitting basic models
3/18	Fitting simulated models

Phase III: Models of neurons and neural circuits

The third phase of the course will cover basic models of neurons and neural circuits. The tentative schedule of this part of the court is as follows:

Date	Topic
3/23	Neurons
3/25	Synapses
3/30	Network: Architectures
4/1	Network: Dynamics
4/6	Coding
4/8	Decoding
4/13	Learning
4/15	Memory