INTERDEPARTMENTAL NEUROSCIENCE PROGRAM

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http://medicine.yale.edu/inp
M.S., M.Phil., Ph.D.

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Professors
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Associate Professors Nii Addy (Psychiatry; Cellular and Molecular Physiology), Meenakshi Alreja (Psychiatry; Neuroscience), Alan Anticevic (Psychiatry; Psychology), Sviatoslav Bagriantsev (Cellular and Molecular Physiology), Abhishek Bhattacharjee (Computer Science), Thomas Biederer (Neurology; Neuroscience), William Cafferty (Neurology; Neuroscience), Jessica Cardin (Neuroscience), Sreeganga Chandra (Neurology; Neuroscience), Steve Chang (Psychology; Neuroscience), Damon Clark (Molecular, Cellular, and Developmental Biology; Physics), Philip Corlett (Psychiatry; Psychology), Marcelo de Oliveira Dietrich (Comparative Medicine; Neuroscience), George Dragoi (Psychiatry; Neuroscience), Tore Eid (Laboratory Medicine; Neurosurgery), Irina Esterlis (Psychiatry; Psychology), Sourav Ghosh (Neurology; Pharmacology), Elena Gracheva (Cellular and Molecular Physiology; Neuroscience), Marc Hammarlund (Genetics; Neuroscience), Michelle Hampson (Radiology and Biomedical Imaging; Psychiatry; Child Study Center), Michael Higley (Neuroscience), Avram Holmes (Psychology), Erdem Karatekin (Molecular Biophysics and Biochemistry), In-Jung Kim (Ophthalmology and Visual Science; Neuroscience), Hedy Kober (Psychiatry; Psychology), Smita Krishnaswamy (Genetics; Computer Science), Ifat Levy (Comparative Medicine; Psychology; Neuroscience), Janghoo Lim (Genetics; Neuroscience), Angeliki Louvi (Neurosurgery; Neuroscience), John Murray (Psychiatry; Neuroscience; Physics), Dhasakumar Navaratnam (Neurology; Neuroscience), Timothy Newhouse (Chemistry), In-Hyun Park (Genetics), Maria Piñango (Linguistics), Helena Rutherford (Child Study Center; Psychology), Dustin Scheinost (Radiology and Biomedical Imaging; Child Study Center; Statistics and Data Science), Justus Verhagen (Neuroscience), Weimin Zhong (Molecular, Cellular, and Developmental Biology), Jiangbing Zhou (Neurosurgery; Biomedical Engineering)

Assistant Professors Moitrayee Bhattacharyya (Pharmacology), Joel Butterwick (Pharmacology), Rui Chang (Cellular and Molecular Physiology; Neuroscience), Alicia Che (Psychiatry), Youngsun Cho (Psychiatry; Child Study Center), Eyiyemisi Damisah (Neurosurgery; Neuroscience), Carolyn Fredericks (Neurology), Dylan Gee (Psychology), Jason Gerrard (Neurosurgery; Neuroscience), Matthew Girgenti (Psychiatry; Pediatrics; Neuroscience), Pallavi Gopal (Pathology), Junjie Guo (Neuroscience), Abha Gupta (Pediatrics; Neuroscience), Brian Hafler (Ophthalmology and Visual Science; Pathology), Ellen Hoffman (Child Study Center; Neuroscience), Monika Jadi (Psychiatry; Neuroscience), James Jeanne (Neuroscience), Al Kaye (Psychiatry), Liang Liang (Neuroscience), Samuel McDougle (Psychology), Anirvan Nandy (Neuroscience), Michael O’Donnell (Molecular, Cellular, and Developmental Biology), Candie Paulsen
FIELDS OF STUDY

The Interdepartmental Neuroscience Program (INP) offers flexible but structured interdisciplinary training for independent research and teaching in neuroscience. The goal of the program is to ensure that degree candidates obtain a solid understanding of cellular and molecular neurobiology, physiology and biophysics, neural development, systems and behavior, and neural computation. In addition to course work, graduate students participate in an annual research-in-progress talk and a regular journal club, organize the Interdepartmental Neuroscience Program Seminar Series, and attend other seminar programs, named lectureships, symposia, and an annual research retreat.

To enter the Interdepartmental Neuroscience Ph.D. program, students apply to the Neuroscience track within the interdepartmental graduate program in Biological and Biomedical Sciences (BBS), https://medicine.yale.edu/bbs.

SPECIAL REQUIREMENTS FOR THE PH.D. DEGREE

Each entering student is assigned a faculty advisory committee to provide guidance. This committee is responsible for establishing the student’s course of study and for monitoring the student’s progress. This committee will be subsequently modified to include faculty with expertise in the student’s emerging area of interest. Although each student’s precise course requirements are set individually to take account of background and educational goals, the course of study is based on a model curriculum beginning with five core required courses: Bioethics in Neuroscience (INP 580), Principles of Neuroscience (INP 701), Foundations of Cellular and Molecular Neurobiology (INP 702), Foundations of Systems Neuroscience (INP 703), and Comparative Neuroanatomy (INP 704), all completed in the first year of enrollment. During the second or third year of enrollment, students are required to take an advanced course on quantitative techniques. Collectively, these courses are designed to ensure broad competence in modern neuroscience. Students are also required to complete at two additional elective courses from a broad set of neuroscience-related courses. The Graduate School uses grades of Honors, High Pass, Pass, and Fail and requires two term grades of Honors during the first two years of study. Students are expected to maintain at least a High Pass average. Additional degree requirements are successful completion of both terms of Lab Rotation for First-Year Students (INP 511, INP 512); both terms of Second-Year Thesis Research (INP 513, INP 514); and RCR Refresher for Senior BBS Students (B&BS 503), completed during the fourth year of enrollment. This will ensure that degree candidates obtain a solid background in systems, cellular, and molecular approaches to neuroscience. Admission to candidacy requires passing a qualifying examination normally given during the second year, and submission of a dissertation prospectus (NIH NRSA grant format) before the end of the third year. In accordance with the expectations of the BBS program, Ph.D. students are expected to participate in two terms (or the equivalent) of teaching. Thesis committee meetings are required at six-month intervals. Also required is the completion and satisfactory defense of the thesis.
Requirements for M.D./Ph.D. students are the same as for Ph.D. students with the following differences: two laboratory rotations are completed while in the medical school prior to degree-program affiliation; three courses are required (Principles of Neuroscience, INP 701; Structural and Functional Organization of the Human Nervous System, INP 510; and one elective graduate-level course). Both terms of Second-Year Thesis Research (INP 513, INP 514) are required. M.D./Ph.D. students are required to serve for one term as teaching assistants; however, two terms of teaching are preferred.

**MASTER’S DEGREES**

**M.Phil.** See Degree Requirements under Policies and Regulations.

**M.S.** Awarded only to students who are not continuing for the Ph.D. degree and have successfully completed the equivalent of 30 credit hours in the doctoral program. This includes a passing grade in the five required courses plus two elective courses, a minimum of two Honors grades, and successful completion of both terms of Lab Rotation for First-Year Students (INP 511, INP 512) and both terms of Second-Year Thesis Research (INP 513, INP 514). Students are not admitted for this degree. Students who are eligible for or who have already received the M.Phil. will not be awarded the M.S.

Program information is available at [http://medicine.yale.edu/inp](http://medicine.yale.edu/inp).

**COURSES**

**INP 510a, Structural and Functional Organization of the Human Nervous System**

Thomas Biederer

An integrative overview of the structure and function of the human brain as it pertains to major neurological and psychiatric disorders. Neuroanatomy, neurophysiology, and clinical correlations are interrelated to provide essential background in the neurosciences. Lectures in neurocytology and neuroanatomy survey neuronal organization in the human brain, with emphasis on long fiber tracts related to clinical neurology. Lectures in neurophysiology cover various aspects of neural function at the cellular and systems levels, with a strong emphasis on the mammalian nervous system. Clinical correlations consist of sessions applying basic science principles to understanding pathophysiology in the context of patients. Seven three-hour laboratory sessions are coordinated with lectures throughout the course to provide an understanding of the structural basis of function and disease. Case-based conference sections provide an opportunity to integrate and apply the information learned about the structure and function of the nervous system in the rest of the course to solving a focused clinical problem in a journal club format. Variable class schedule; contact course instructors. This course is offered to graduate and M.D./Ph.D. students only and cannot be audited.

**INP 511a, Lab Rotation for First-Year Students**

Charles Greer

Required of all first-year Neuroscience track graduate students. Rotation period is one term. Grading is Satisfactory/Unsatisfactory.

**INP 513a and INP 514a, Second-Year Thesis Research**

Staff

Required of all second-year INP graduate students. Grading is Satisfactory/Unsatisfactory.
INP 519a, Tutorial  Staff
By arrangement with faculty and approval of DGS.

INP 523a / ENAS 880a, Imaging Drugs in the Brain  Evan Morris, Kelly Cosgrove, and Michelle Hampson
Seminar course to explore the uses of functional imaging (PET and fMRI) to study the mechanisms of action and long-term effects of drugs (legal and illegal) on brain function. Basic research findings are the main topics, augmented by some discussion of imaging in drug development by Pharma. The central theme of the course is experiment design: how to design the proper imaging experiment to ask the question. What are the endpoints of the experiment? What are the limitations of interpretation? What are the proper controls and what are the proper analyses to ensure reliable, interpretable results? The syllabus is comprised primarily of classic journal articles, in addition to the occasional book chapter or review article. Most class periods begin with a short lecture to cover methodological concepts, followed by discussion of reading material. A number of class periods are organized as games, contests, or other in-class exercises. The emphasis is on formulating the question and designing the experiment. Topics include basic understanding of imaging technology (brief physics, biochemistry, and mathematics) as it relates to imaging of drugs, receptors, neurotransmitters; understanding the primary outcomes of imaging experiments; imaging experiment design; recent findings related to drug abuse; common neurophysiological pathways of addictive drugs (how to image reward); and uses of imaging in drug development (what do drug companies want to measure?). Weekly homework: concise written synopses of assigned articles (students routinely endorse the synopses as the best way to learn the material).

INP 562b / AMTH 765b / CB&B 562b / ENAS 561b / MB&B 562b / MCDB 562b / PHYS 562b, Modeling Biological Systems II  Joe Howard
This course covers advanced topics in computational biology. How do cells compute, how do they count and tell time, how do they oscillate and generate spatial patterns? Topics include time-dependent dynamics in regulatory, signal-transduction, and neuronal networks; fluctuations, growth, and form; mechanics of cell shape and motion; spatially heterogeneous processes; diffusion. This year, the course spends roughly half its time on mechanical systems at the cellular and tissue level, and half on models of neurons and neural systems in computational neuroscience. Prerequisite: a 200-level biology course or permission of the instructor.

INP 575a / CPSC 575a / ENAS 575a, Computational Vision and Biological Perception  Steven Zucker
An overview of computational vision with a biological emphasis. Suitable as an introduction to biological perception for computer science and engineering students, as well as an introduction to computational vision for mathematics, psychology, and physiology students.

INP 585b / ENAS 585b, Fundamentals of Neuroimaging  Fahmeed Hyder, Elizabeth Goldfarb, and Douglas Rothman
The neuroenergetic and neurochemical basis of several dominant neuroimaging methods, including fMRI. Topics range from technical aspects of different methods to interpretation of the neuroimaging results. Controversies and/or challenges for application of fMRI and related methods in medicine are identified.
INP 610a / GENE 680a, Advanced Topics in Neurogenomics  Kristen Brennand and Laura Huckins
This course focuses on the rapidly changing field of functional genomics of psychiatric disease, centered on validations using human cell-based models. It is designed for students who already have basic knowledge of neuroscience and human genetics.

INP 701a, Principles of Neuroscience  Angeliki Louvi and William Cafferty
General neuroscience seminar: lectures, readings, and discussion of selected topics in neuroscience. Emphasis is on how approaches at the molecular, cellular, physiological, and organismal levels can lead to understanding of neuronal and brain function.

INP 702a, Foundations of Cellular and Molecular Neurobiology  Michael Higley and Janghoo Lim
A comprehensive overview of cellular and molecular concepts in neuroscience. Each exam (of three) covers one-third of the course (cell biology, electrophysiology, and synaptic function) and is take-home, with short answer/essay questions.

INP 720a / MCDB 720a, Neurobiology  Haig Keshishian and Paul Forscher
Examination of the excitability of the nerve cell membrane as a starting point for the study of molecular, cellular, and intracellular mechanisms underlying the generation and control of behavior.