Mathematical and Computational Neuroscience
MATH 568/BIOINF 568, Fall 2019

Meeting times: MW 10:00 – 11:20am, EH 3088

Instructor: Victoria Booth
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Office Hours: M, W 5:30-6:30pm, Th 12-1pm and by appointment

CANVAS Website: MATH 568 001 FA 2019

Textbook: No required textbook. Readings will be posted on course webpage. Readings and homework problems will be selected from a number of different texts including:

1. Mathematical Foundations of Neuroscience by G.B. Ermentrout and D.H. Terman (Springer 2010). Available electronically through UM library.
2. An Introduction to Modeling Neuronal Dynamics by C. Borgers (Springer 2017). Available electronically through UM library.
3. Theoretical Neuroscience: Computational and Mathematical Modeling of Neural Systems by P. Dayan and L. Abbott (MIT Press, 2005). Available electronically through UM library.
4. Foundations of Cellular Neurophysiology by D. Johnston and S.M. Wu (MIT Press 1995).
5. Biophysics of Computation by C. Koch (Oxford University Press, 1999).
6. Methods in Neuronal Modeling, C. Koch and I. Segev, eds. (MIT Press, 1999).

Homework: Bi-weekly homework assignments will include analytical and numerical-based problems. Late homework will be grudgingly accepted. Additionally, short, class work assignments will be given for some lectures. Electronic submissions should be in pdf format and uploaded to the course CANVAS site.

Course project: A modeling project will occupy a substantial portion of your time and effort in the course. Students should work in teams of two or three. For the project, you will give a 20-minute in-class presentation and submit a project report. Be prepared to submit project topics in early October and project outlines in November. Presentations will be given in class on Dec 4 - 11. The research paper is due Dec 18.

Start early thinking about and doing internet searches on a neurological system, process or pathology that you are interested in learning about and modeling, or a type of neuronal model or analysis that we won't be covering in class. For the project, you can provide extensions or new applications for an existing mathematical model or develop a novel model related to your topic. It will not be sufficient to study an existing model and recreate already reported results; there must be a novel component to your project. The project can be related to research you are currently participating in. More details will be given later.

Grading: Homework 45%, modeling project 45%, class work and participation 10%

Numerics: Numerical implementation and analysis of the models presented in the lectures will be an integral part of the course. You may use a programming language or numerical package of your choice. Demonstration codes in Matlab will be provided.

Approximate dates for topics covered (may be subject to change):
Sept 4, 9: Introduction, biophysics of ion flow, Nernst and Goldman-Hodgkin-Katz equations
Sept 11,16: Circuit model of neuronal membrane, passive membrane properties, integrate-and-fire models
Sept 18, 23: Hodgkin-Huxley models
Sept 25,30: Diverse ionic currents in Hodgkin-Huxley formalism
Oct 2: Synaptic currents, coupled neurons
Oct 7, 9: Excitatory and inhibitory neural networks
Oct 16: Brain rhythm generation, ING, PING
Oct 21, 23: Neural modeling in research guest lectures
Oct 28, 30, Nov 4, 6: Reductions of the Hodgkin-Huxley model, Morris-Lecar model, phase plane analysis, linear stability of equilibrium points, bifurcation analysis
Nov 11, 13: Cable equation, propagation of action potentials, compartmental models
Nov 18, 20: Neural modeling in research guest lectures
Nov 25: Neural networks as coupled oscillators, phase response curves
Nov 27: Neural coding applications
Dec 2: Synaptic Plasticity
Dec 4, 9, 11: Presentations of projects