COMMITTEE ON COMPUTATIONAL NEUROSCIENCE

Chair
• David Freedman

Professors
• Yali Amit, Statistics
• Nicolas Brunel, Statistics
• Jack Cowan, Mathematics
• Ruth Anne Eatock, Neurobiology
• John Ebersole, Neurology
• Jay Goldberg, Neurobiology, Pharmacology and Physiology
• John Goldsmith, Linguistics
• Melina Hale, Organismal Biology and Anatomy
• Dorothy Hanck, Medicine
• Christian Hansel, Neurobiology
• Nicholas Hatsopoulos, Organismal Biology and Anatomy
• Richard P. Kraig, Neurology
• Daniel Margoliash, Organismal Biology and Anatomy
• John Maunsell, Neurobiology
• Martha McClintock, Psychology
• Howard Nusbaum, Psychology
• Eduardo Perozo, Biochemistry and Molecular Biology
• Brian Prendergast, Psychology
• S. Murray Sherman, Neurobiology
• Steven Shevell, Psychology
• Wim van Drongelen, Pediatrics
• V. Leo Towle, Neurology

Associate Professors
• Leslie Kay, Psychology
• David Freedman, Neurobiology
• Xiaoxi Zhuang, Neurobiology

Assistant Professors
• Sliman Bensmaia, Organismal Biology and Anatomy
• David Biron, Physics
• Jason MacLean, Neurobiology
The University of Chicago has a long tradition of innovative research in the neurosciences. K. C. Cole developed the voltage clamp here, Stephen Polyak and C. J. Herrick did pioneering work on the anatomy of the retina and brain, and Jack Cowan and Hugh Wilson were among the first to develop mathematical analyses of the dynamics of cortical neurons using non linear dynamics. This tradition is continued in the Committee on Computational Neuroscience, which draws on faculty from many departments in all four graduate divisions in the University to create a multidisciplinary program in neuroscience. Computational neuroscience is a relatively new area of inquiry that is concerned with how components of animal and human nervous systems interact to produce behaviors. Using quantitative and modeling methods, the interdisciplinary approach of computational neuroscience seeks to understand the function of the nervous system, natural behaviors and cognitive processes and to design human made devices that duplicate behaviors. Course work in computational neuroscience prepares students for research in neurobiology, psychology, or in the mathematical or engineering sciences. Graduates from this program move to traditional academic careers, to careers in biomedical research or engineering, or to opportunities in the corporate world.

**GRADUATE DEGREES**

Students with undergraduate degrees in biology or psychology, any of the quantitative sciences or any of the engineering disciplines are welcome to apply for graduate study. Computational neuroscience is inherently interdisciplinary, and most students doing graduate work in this area will have strengths in one of the relevant areas and weaknesses in others. Program requirements in the committee are designed to correct background deficiencies, so students with uneven backgrounds should not hesitate to apply. A year of college level calculus is an absolute prerequisite. Ideally, applicants should have some collegiate level course work in biology (optimally including an introductory neurobiology course), an introductory psychology course, and some mathematics (such as linear algebra and elementary differential equations) beyond calculus. Students who have not had prior exposure to linear algebra and differential equations may be asked to take appropriate courses in these areas before taking the mathematics sequence within the computational neuroscience curriculum.

**DOCTOR OF PHILOSOPHY**

Students seeking the Ph.D. in computational neuroscience must take the nine formal courses in the computational neuroscience curriculum, and enroll for nine quarters of research. The formal courses are typically taken in the first year and arranged into three themes. The neuroscience theme presents the basic concepts and phenomena in neuroscience. The mathematics theme presents the quantitative techniques required for a modern analysis of the nervous system and behavior. The courses in this theme have prior exposure to linear algebra and differential
equations as a prerequisite. The computational neuroscience theme illustrates how quantitative methodologies are used to understand neurons and behavior. The courses in this theme have completion of a year of calculus as a prerequisite. Students must complete two laboratory rotations which can be started in the first year. Students can also take graduate courses offered by the Departments of Computer Science, Linguistics, Mathematics, Psychology and Statistics, or from any of the graduate programs in the Division of the Biological Sciences. Please consult the listings elsewhere in these Announcements or on the University of Chicago web page for current lists of such courses. Courses in engineering applications of computational neuroscience are also available through a limited reciprocal course arrangement with the Department of Biomedical Engineering at the Illinois Institute of Technology. Students must pass a qualifying examination with both written and oral components at the end of their second year. In addition to satisfying course requirements, students must write and defend a dissertation based on original and publishable research. Students are expected to participate in the ongoing computational neuroscience seminar series, as well as occasional workshops, that are conducted during their stay in the program.

M.D./Ph.D. Program

Students interested in earning both an M.D. and a Ph.D. in computational neuroscience at the University of Chicago can follow one of two routes. The first is to apply to the Medical Science Training Program (MSTP) within the Pritzker School of Medicine. The MSTP training grant provides support for both the M.D. and Ph.D. components of the training. Second, a student in the Pritzker School of Medicine may take a leave of absence from the School of Medicine after the first two, preclinical years of medical training and apply to the Ph.D. program in the normal fashion. The student would then return to finish the two clinical years of medical studies after completing the Ph.D. Several of the preclinical medical school courses may be used as electives in the computational neuroscience Ph.D. program. Students with an undergraduate degree in one of the engineering disciplines can earn an M.D. through the Pritzker School of Medicine and a Ph.D. in Biomedical Engineering through the Department of Biomedical Engineering at the Illinois Institute of Technology (which is located approximately three miles north of the University of Chicago Campus). They are able to emphasize neural engineering in the Biomedical Engineering Ph.D. program and take courses in the Committee on Computational Neuroscience.

Admission to Graduate Programs

Admission to the Committee on Computational Neuroscience is coordinated through the Neuroscience Cluster within the Division of the Biological Sciences. The most recent admissions policies, including an online application, can be viewed at http://gradprograms.bsd.uchicago.edu/. Students preparing an application must submit transcripts of their undergraduate and prior graduate work, recent test scores from the general Graduate Record Exam, and three letters of recommendation under separate cover. Foreign applicants from non English speaking nations must also submit TOEFL scores with their application materials.
Applications are due by December 1st for students beginning their studies in the following autumn quarter.

**FINANCIAL AID**

Students enrolled in the Ph.D. program receive financial support in the form of a stipend and tuition payments as long as they remain in good standing. Students are encouraged to apply for individual fellowships from the National Science Foundation or other sources.

**RESEARCH OPPORTUNITIES**

Unparalleled research opportunities and facilities are available through the facilities and faculty on the University of Chicago campus, at the Argonne National Laboratory, the Illinois Institute of Technology campus and corporate partners. Research interests of faculty in the Committee on Computational Neuroscience can be accessed through the committee web page at http://neuroscience.uchicago.edu/?p=neuro/cns. Ongoing research topics range from work at the molecular level to studies in cognitive neuroscience. These projects involve modern methods of recording and imaging the activities of individual neurons, populations of neurons and human brain regions. Quantitative approaches currently utilized by faculty and students include those derived from non-linear dynamics, large scale simulations of neural activity, time series analysis, and pattern recognition. Research projects address basic problems in neuroscience using approaches that range from molecular neurobiology to cognitive neuroscience, biomedical applications such as the construction of neural prostheses and the control of epilepsy, and technological applications to computational vision and language.

**COMPUTATIONAL NEUROSCIENCE COURSES**

**CPNS 30000. Cellular Neurobiology. 100 Units.**

This course is concerned with the structure and function of the nervous system at the cellular level. The cellular and subcellular components of neurons and their basic membrane and electrophysiological properties will be described. Cellular and molecular aspects of interactions between neurons will be studied. This will lead to functional analyses of the mechanisms involved in the generation and modulation of behavior in selected model systems.

Instructor(s): C. Hansel and P. Lloyd Terms Offered: Autumn
CPNS 30107. Behavioral Neuroscience. 100 Units.
This course is concerned with the structure and function of systems of neurons, and how these are related to behavior. Common patterns of organization are described from the anatomical, physiological, and behavioral perspectives of analysis. The comparative approach is emphasized throughout. Laboratories include exposure to instrumentation and electronics, and involve work with live animals. A central goal of the laboratory is to expose students to in vivo extracellular electrophysiology in vertebrate preparations. Laboratories will be attended only on one day a week but may run well beyond the canonical period.
Instructor(s): D. Margoliash Terms Offered: Winter
Equivalent Course(s): NURB 30107, PSYC 40107

CPNS 30116. Survey Systems Neuroscience. 100 Units.
This lab-centered course teaches students the fundamental principles of vertebrate nervous system organization. Students learn the major structures and the basic circuitry of the brain, spinal cord and peripheral nervous system. Somatic, visual, auditory, vestibular and olfactory sensory systems are presented in particular depth. A highlight of this course is that students become practiced at recognizing the nuclear organization and cellular architecture of many regions of brain in rodents, cats and primates.
Instructor(s): C. Hansel, N. Hatsopoulos Terms Offered: Autumn

CPNS 31000. Mathematical Methods for Biological Sciences I. 100 Units.
This course builds on the introduction to modeling course biology students take in the first year (BIOS 20151 or 152). It begins with a review of one-variable ordinary differential equations as models for biological processes changing with time, and proceeds to develop basic dynamical systems theory. Analytic skills include stability analysis, phase portraits, limit cycles, and bifurcations. Linear algebra concepts are introduced and developed, and Fourier methods are applied to data analysis. The methods are applied to diverse areas of biology, such as ecology, neuroscience, regulatory networks, and molecular structure. The students learn computations methods to implement the models in MATLAB.
Instructor(s): D. Kondrashov Terms Offered: Autumn. L
Prerequisite(s): BIOS 20151 or BIOS 20152 or consent of the instructor
Equivalent Course(s): BIOS 26210, PSYC 36210

CPNS 31100. Mathematical Methods for Biological Sciences II. 100 Units.
This course is a continuation of BIOS 26210. The topics start with optimization problems, such as nonlinear least squares fitting, principal component analysis and sequence alignment. Stochastic models are introduced, such as Markov chains, birth-death processes, and diffusion processes, with applications including hidden Markov models, tumor population modeling, and networks of chemical reactions. In computer labs, students learn optimization methods and stochastic algorithms, e.g., Markov Chain, Monte Carlo, and Gillespie algorithm. Students complete an independent project on a topic of their interest.
Instructor(s): D. Kondrashov Terms Offered: Winter. L
Prerequisite(s): BIOS 26210
Equivalent
Equivalent Course(s): BIOS 26211, PSYC 36211
CPNS 31358. Simulation, Modeling, and Computation in Biophysics. 100 Units.
This course develops skills for modeling biomolecular systems. Fundamental knowledge covers basic statistical mechanics, free energy, and kinetic concepts. Tools include molecular dynamics and Monte Carlo simulations, random walk and diffusion equations, and methods to generate random Gaussian and Poisson distributors. A term project involves writing a small program that simulates a process. Familiarity with a programming language or Matlab would be valuable.
Instructor(s): B. Roux
Terms Offered: Winter
Prerequisite(s): BIOS 20200 and Bios 26210-26211, or consent from instructor
Equivalent Course(s): BIOS 21358, BCMB 31358

CPNS 32111. Modeling and Signal Analysis for Neuroscientists. 100 Units.
The course provides an introduction into signal analysis and modeling for neuroscientists. We cover linear and nonlinear techniques and model both single neurons and neuronal networks. The goal is to provide students with the mathematical background to understand the literature in this field, the principles of analysis and simulation software, and allow them to construct their own tools. Several of the 90-minute lectures include demonstrations and/or exercises in Matlab.
Instructor(s): W. van Drongelen
Terms Offered: Spring
Prerequisite(s): BIOS 26210 and 26211, or consent of instructor
Equivalent Course(s): BIOS 24408

CPNS 33200. Computational Approaches for Cognitive Neuroscience. 100 Units.
This course is concerned with the relationship of the nervous system to higher order behaviors such as perception and encoding, action, attention, and learning and memory. Modern methods of imaging neural activity are introduced, and information theoretic methods for studying neural coding in individual neurons and populations of neurons are discussed.
Instructor(s): N. Hatsopoulos
Terms Offered: Spring
Prerequisite(s): BIOS 24222 or CPNS 33100
Equivalent Course(s): PSYC 34410, ORGB 34650

CPNS 34206. Peering Inside the Black Box: Neocortex. 100 Units.
The neocortex is the multilayered outermost structure of the mammalian brain. It is the site of higher brain functions including reasoning and creativity. However, the complexity of the neocortex—it is comprised of ~20 billion neurons which have 0.15 quadrillion connections between them—seems to preclude any hope of achieving a fundamental understanding of the system. Recent technological innovations have opened novel avenues of investigation making realization of the neocortex an increasingly tractable problem. This course will place particular emphasis on how to critically read scientific papers as we evaluate and discuss current experimental approaches to the neocortex. Integral to this evaluation will be the detailed discussion of the latest technological approaches.
Instructor(s): J. MacLean
Terms Offered: Autumn
Prerequisite(s): BIOS 24205 or consent of instructor.
Equivalent Course(s): BIOS 24206
CPNS 34231. Methods in Computational Neuroscience. 100 Units.
Topics include (but are not limited to): Hodgkin-Huxley equations, Cable theory, Single neuron models, Information theory, Signal Detection theory, Reverse correlation, Relating neural responses to behavior, and Rate vs. temporal codes. Instructor(s): S. Bensmaia Terms Offered: Winter. L.
Prerequisite(s): BIOS 26210 and BIOS 26211 which must be taken concurrently, or consent of instructor.
Equivalent Course(s): BIOS 24231

CPNS 34600. Neurobiology of Disease I. 100 Units.
Instructor(s): C. Gomez Terms Offered: Winter

CPNS 34700. Neurobiology of Disease II. 100 Units.
This seminar course is devoted to understanding pathogenic mechanisms of neuronal death, neurodegenerative disease, and neuronal repair. Weekly seminars are given by experts in the basic and clinical aspects of neurodegenerative diseases. For each lecture, students are provided with a brief description of clinical and pathological features of a given set or mechanistic category of neurodegenerative diseases that is followed by a more detailed description of the current status of knowledge of several of the prototypical pathogenic mechanisms. Instructor(s): C. Gomez, Staff Terms Offered: Spring
Prerequisite(s): BIOS 24246
Equivalent Course(s): BIOS 24247, NURB 34700

CPNS 35510. Theoretical Neuroscience: Single Neuron Dynamics and Computation. 100 Units.
This course is the first part of a three-quarter sequence in theoretical/computational neuroscience. It will focus on mathematical models of single neurons. Topics will include: basic biophysical properties of neurons; Hodgkin-Huxley model for action potential generation; 2D models, phase-plane analysis and bifurcations leading to action potential generation; integrate-and-fire-type models; noise; characterization of neuronal activity with stochastic inputs; spatially extended models; models of synaptic currents and synaptic plasticity; unsupervised learning; supervised learning; reinforcement learning.
Terms Offered: Autumn
Prerequisite(s): Prior exposure to differential equations, linear algebra, probability theory
Equivalent Course(s): STAT 42510
CPNS 35520. Theoretical Neuroscience: Network Dynamics and Computation. 100 Units.
This course is the second part of a three-quarter sequence in theoretical/computational neuroscience. It will focus on mathematical models of networks of neurons. Topics will include: firing rate models for populations of neurons; spatially extended firing rate models; models of visual cortex; models of brain networks at different levels; characterization of properties of specific brain networks; models of networks of binary neurons, mean rates, correlations, reductions to rate models; learning in networks of binary neurons, associative memory models; models of networks of spiking neurons: asynchronous vs synchronous states; oscillations in networks of spiking neurons; learning in networks of spiking neurons; models of working memory; models of decision-making.
Terms Offered: Winter
Prerequisite(s): Prior exposure to differential equations, linear algebra, probability theory, STAT 42510 or instructor consent.
Equivalent Course(s): STAT 42520

CPNS 35600. Theoretical Neuroscience: Statistics and Information Theory. 100 Units.
This course is the third part of a three-quarter sequence in theoretical/computational neuroscience. It begins with the spike sorting problem, used as an introduction to inference and statistical methods in data analysis. We then cover the two main sections of the course: I) Encoding and II) Decoding in single neurons and populations. The encoding section will cover receptive field analysis (STA, STC and non-linear methods such as maximally informative dimensions) and will explore linear-nonlinear-Poisson models of neural encoding as well as generalized linear models and newer population coding models. The decoding section will cover basic methods for inferring the stimulus from spike train data, including both linear and correlational approaches to population decoding. The course will use examples from real data (where appropriate) in the problem sets which students will solve using MATLAB.
Instructor(s): S. Palmer Terms Offered: Spring
Prerequisite(s): Prior exposure to basic calculus and probability theory, CPNS 35500 or instructor consent.
Equivalent Course(s): ORGB 42600, STAT 42600