NBIO 303: Neuronal coding and computation
HSB G417, 3.30-5.30pm

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Course overview:

The primary goal of this course is to act as a mathematically and computationally oriented companion course to NBIO 301, although it may be taken in isolation on consultation with the lecturers. The course is an introduction to computational neuroscience, with a particular focus on concepts that are related to neuronal and synaptic biophysics that parallel the lecture and laboratory material of NBIO 301. The course will work through mathematical concepts and methods to describe neuronal dynamics, and will introduce methods to analyze and characterize neural coding. The course will make use of Matlab as a programming language to implement models of neuronal dynamics and perform data analysis. Some instruction in Matlab will be provided, although students will be expected to have some Matlab or other programming background or be willing to work on it on their own using provided materials. Topics are chosen to expand upon and extend material from the NBIO 301 laboratory class. Students will be encouraged to deepen that connection by choosing a computationally oriented project for NBIO 301 that draws on material from the course. The course will meet twice weekly for 1 hour each time. The first hour will be in lecture format, and the second hour will be in workshop/tutorial format, when students will be able to work on Matlab or other computational problems with guidance from the lecturer.

Prerequisites: Equivalent of 200 level calculus, otherwise by permission of instructor.

Learning goals:

The goal of this course is to introduce students to two core concepts of computational neuroscience: neural coding and models of neuronal dynamics, and in doing so, to become familiar with programming in Matlab and the mathematics of neuronal signaling. Students will learn to model and test how sensory systems represent information, to work with differential equations that describe biophysical processes, and to understand how one may reduce complex mathematical descriptions to simpler ones that retain certain important behaviors. They will learn to use the scripting language Matlab to integrate differential equations and perform some elementary data analysis.

Required text/readings:

No required texts, but recommended reading includes:
Strogatz, *Nonlinear dynamics and chaos : with applications to physics, biology, chemistry, and engineering*
Dayan and Abbott, *Theoretical Neuroscience*
Izhikevich, *Dynamical Systems in Neuroscience*

Grading:
Assessment is CR/NC and will be based on completion of two problem sets. The goal of these problem sets is to provide an opportunity to implement concepts learned in class. Workshop sessions will be held in class to help in carrying these out.

Approximate weekly course schedule:

(Note that the shaded Laboratory is part of 301, not this course: included to show coordination)

Week 1	Laboratory	Lab orientation
Week 1	Lecture	Basic concepts of neural coding • Spikes as carriers of information • Rate and timing codes • Linear/nonlinear models of neural coding
Week 1	Workshop	Matlab introduction
Week 2	Laboratory	Extracellular recording in cockroach
Week 2	Lecture	Coding, noise and discriminability • Two-alternative forced choice tasks • Response distributions • Signal detection theory
Week 2	Workshop	Introduction to Problem Set 1
Week 3	Laboratory	RC circuits
Week 3	Lecture	RC circuits and linearity • Numerical integration • First order linear differential equations • Properties of linear systems
Week 3	Workshop	Integrating differential equations • Integrating linear differential equations • Euler method • Runge-Kutta method
Week 4	Laboratory	Intracellular recording in snail
Week 4	Lecture	Neuronal dynamics • Impulse response • Current vs conductance inputs
Week 4	Workshop	Problem set 1 review
Week 5	Laboratory	Intracellular recording in snail
Week 5		Neuronal dynamics: ion channels • The Hodgkin-Huxley model • Nonlinearity • Coding by single neurons
Week 5	Workshop	Integrating the HH equations • Euler method for multivariate systems • Including nonlinearities
Week 6	Laboratory	Intracellular recording in snail
Week 6	Lecture	Simplified models of neural dynamics • Integrate-and-fire models • Basics of excitable systems • Connection to linear/nonlinear coding models
Week 6	Workshop	Introduction to problem set 2
Week 7	Laboratory	Intracellular recording at crayfish NMJ

Week 7	Lecture	Synaptic dynamics • Driving neurons through conductance inputs • Introduction to network modeling
Week 7	Workshop	Planning course projects
Week 8	Laboratory	Intracellular recording in crayfish NMJ
Week 8	Lecture	Synaptic modeling • Synaptic strength • Short-term synaptic plasticity
Week 8	Workshop	Review of Problem Set 2
Week 9	Laboratory	Intracellular recording in crayfish NMJ
Week 9	Lecture	Project-driven workshop on data analysis: possible topics: • Spike sorting and clustering • Principle component analysis • Cross-correlation • Reverse correlation methods
Week 9	Workshop	Data analysis methods
Week 10	Laboratory	Project presentations
Week 10	Lecture	Course recap and summary