



Catalog Description:

Introduction to mathematical modeling and computational analysis of neuronal systems, Hodgkin-Huxley model, dynamical systems methods, neuronal networks, models for neurological disease.

Prerequisite:

Math 1152 (152) or 1157 or permission of instructor.

Text:

Foundations of Mathematical Neuroscience, by G. Bard Ermentrout and David H. Terman

Purpose:

Mathematical models and computational methods have been very useful in understanding biological mechanisms underlying neuronal behavior. The Hodgkin-Huxley model, for example, has formed the basis for our understanding of how action potentials are generated and how they propagate along a nerve axon. More recently, mathematical models have been used to help understand cellular processes responsible for both normal and pathological firing patterns that arise in a wide range of neuronal systems. Examples include models for sensory processing, motor control, neurological disease, sleep rhythms and working memory.

This course provides a detailed introduction to how mathematical and computational methods have been used to both develop and analyze models that arise in neuroscience. We begin by deriving the Hodgkin-Huxley model and then describe dynamical system methods for analyzing models. After discussing the dynamics of single neurons, we consider neuronal networks and describe how different types of population firing patterns depend on biological details, such as the intrinsic properties of individual neurons and synaptic coupling. We conclude by considering specific brain systems.

Topics List:

1. Overview: Neurons, synapses, neuronal firing patterns
2. Hodgkin-Huxley Model: Resting potential, Nernst equation, Goldman-Hodgkin-Katz equation, cable equation, action potential
3. Dynamics I: Introduction to differential equations; phase-planes; oscillations
4. Dynamics II: Stability analysis, bifurcation theory, numerical methods
5. Single cell dynamics I: Propagating action potentials; rhythmic behavior
6. Single cell dynamics II: Variety of channels, bursting oscillations; dendrites; multi-compartment models
7. Synapses: Simple networks
8. Networks: Classification of network behavior; synchrony, role of different types of channels and coupling
9. Specific brain systems: Possible topics include models for working memory, vision, olfaction, sleep, Parkinson's tremor, stroke
10. Presentation of projects