Bi/CNS/NB 153 – Brain Circuits – Fall 2016

Instructor: Markus Meister
Teaching fellow: Yang Liu

Course description
What functions arise when many thousands of neurons combine in a densely connected circuit? Though the operations of neural circuits lie at the very heart of brain science, our textbooks have little to say on the topic. This course explores what is known, and how we will learn more. The emphasis is on experimental science, but theory and computation play essential roles in linking the structure and function of large neural systems.

Neural circuits are best understood in brain areas whose basic purpose is well known. So we will begin with a foray into sensory systems and motor systems. In each case we consider what basic functions need to be accomplished and examine neural circuits that implement them. After this survey, we will ask whether the various circuit motifs we encountered are also found in central brain areas, and what role they play there. Here the emphasis will be on sensory-motor integration and learning. Finally we will explore design principles for neural circuits and what constraints have shaped their structure and function in the course of evolution.

Prerequisites: Bi/CNS/NB 150 or equivalent.

Location: Wed and Fri 10:30-12:00 am, BBB Room B101 (Bldg 76 basement north end).

Format:
Equal parts lecture (Fri) and student-led discussion of research articles (Wed).
Weekly assignments: Background readings before the lecture. Several research articles before the discussion. Homework problems due before discussion.
Grading: Class participation. Homework. Midterm exam. Final term paper.

Literature
Readings will be drawn from many sources. As a reference work, students should have a copy of "Synaptic Organization of the Brain", edited by Gordon M. Shepherd, 5th edition, ISBN 019515956X.

Topics, approximate [weeks]
Single neuron processing: A refresher of cellular neurophysiology; models of dendritic integration and synaptic transmission; graded and spiking signals; diversity of neuron types. These concepts are essential for thinking about interconnected neurons. [0.5]
Sensory systems. Some core functions: amplifying weak signals while suppressing noise; detecting change in space and time; detecting specific stimulus features; adapting to different sensory environments. Special focus on vision and olfaction. [2.5]
Motor systems. Some core functions: generating precise temporal sequences; coordinating motor patterns; high-level control of movement. Focus on spinal cord and invertebrate pattern generators. [3]

Cerebellum and related circuits. Poised at the interface between sensory and motor systems, these circuits are involved in adaptive control of movement and in active filtering of sensory inputs. [2]

Dynamics. Neural systems process signals on many time scales, from the microsecond timing of sounds to the many seconds of working memory. What neural circuits accomplish this spread of dynamics? [1]

Circuit design principles. What led Nature to evolve the circuits we find today rather than any other solution? Some basic constraints that shape circuit function and structure: the need for efficient coding of sensory information; metabolic costs of neural signaling; connectivity in a limited brain volume. [1]