INTERDEPARTMENTAL
NEUROSCIENCE PROGRAM

Hope Memorial Building 212, 203.785.5932
http://medicine.yale.edu/inp
M.S., M.Phil., Ph.D.

Director of Graduate Studies
Charles Greer (Neurosurgery; Neuroscience)
(LH 412, 203.785.4034, charles.greer@yale.edu)

Professors
Amy Arnsten (Neuroscience; Psychology),
Anton Bennett (Pharmacology; Comparative Medicine),
Hilary Blumberg (Psychiatry; Child Study Center; Radiology & Biomedical Imaging),
Hal Blumenfeld (Neurology; Neuroscience; Neurosurgery),
Angélique Bordey (Neurosurgery; Cellular & Molecular Physiology),
Kristen Brennand (Psychiatry; Genetics),
Tyrone Cannon (Psychology; Psychiatry),
Lawrence Cohen (Cellular & Molecular Physiology),
Daniel Colón-Ramos (Cell Biology; Neuroscience),
Lawrence Cohen (Neuroscience),
R. Todd Constable (Radiology & Biomedical Imaging; Neurosurgery),
Kelly Cosgrove (Psychiatry; Radiology & Biomedical Imaging; Neuroscience),
Michael Crair (Neuroscience; Ophthalmology & Visual Science),
Pietro De Camilli (Cell Biology; Neuroscience),
Jaime Grutzendler (Neurology; Neuroscience),
David Hafler (Neurology; Immunobiology),
Joy Hirsch (Psychiatry; Comparative Medicine; Neuroscience),
Tamas Horvath (Comparative Medicine; Neuroscience),
Arthur Horwich (Genetics; Pediatrics),
Jonathon Howard (Molecular Biophysics & Biochemistry; Physics),
Fahmeez Haider (Radiology & Biomedical Imaging; Biomedical Engineering),
Yong-Hui Jiang (Genetics),
Elizabeth Jonas (Internal Medicine; Neuroscience),
Leonard Katz (Pharmacology; Cellular & Molecular Physiology),
Haig Keshishian (Molecular, Cellular, & Developmental Biology),
Jeffery Koester (Neurology; Neuroscience),
Anthony Koleske (Molecular Biophysics & Biochemistry),
John Krystal (Psychiatry; Neuroscience),
Robert LaMotte (Anesthesiology; Neuroscience),
Chiang-shan Ray Li (Psychiatry; Neuroscience),
Gregory McCarthy (Psychology),
James McPartland (Child Study Center; Psychology),
Mark Mooseker (Molecular, Cellular, & Developmental Biology; Cell Biology),
Evan Morris (Radiology & Biomedical Imaging; Biomedical Engineering; Psychiatry),
Angus Nairn (Psychiatry; Pharmacology),
Michael Nitabach (Cellular & Molecular Physiology; Genetics),
Marina Picciotto (Psychiatry; Pharmacology; Neuroscience),
Vincent Pieribone (Cell Biology; Neuroscience),
Christopher Pittenger (Psychiatry; Child Study Center),
Marc Potenza (Psychiatry; Child Study Center; Neuroscience),
Pasko Rakic (Neuroscience; Psychology),
Carla Rothlin (Immunobiology; Pharmacology),
Gary Rudnick (Pharmacology),
W. Mark Saltzman (Biomedical Engineering; Cellular & Molecular
Physiology; Chemical & Environmental Engineering), Laurie Santos (Psychology), Joseph Santos-Sacchi (Surgery; Cellular & Molecular Physiology; Neuroscience), Nenad Sestan (Neuroscience; Comparative Medicine; Genetics; Psychiatry), Fred Sigworth (Cellular & Molecular Physiology; Biomedical Engineering), Dana Small (Psychiatry; Psychology), Stephen Strittmatter (Neurology; Neuroscience), Jane Taylor (Psychiatry; Psychology), Susumu Tomita (Cellular & Molecular Physiology; Neuroscience), Nicholas Turk-Browne (Psychology), Flora Vaccarino (Child Study Center; Neuroscience), Christopher van Dyck (Psychiatry; Neuroscience; Neurology), Stephen Waxman (Neurology; Pharmacology; Neuroscience), David Zenisek (Cellular & Molecular Physiology; Ophthalmology & Visual Science), Z. Jimmy Zhou (Ophthalmology & Visual Science; Cellular & Molecular Physiology; Neuroscience), Steven Zucker (Computer Science; Biomedical Engineering)

**Associate Professors** Nii Addy (Psychiatry; Cellular & Molecular Physiology), Meenakshi Alreja (Psychiatry; Neuroscience), Alan Anticevic (Psychiatry; Psychology), Sviatoslav Bagriantsiev (Cellular & 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, & 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 & Molecular Physiology; Neuroscience), Marc Hammarlund (Genetics; Neuroscience), Michelle Hampson (Radiology & Biomedical Imaging; Psychiatry; Child Study Center), Michael Higley (Neuroscience), Avram Holmes (Psychology), Erdem Karatekin (Cellular & Molecular Physiology; Molecular Biophysics & Biochemistry), In-Jung Kim (Ophthalmology & 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 & Biomedical Imaging; Child Study Center; Statistics & Data Science), Justus Verhagen (Neuroscience), Weimin Zhong (Molecular, Cellular, & Developmental Biology), Jiangbing Zhou (Neurosurgery; Biomedical Engineering)

**Assistant Professors** Moitrayee Bhattacharyya (Pharmacology), Joel Butterwick (Pharmacology), Rui Chang (Cellular & Molecular Physiology; Neuroscience), Alicia Che (Psychiatry), Youngsun Cho (Psychiatry; Child Study Center), Eyiymesi Damisah (Neurosurgery; Neuroscience), Carolyn Fredericks (Neurology), Dylan Gee (Psychology), Jason Gerrard (Neurosurgery; Neuroscience), Matthew Girgenti (Computational & Systems Biology), Elizabeth Goldfarb (Psychiatry; Psychology), Pallavi Gopal (Pathology), Junjie Guo (Neuroscience), Abha Gupta (Pediatrics; Neuroscience), Brian Hafler (Ophthalmology & 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, & Developmental Biology), Candic Paulsen (Molecular Biophysics & Biochemistry), Albert Powers (Psychiatry; Psychology), Hyejung Seo
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.

COURSES

INP 507b, Cellular and Molecular Mechanisms of Neurological Disease  Sreeganga Chandra and William Cafferty
This course focuses on diseases/disorders such as Alzheimer’s, Parkinson’s, schizophrenia, multiple sclerosis, autism, and epilepsy, in which modern neuroscience has advanced mechanistic explanations for clinical conditions. The course highlights recent genetic, molecular, electrophysiological, and imaging experiments in parsing disease mechanisms.

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 two-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, Second-Year Thesis Research  Charles Greer
Required of all second-year INP graduate students. Grading is Satisfactory/Unsatisfactory.

INP 521b, Neuroimaging in Neuropsychiatry II: Clinical Applications  Irina Esterlis
Neuroimaging methodologies including Positron Emission Tomography (PET), Single Photon Emission Computed Tomography (SPECT), Magnetic Resonance Imaging (MRI), functional Magnetic Resonance Imaging (fMRI), and Magnetic Resonance Spectroscopy (MRS) are rapidly evolving tools used to study the living human brain. Neuroimaging has unprecedented implications for routine clinical diagnosis, for assessment of drug efficacy, for determination of psychotropic drug occupancy, and for the study of pathophysiological mechanisms underlying neurologic and psychiatric disorders. The course is designed to provide an overview of the application of state-of-the-art neuroimaging methods to research in neurologic and psychiatric disorders.

INP 542a, Developing and Writing Fellowship Proposals  Steve Chang, Jonathan Demb, and Thomas Biederer
In this course, students learn how fellowship award review panels are run and what the selection criteria are. The NIH National Research Service Award (NRSA) Fellowship is used as the main framework for learning. Students develop NIH-style Biosketches, learn to generate key points in the NIH Research Training Plan, and learn how to write a Specific Aims page and what to consider for the Project Narrative. Through student-led groups, students learn how to critique Specific Aims pages, with input from instructors, and then develop Project Narratives with specific focuses on effective communication of the underlying hypotheses, impact and significance, and experimental plans.

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 580b, Bioethics in Neuroscience  Charles Greer
This course is an introduction to ethics and ethical decision-making in the neurosciences. Format for the course is an informal discussion. Each week we are joined by members of the Yale faculty and community who share their experiences and expertise as it relates to the topic of the week. Required of first-year INP students. Grading is Satisfactory/Unsatisfactory and is based on attendance/participation, weekly reaction papers, and a final term paper. Enrollment limited to Neuroscience track students.

INP 585b / ENAS 585b, Fundamentals of Neuroimaging  Fahmeed Hyder 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 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 703b, Foundations of Systems Neuroscience**  Amy Arnsten
An examination of the neural circuits that subserve sensory, motor, cognitive, and affective function, and their relationships to human disorders. A comparative species approach is used to highlight the evolution of neural circuits and their functions. Required of first-year Neuroscience track students.

**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.