SYLLABUS FOR NBIO 228 (MATH TOOLS FOR NEUROSCIENCE)

Dates: SPRING QUARTER. Wednesday 3-5 PM in Fairchild D202.

General organization:

This course will consist of 3 main components: in-class lectures, problem sets, and a class project. There will be 8 in-class lectures, including 2 guest lectures (see schedule below). There will be a problem set associated with every lecture. These problem sets will not be overly difficult or time-consuming but instead will (hopefully!) help you digest the material in a fun, painless, and efficient way. (The same goes for the lectures.) In general, there will be a minimal emphasis on coding, but for some topics we may give a general background on the numerical implementation or methods for finding numerical solutions. In these cases, we might also provide partially-completed code for you to work with (eg for a problem set). For the class projects, we envision that students will either: 1) pick a paper to work through and present (we will provide some potential paper options) or 2) use the methods discussed in class to analyze a dataset. This dataset can be provided by the student, or the course instructors - just let us know what you want to practice your math tools on! The main goal for the class projects is simply to give everyone a chance to practice their new favorite analytical tool in a fun and useful way - beyond that, we are quite flexible. Grades will be based on some combination of the problem sets and class project.

We hope to make this course both super fun and super useful - especially for those who want to up their data analysis/modeling game (or apply more quantitative techniques to their science) but haven't taken many math courses beyond calculus. Feel free to email the instructors: Lane McIntosh (lanemc@stanford.edu) and Kiah Hardcastle (khardcas@stanford.edu) if you have any questions!

Schedule:

1. **Week 1 (4/1): Linear Algebra**
   1.1. Matrices and geometrical interpretations of matrices
   1.2. Developing an intuition for eigenvalues and eigenvectors
   1.3. PCA, matrix decompositions
2. **Week 2 (4/8): Fourier Transforms**
   2.1. What it means to decompose a function into its sine and cosine components
   2.2. Filtering signals, decomposing, convolutions
3. **Week 3 (4/15): Dynamical Systems Part 1**
   3.1. Analytical, qualitative, and numerical solutions to 1D linear and nonlinear ODEs
   3.2. Examples: population growth models, spiking single neuron models, models of channel kinetics, modeling firefly synchrony
4. **Week 4 (4/22): Dynamical Systems Part 2**

    4.1. Analytical, qualitative, and numerical solutions to 2D+ linear and nonlinear ODEs
    4.2. Examples: Hodgkin-huxley-type models, multiple neuron models, predator-prey models
5. **Week 5 (4/29): Optimizing Non-explicit Models**
    5.1. Guest lecture from Niru Maheswaranathan
6. **Week 6 (5/6): Statistics**
    6.1. Formalizing concepts of variance, standard error, significance, covariance matrix
    6.2. Thinking outside the t-test and applying non-standard statistical tests (eg bootstrapping)
    6.3. How to create a statistical test from scratch
7. **Week 7 (5/13) - Probabilistic Thinking**
    7.1. What is a prior? A posterior?
    7.2. Topics on information theory
8. **Week 8 (5/20) - Application: Models of the retina**
    8.1. Guest lecture from Jonathan Leong
    8.2. Work on class projects
9. **Week 9 and Week 10 (5/27 and 6/3): Working on projects and presenting!**