Neurbio 220 “Neural Dynamics” Tu Th 2:00-3:20pm in MH2246 Conference room

Theoretical principles and biological mechanisms underlying how brains acquire, assimilate, store, and retrieve information, compute adaptive responses to external inputs, and how knowledge is extracted from experience to generate an internal model of the world.

20 Lectures/classes

N220 - Neural Coding, Computation and Dynamics

Instructor: Bruce L McNaughton Ph.D. Distinguished Professor, Neurobiology and Behavior

Prerequisite

At least one upper division course in the field of Neuroscience OR one upper division course in Cognitive science OR permission of the instructor

Syllabus

The course covers the fundamental theoretical principles and biological mechanisms underlying how brains acquire, assimilate, store and retrieve information, compute adaptive responses to external inputs, and how knowledge is extracted from experience to generate an internal model of the world leading to successful prediction of the outcome of events and actions: how brains become intelligent.

This course provides an essential foundation for understanding the brain from a computational and dynamics perspective. It is directed towards graduate students in several disciplines including systems and behavioral neuroscience, cognitive neuroscience, cognitive science, psychology, engineering and computer science, who intend to do advanced work in a related field. The course consists of lectures which outline fundamental principles, illustrated with scientific data and theoretical models. Students are expected to have a working knowledge of basic neurobiology. Principles are explained with minimal resort to mathematics, but quantitative reasoning skills are required. Lectures will be supplemented by readings, student presentations, and a term paper on a course-relevant topic of the student’s choice (subject to instructor approval).

Lecture topics:

- Neural computation and computational neuroscience: two sides of a coin. Levels of analysis and levels of approximation. Fundamental concepts of neural signalling.
- Principles of associative memory in neuronal networks I; the learning matrix, associative retrieval (pattern completion), constraints on capacity.
- Principles of associative memory in neuronal networks II; Hebb-Marr networks, the role of inhibition, pattern separation, sequence learning and the synaptic matrix symmetry problem. Attractor dynamics and the continuous attractor concept.
- Acquiring and making sense of neural data: basic principles of electrophysiological recording and optical imaging of neural activity and standard analytical approaches. Transmembrane vs extracellular current flow patterns and resulting voltage (potential) changes. The interpretation of LFP (EEG) signals and neuronal spike time-series.
- Principles of neural coding: rate, population, and spike timing codes; coincidence detection, sequence detection. Bayesian decoding of neural signals.
- Teaching brains to compute: representing the world with neurons; the classic problem of neural network theory and its solution; `hidden layers` and conjunctive coding.
- Neural feature detectors and how they are created (BCM rule, competitive learning).

- Maps in the brain; Modular information processing: the cortical column; Hierarchical Information Processing.
- Passive and 'active' properties of membrane cylinders and trees (i.e., axons and dendrites).
- Neurotransmitter release and synaptic potentials.
- Synaptic morphology and configurations; networks.
- Synaptic plasticity I: mechanisms of association, Hebb`s hypothesis, LTP /LTD, spike-timing dependent plasticity.
- Synaptic plasticity II:
- The hippocampus I: anatomy and the neural basis of the cognitive map.
- The hippocampus II: the indexing theory and memory consolidation. Sleep and memory consolidation.
- Oscillations in the brain; cortical desynchronization, slow waves, up-down states, hippocampal theta rhythm sharp-waves & ripples, and spike timing relationships.

Grades (tentative)

Evaluation will be based on

- class attendance and participation (i.e., engaging in discussions, volunteering answers to instructor's questions etc. Permission for absence from a class will be granted on reasonable request, but the student will be asked to meet with the instructor for a make-up tutorial. (25%)
- a student paper of 3000-5000 words, which should be a critical and insightful review of a topic relevant to the course material (selected in consultation with instructor), in the format of a review article in the field (e.g., Nature Neuroscience Reviews, Trends in Neuroscience). (25%),
- a seminar presented by the student on the term paper topic. (25%)
- a final examination (take-home format). (25%)

Detailed Syllabus

03.29 Tu	L1	What is neural computation?
03.31 Th	L2	Fundamental concepts in associative memory Part 1: associative nets

04.05 Tu	L3	Fundamental concepts in associative memory Part 1: role of inhibition
04.07 Th	L4	Neural coding
04.12 Tu	L5	Teaching Brains to Compute
04.14 Th	L6	Collecting and making sense of neural data
04.19 Tu	L7	Oscillations
04.21 Th	L8	Hippocampus 1, Basic circuits
04.26 Tu	L9	Hippocampus 2, Place cells, Grid cells and Head-Direction cells
04.28 Th	L10	Hippocampus 3, Models
05.03 Tu	L11	Hippocampus 4, memory consolidation and prediction
05.05 Th	L12	
05.10 Tu	L13	
05.12 Th	L14	
05.17 Tu		
05.19 Th		
05.24 Tu		
05.26 Th		
05.31 Tu		
06.02 Th		

The instruction for Spring 2016 begins March 28th and ends June 3rd. The final examinations will be on the week of June 4-9. Please find below the course that you will be teaching:

Neurbio 209 "Behavioral Neurosci" 9:00-10:20AM in MH2246. This course is a team taught: Drs. Fortin, Fowler, Mahler, McGaugh, McNaughton and Stark.

http://senselab.med.yale.edu/ModelDB/helpmenu.cshtml