Committee on Computational Neuroscience

Chair

- Brent Doiron, Neurobiology, Statistics

Professors

- Yali Amit, Statistics
- Ed Awh, Psychology
- Marlene Cohen, Neurobiology
- Brent Doiron, Neurobiology, Statistics
- Ruth Anne Eatock, Neurobiology
- David Freedman, Neurobiology
- William (Bill) Green, Neurobiology
- 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
- Jason MacLean, Neurobiology
- Howard Nusbaum, Psychology
- Eduardo Perozo, Biochemistry and Molecular Biology
- Brian Prendergast, Psychology
- S. Murray Sherman, Neurobiology
- Steven Shevell, Psychology
- V. Leo Towle, Neurology
- Wim van Drongelen, Pediatrics
- Ed Vogel, Psychology
- Joel Voss, Neurology
- Wei Wei, Neurobiology
- Xiaoxi Zhuang, Neurobiology

Associate Professors

- Narayanan (Bobby) Kasthuri, Neurobiology
- Anne-Marie Oswald, Neurobiology
- Stephanie Palmer, Organismal Biology and Anatomy
- Mark Sheffield, Neurobiology

Assistant Professors

- Jorge Jaramillo, Neurobiology
- Matthew Kaufman, Organismal Biology and Anatomy
- Ramon Nogueira Manas, Neurobiology
- Monica Rosenberg, Psychology
- Jai Yu, Psychology
- Zhuzhu Zhang, Human Genetics

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 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 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): R. A. Eatock, X. Zhuang, D. McGehee Terms Offered: Winter
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): NURB 30107, PSYC 40107

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): Oswald, A. M. Terms Offered: Autumn
Prerequisite(s): NSCI 20100, NSCI 20111, NSCI 20130.
Note(s): Undergrads by consent only
Equivalent Course(s): NURB 31600, ORGB 32500, NSCI 23500

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 to implement the models using Python in the Jupyter notebook platform.
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 courses 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.
Note(s): CB.
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 Mathlab would be valuable.
Instructor(s): B. Roux Terms Offered: Winter
Prerequisite(s): Three quarters of a Biological Sciences Fundamentals sequence, BIOS 20200 and BIOS 26210-26211, or consent from instructor
Note(s): CB
Equivalent Course(s): BIOS 21358, BCMB 31358, CHEM 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.
Terms Offered: Autumn
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. L.
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.
Note(s): CB.
Equivalent Course(s): BIOS 24408, NSCI 24000

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 Neuroscience sequence.
Instructor(s): P. Kratsios, C. Martineau 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): NURB 32300, DVBI 32300, NSCI 22300

CPNS 32610. Theories of Cortical Circuit Dynamics and Computation. 100 Units.
This course will present mathematical frameworks for the construction and analysis of contemporary models of cortical circuits. Topics will include: models of neuronal spiking and synaptic dynamics, balanced networks, mean field theory of cortical networks, diffusion approximation and linear response in stochastically forced neuronal networks, models of decision making and working memory, information flow in cortical networks.
Instructor(s): B. Doiron Terms Offered: Winter
Equivalent Course(s): STAT 42610, CAAM 42610

CPNS 33600. Experimental Design in Motor Control Research. 100 Units.
Motor control research examines how animals move. Aims of motor control studies range widely from exploring fundamental principles of motor systems and evolved specializations in animal models, to understanding and improving motor function in disease and injury, to increasing athletic performance. In this course, we will examine experimental design in research through the lens of motor control studies.
Instructor(s): M. Hale Terms Offered: Autumn

Equivalent Course(s): NURB 33600

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): M. Kaufman Terms Offered: Winter
Prerequisite(s): For Neuroscience Majors: NSCI 20130, BIOS 26210 and BIOS 26211 which must be taken concurrently, or consent of instructor.
Equivalent Course(s): NSCI 23700, PSYC 24231

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): Garcia, A. 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 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.
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): STAT 42600, ORGB 42600

CPNS 36050. Principles of Data Science and Engineering for Laboratory Research. 100 Units.
The quantity of data gathered from laboratory experiments is constantly increasing. This course will explore the latest concepts, techniques and best-practice to create efficient data analysis pipelines. We will focus on the python ecosystem. By the end of the course, you are expected to be able to apply appropriate tools to streamline your own data analysis.
Instructor(s): J. Yu Terms Offered: Autumn
Prerequisite(s): Familiarity with coding in python.
Equivalent Course(s): NURB 36050, PSYC 46050

CPNS 37700. Talking Neuroscience. 100 Units.
This course is designed to help students effectively prepare for and deliver student talks. This course is required for all students who are participating in Student Seminars for the first time. Each enrolled student will be required to meet with the faculty one week prior to their seminar to receive feedback on the structure of their talk. A group discussion of the strengths and weaknesses of each presentation will be held after every seminar.
Equivalent Course(s): NURB 37700

CPNS 38800. Neuroscience Ethics. 100 Units.
Neuroscience Senior Ethics class: compulsory for Neurobiology and Computational Neuroscience PhD students in their 4th and/or 5th year (to fulfill BSD ethics requirement). The course, offered every other year, is directed by the graduate programs chairs, and consists of 4 sessions with invited speakers to be held in May (first four Tuesdays).
Instructor(s): D. McGehee Terms Offered: Spring
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 70000. Advanced Study: Computational Neuroscience. 300.00 Units.
Advanced Study: Computational Neuroscience