Core Elective Course on Computational Neuroscience:  
From biophysics to circuit dynamics and cognitive functions

**Course director:** Xiao-Jing Wang (Meyer Building, Room 752)

**When:** Fall semester, Mondays and Wednesdays, 9:00-10:30am  
**Where:** Meyer Room 760  
**Recitations:** 1h once a week or 2h every other week. Time TBD  
**Office hour:** TBD

**Description:** This is a new, core elective course on computational neuroscience for NYU’s neuroscience program.

Computational Neuroscience is a highly cross-disciplinary field where theory and modeling are used to study how the brain works. The course will be an introduction to this subject, covering basic concepts and models, neural circuit mechanisms of various brain functions, such as information coding and processing, learning and memory, working memory, decision-making. The course is designed for students to become well versed in key concepts and tools, canonical circuit mechanisms and computational principles for cross-level understanding from neural biophysics to recurrent networks to functions and behavior.

The prerequisites are Math Tools (NEURL-GA.2201) and Systems Neuroscience (NEURL-GA2202), or permission by the course director. Some familiarity with differential equations is desirable.

Graduate students in the Systems and Computational Neuroscience track are recommended to take this course before more specialized elective computational courses; students from other fields are welcome, as well as higher level undergraduates majoring in diverse areas (ranging from Physics to Cognitive Science).

**Grade** will be based on class and recitation participation (20%), weekly reading (10%), regular homework that requires computer model simulations using Python (70%).

**Weekly reading:** 2-3 book chapters and papers

**Reference books:**


Lecture Notes, Xiao-Jing Wang (Manuscript tentatively entitled “*Computational Neuroscience of Elemental Cognition*”).


Biophysics of Computation, by C. Koch, Oxford University Press, 1999

Spikes, Decisions and Actions, by H. Wilson, Oxford University Press, 1999


Schedule

9/2 (Wednesday) Introduction to Neuroscience. Neural microcircuits, neocortex. Biophysics of neural membrane and synapses

9/7 (Monday) Labor Day, no class

9/9 (Wednesday) integrate-and-fire model, Spike-frequency Adaptation. (homework #1)

9/14 (Monday) Hodgkin-Huxley theory of action potential. (homework #2)

9/16 (Wednesday) Biophysics of synaptic interactions

9/21 (Monday) Short-term synaptic plasticity. (homework #3)

9/23 (Wednesday) Elements of graph theory and network science.

9/28 (Monday) Balanced excitatory-inhibitory recurrent circuits, neural variability and noise correlation.

9/30 (Wednesday) Network synchronization. Mean-field theory (rate models versus spiking models).

10/5 (Monday) modeling the visual cortex. (homework #4)

10/7 (Wednesday) Population coding

10/12 (Monday) Population decoding

10/14 (Wednesday) Bayesian theory

10/19 (Monday) Multi-sensory integration
10/21 (Wednesday) High-dimensional neural population dynamics, manifold discovery

10/26 (Monday) SfN meeting, no class

10/28 (Wednesday) SfN meeting, no class

11/2 (Monday) Hebbian plasticity and homeostatic regulation.

11/3 (Thursday) Midterm grades due.

11/4 (Wednesday) Hopfield network model of associative memory. Attractor networks. (homework #5)

11/9 (Monday) Working memory and selective attention (homework #6)

11/11 (Wednesday) Decision-making from behavioral models to physiology.

11/16 (Monday) Neural circuit models of decision-making. (homework #7)

11/18 (Wednesday) Reinforcement learning

11/23 (Monday) Models of value-based choice. (homework #8).

11/25 (Wednesday) Basics of machine learning

11/30 (Monday) Training artificial neural networks. (homework #9)

12/2 (Wednesday) Recurrent neural networks and AI.

12/7 (Monday) Large-scale, multi-regional brain circuits: connectome & dynamics. (homework #10)

12/9 (Wednesday) Distributed cognition in the brain

12/21 (Monday) Final grades due.