Committee on Computational Neuroscience

Chair

- David Freedman, Neurobiology

Professors

- Yali Amit, Statistics
- Ed Awh, Psychology
- Jack Cowan, Mathematics
- Jean Decety, Psychology
- Ruth Anne Eatock, Neurobiology
- David Freedman, Neurobiology
- William (Bill) Green, Neurobiology
- John Goldsmith, Linguistics
- Melina Hale, Organismal Biology and Anatomy
- Christian Hansel, Neurobiology
- Nicholas Hatsopoulos, Organismal Biology and Anatomy
- Leslie Kay, Psychology
- Yamuna Krishnan, Chemistry
- Daniel Margoliash, Organismal Biology and Anatomy
- John Maunsell, Neurobiology
- Howard Nusbaum, Psychology
- Eduardo Perozo, Biochemistry and Molecular Biology
- Brian Prendergast, Psychology
- S. Murray Sherman, Neurobiology
- Steven Shevell, Psychology
- V. Leo Towe, Neurology
- Wim van Drongelen, Pediatrics
- Ed Vogel, Psychology
- Xiaoxi Zhuang, Neurobiology

Associate Professors

- Jason MacLean, Neurobiology
- Sliman Bensmaia, Organismal Biology and Anatomy
- Wei Wei, Neurobiology

Assistant Professors

- Stephanie Cacioppo, Psychiatry and Behavioral Neuroscience
- Narayanan (Bobby) Kasthuri, Neurobiology
- Matthew Kaufman, Organismal Biology and Anatomy
- Stephanie Palmer, Organismal Biology and Anatomy
- Mark Sheffield, 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 fields.
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Grades 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 at least nine quarters of research. The formal courses are typically taken during the first two years 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 on-line application, can be viewed at https://biosciences.uchicago.edu/admissions. 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 Neuroscience web page at http://neuroscience.uchicago.edu/faculty/. 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 nonlinear 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, X. Zhuang, and R. A. Eatock Terms Offered: Autumn
Equivalent Course(s): NURB 31800

**CPNS 30107. Behavioral Neuroscience. 100 Units.**
This course provides an introduction to neuroethology, examining brain activity relative to behaviors and organisms evaluated from an adaptive and evolutionary perspective. It starts with a brief introduction to classical ethology, and then develops a series of example animal model systems. Both invertebrate and vertebrate models are considered although there is a bias towards the latter. Many of these are “champion” species. There is a heavier demand for reading original data papers than typical in introductory graduate level courses. An integral part of the course is a series of assignments where you develop grant proposals describing novel science experiments in the animal models, thereby challenging your knowledge of the material and teaching aspects of scientific writing. In recent years there has been more computational material presented. The course is not available to undergraduates without prior approval of the instructor.

Instructor(s): D. Margoliash Terms Offered: Spring
Note(s): The course is not available to undergraduates without prior approval of the instructor.
Equivalent Course(s): PSYC 40107, NURB 30107

**CPNS 30116. Survey of 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): S. Bensmaia Terms Offered: Autumn
Prerequisite(s): NSCI 20130. For Biological Sciences majors: Three quarters of a Biological Sciences fundamentals sequence
Equivalent Course(s): BIOS 24208, NURB 31600, NSCI 23500, ORGB 32500

**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 equivalent quantitative experience by consent of instructor, and three quarters of a Biological Sciences Fundamentals sequence or consent of the instructor.
Equivalent Course(s): PSYC 36210, BIOS 26210

**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 or 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 distributions. 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 31900. Intro To Faculty Research. 100 Units.
First-year students in Neurobiology and Computational Neuroscience are required to attend this chalk talk series where faculty members looking for rotating students present the research conducted in their labs.
Equivalent Course(s): NURB 32000

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): Undergraduates: Biology Major - BIOS 26210 and 26211, or consent of instructor. Neuroscience Major - NSCI 20130, BIOS 26210 and 26211, or consent of instructor.
Equivalent Course(s): NSCI 24000, BIOS 24408

CPNS 32300. Molecular Principles of Nervous System Development. 100 Units.
This elective course provides an overview of the fundamental questions in developmental neurobiology. It is based on primary research papers and highlights key discoveries in vertebrate and invertebrate animals that advanced our understanding of nervous system development. Topics covered, among others, will include neural stem cells, neuronal specification and terminal differentiation, and circuit assembly. Dogmas and current debates in developmental neurobiology will be discussed, aiming to promote critical thinking about the field. This advanced-level course is open to upper level undergraduate and graduate students and combines lectures, student presentations, and discussion sections. Neuroscience major undergrads need to have completed the Fundamentals of Neurosciences course.
Instructor(s): E. Grove, P. Kratsios Terms Offered: Spring.
Prerequisite(s): For undergrads: NSCI 20110, 20120, 20130 and a basic understanding of Genetics, or ‘BIOS 20187’ (Fundamentals of Genetics) is recommended, but not required.
Equivalent Course(s): DVBI 32300, NSCI 22300, NURB 32300

CPNS 33200. Computational Approaches to Cognitive Neuroscience. 100 Units.
This course is concerned with the relationship of the nervous system to higher order behaviors (e.g., perception, object recognition, action, attention, learning, memory, and decision making). Psychophysical, functional imaging, and electrophysiological methods are introduced. Mathematical and statistical methods (e.g. neural networks and algorithms for studying neural encoding in individual neurons and decoding in populations of neurons) are discussed. Weekly lab sections allow students to program cognitive neuroscientific experiments and simulations.
Instructor(s): N. Hatsopoulos Terms Offered: Winter.
Prerequisite(s): For Neuroscience Majors: NSCI 20110, NSCI 20130, BIOS 26210, and knowledge using Matlab, or consent of instructor.
Equivalent Course(s): NSCI 23600, PSYC 34410, ORGB 34650, BIOS 24232

CPNS 34133. Neuroscience of Seeing. 100 Units.
This course focuses on the neural basis of vision, in the context of the following two questions: 1. How does the brain transform visual stimuli into neuronal responses? 2. How does the brain use visual information to guide behavior? The course covers signal transformation throughout the visual pathway, from retina to thalamus to cortex, and includes biophysical, anatomical, and computational studies of the visual system, psychophysics, and quantitative models of visual processing. This course is designed as an advanced neuroscience course for undergraduate and graduate students. The students are expected to have a general background in neurophysiology and neuroanatomy.
Instructor(s): W. Wei, J. Maunsell, M. Sherman, S. Shevell Terms Offered: Autumn.
Prerequisite(s): NSCI 20111 or BIOS 24110 or consent of instructor.
Equivalent Course(s): NSCI 22400, PSYC 24133, BIOS 24133, PSYC 34133, NURB 34133
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CPNS 34200. Gazing into 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. This course will not be taught in Autumn 2019. Course will resume in Autumn 2020.
Prerequisite(s): NSCI 20111, 20121, 20130 or consent of instructor. For Biology majors: Three quarters of a Biological Sciences Fundamentals sequence.
Equivalent Course(s): BIOS 24226, NSCI 22000

CPNS 34231. Methods in Computational Neuroscience. 100 Units.
Topics include (but are not limited to): relating neural data to behavior, Signal Detection theory, models of vision and artificial neural networks, Information Theory, Generalized Linear Models, dimensionality reduction, classification, and clustering.
Instructor(s): S. Bensmaia, D. Freedman, M. Kaufman Terms Offered: Winter. L.
Prerequisite(s): For Neuroscience Majors: NSCI 20130, BIOS 26210 and BIOS 26211 which must be taken concurrently, or consent of instructor.
Equivalent Course(s): BIOS 24231, PSYC 24231, NSCI 23700

CPNS 34600. Neurobiology of Disease I. 100 Units.
This graduate-level, 100-unit course has an unusual format aimed at fostering lively discussion and interaction. There will be 10 meetings spread at 1-month intervals over the winter, spring and fall quarters. Each meeting will focus on a topic such as Epilepsy, Alzheimer’s, or Autism, and feature a brief introduction (by a student) and chalk talks by two faculty, one on clinical aspects of the disease and one on basic research approaches. The student’s grade is based on the presentation at one meeting and participation across all meetings.
Instructor(s): C. Gomez, X. Zhuang Terms Offered: Autumn Spring Winter
Note(s): Class meets on the 3rd Wednesday of the month; 100 credits given after 3 quarters attendance.
Equivalent Course(s): NURB 34600

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.
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: Not offered in 2019-2020
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 begins with 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 neural 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 alongside newer population coding models. The decoding section will cover basic methods for inferring stimuli or behaviors 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.
Prerequisite(s): Prior exposure to basic calculus and probability theory, CPNS 35500 or instructor consent.
Equivalent Course(s): ORGB 42600, STAT 42600

CPNS 38800. Neuroscience Ethics. 100 Units.
Neuroscience Senior Ethics class: compulsory for Neurobiology and Computational Neuroscience PhD students in their 4th year (to fulfill BSD ethics requirement). The course, directed by the graduate programs chairs, will consist of 4 sessions with invited speakers to be held in May and June.
Instructor(s): D. McGehee Terms Offered: Winter
Equivalent Course(s): NURB 38800

CPNS 39900. Readings: Computational Neuroscience. 300.00 Units.
Subject matter for individual tutorial-based study is selected through prior consultation and is given under the guidance of a faculty member. The student and faculty member must indicate at time of registration whether the course will be taken on a letter grade or pass/fail basis.

CPNS 40100. Research: Computational Neuroscience. 300.00 Units.
The student conducts original investigation under the direction of a faculty member. The research is presented and defended as a dissertation in candidacy for the degree of Doctor of Philosophy.

CPNS 42900. Mathematical Modeling of Large-Scale Brain Activity I. 100 Units.
An independent study in mathematical modeling.
Equivalent Course(s): MATH 42900

CPNS 42901. Mathematical Modeling of Large-Scale Brain Activity II. 100 Units.
Independent study in Mathematical Modeling of Large-Scale Brain Activity 2.
Equivalent Course(s): MATH 42901

CPNS 70000. Advanced Study: Computational Neuroscience. 300.00 Units.
Advanced Study: Computational Neuroscience