An interdepartmental program

Neuroscience

Courses of Study:
Major (B.A. / B.S.)
Master of Science
Doctor of Philosophy

Objectives

Undergraduate Major
The major in neuroscience is designed to provide an interdisciplinary program of study of the neural mechanisms involved in the control of human or animal behavior. The major combines a strong foundation in basic science with more specialized courses in biology and psychology. This program is especially appropriate for students wishing to pursue further study in medicine, experimental psychology, or neuroscience.

Graduate Program in Neuroscience
The graduate program in neuroscience, leading to the M.S. and Ph.D. degrees, is designed to equip students with the advanced knowledge and training necessary to conduct research in this interdisciplinary field. The program comprises three broadly defined areas: behavioral neuroscience involves work with humans in neuropsychology, experimental cognitive neuroscience and sensory psychophysics, and with animal behavior and electrophysiology; cellular and molecular neuroscience provides training in electrophysiology, molecular biology, biophysics, and biochemistry appropriate to neurobiology; and computational and integrative neuroscience trains students in the use of experimental and theoretical methods for the analysis of brain function. A typical program will consist of laboratory rotations as well as formal courses, including an advanced course in the student's area of interest.

How to Become an Undergraduate Major

The neuroscience major requires a strong science courseload. There is a meeting each fall at which interested students can discuss the major with neuroscience faculty. Students can schedule an appointment with the undergraduate advising head for further information or to enroll in the major. The requirements are listed below and include many options. It is recommended that each major meet with his or her advisor to determine which options best satisfy each student's needs. Because of the number of basic science requirements, it is recommended that students begin enrolling in these courses early, especially those listed as prerequisites for advanced courses in the major. Students interested in senior research should contact prospective mentors by the spring of their junior year.

How to Be Admitted to the Graduate Program

The general requirements for admission to the Graduate School, given in an earlier section of this *Bulletin*, apply here. Applicants for admission to the neuroscience program are also required to take the Graduate Record Examination. The student's undergraduate curriculum should include related fundamental science courses.

Students currently enrolled in other programs at Brandeis may elect to switch over to obtain a neuroscience Ph.D. if they have already met or will meet the degree requirements for the neuroscience degree.

Faculty

John Lisman, Chair
(Biology, Volen National Center for Complex Systems)

Laurence Abbott
(Biology, Volen National Center for Complex Systems)

Susan Birren
(Biology, Volen National Center for Complex Systems)

Paul DiZio, Undergraduate Advising Head
(Psychology, Volen National Center for Complex Systems)

Irving Epstein
(Chemistry, Volen National Center for Complex Systems)

Leslie Griffith
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Jeffrey Hall
(Biology, Volen National Center for Complex Systems)

Donald Katz
(Psychology, Volen National Center for Complex Systems)

James Lackner
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Eve Marder
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Robert Sekuler
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Piali Sengupta
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Gina Turrigiano
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Xiao-Jing Wang
(Physics, Volen National Center for Complex Systems)

Kalpana White, Senior Honors Coordinator
(Biology, Volen National Center for Complex Systems)

Arthur Wingfield
(Psychology, Volen National Center for Complex Systems)

Requirements for the Undergraduate Major

A. All students will be required to take the core course in neurobiology, NBIO 140b (Principles of Neuroscience) and at least one core course in quantitative methods: BIOL 51b (Biostatistics), NBIO 136b (Computational Neuroscience), NPHY 115a (Dynamical Systems, Chaos, and Fractals), NPSY 137b (Cognitive Modeling), PSYC 51a (Statistics), or PSYC 210a (Advanced Psychological Statistics). A course taken to satisfy the quantitative method requirement cannot also count as an elective course.

Students must choose one of the two tracks described below—Option I leading to a B.A. degree in neuroscience, or Option II leading to a B.S. degree in neuroscience.

Among courses offered to fulfill the requirements of this concentration: no course may be taken pass/fail; no more than one grade of D in a semester course will be allowed.

Option I: The B.A. Degree in Neuroscience
The standard neuroscience option is designed to provide students with a general background in neuroscience. In addition to the courses required of all candidates (listed above), students must take six semester courses from those courses listed below under Neuroscience Electives—at least two courses must be selected from Group I and two from Group II. Students must also take at least nine semester courses from the Basic Science Electives.

Neuroscience Electives
Group 1: BIOL 42a (Physiology), NBIO 136b (Computational Neuroscience), 143b (Developmental Neurobiology), 145b (Systems Neuroscience), 147a (Neurogenetics), 148b (Cellular Neuroscience), BIOL 149b (Molecular Pharmacology), NBIO 150a (Autism and Human Developmental Disorders), NPHY 115a (formerly PHYS 115a) (Dynamical Systems, Chaos, and Fractals).

Group 2: NPSY 11b (Introduction to Behavioral Neuroscience), 12a (Sensory Processes), 22b (Introduction to Cognitive Neuroscience), 120b (Man in Space), 125a (Advanced Topics in Perception and Adaptation), 127a (Motor Control), 128b (Motor Control, Orientation, and Adaptation), 137b (Cognitive Modeling), 154a (Human Memory), 159a (Advanced Topics in Episodic Memory), 168b (Eletrophysiology of Human Memory), 174a (Visual Cognition), 175a (The Neuroscience of Vision), 196b (Advanced Topics in Cognition), 197a (Advanced Topics in Behavioral Neuroscience), 199a (Human Neuropsychology).

Group 3: BCHM 100a (Introductory Biochemistry), 101a (Advanced Biochemistry: Enzyme Mechanisms), BIOL 22a (Genetics and Molecular Biology), 22b (Cell Structure and Function), 50b (Biology of Behavior), 103b (Mechanisms of Cell Functions), 105b (Molecular Biology), 111a (Developmental Biology).

A student who has completed two courses in both Groups 1 and 2 may petition to substitute NEUR 98a,b (Readings in Neuroscience), or NEUR 99d (Senior Research) for one of the remaining two courses. Students must enroll in all laboratories that accompany electives used to satisfy these requirements (BIOL 18a and b must be taken along with BIOL 22a and b, but no additional concentration credit will be received).

Basic Science Electives
The basic science electives include all courses numbered 10 and above in chemistry, computer science, mathematics, and physics. Courses numbered below 10 may not be included in this group. Laboratory courses are counted as one-half of a regular semester course.

Option II: The B.S. Degree in Neuroscience
The B.S. program is an intensive neuroscience option designed to provide students with a strong background in neuroscience and associated areas. In addition to the courses required of all candidates (listed above), students must take seven semester courses from those listed above in Neuroscience Electives, with at least two courses selected from Group 1 and two from Group 2. Candidates for the B.S. must also take at least 10 semester courses from the offerings given above in Basic Science Electives. Courses numbered below 10 may not be included in this group.

B. Senior Research and Honors Program
Seniors can receive credit for senior research in neuroscience by petitioning the program committee during the fall of their senior year. Candidates must enroll in NEUR 99d or 99e to carry out a senior research project and submit a thesis. Candidates interested in honors must state this in their petition and also present an oral defense of their thesis.

Combined B.S./M.S. Program

Candidates for honors in neuroscience may be admitted to a special four-year B.S./M.S. program upon recommendation of the neuroscience program and approval by the Graduate School. Application to the Graduate School must be made by May 1 preceding the senior year. Applications should include a proposed course of study specifying how the degree requirements will be met, a transcript, a letter of recommendation from their research sponsor, and a brief description of the proposed research project. To qualify for the B.S./M.S. degree in neuroscience students must complete a total of 38 courses. These courses must include those needed to satisfy the requirements for the B.S. degree, as indicated above, plus three additional electives chosen from the neuroscience electives listed above. Of the 10 electives required for the B.S./M.S. degree, at least six must be at the graduate level (and completed with a grade of B- or above). In addition, a substantial research contribution is required and students must submit a research thesis to the neuroscience graduate committee for review. A thesis submitted for the master's degree may also be submitted for honors in neuroscience.

Special Notes Relating to Undergraduates

It is the policy of the neuroscience program to allow no more than two Advanced Placement courses per student to count toward the general science requirements for the neuroscience major. Please refer to the Advanced Placement chart for test score requirements.

Requirements for the Degree of Master of Science

Graduate students will be eligible for an M.S. in neuroscience if they complete six graduate-level courses in neuroscience that must include NBIO 140b with the balance of courses to be agreed upon with the neuroscience advising head. A grade of B- or better must be obtained in each course. In addition to coursework, students must complete a research project. The research component can be met by satisfactory performance in four laboratory rotations (including submission of written rotation reports) *or* submission of a research thesis to the Neuroscience Graduate Committee for review. All students are required to take CONT 300b (Ethical Practice in Health-Related Sciences), typically offered in the spring.

Residence Requirement
The minimum residence requirement for the M.S. degree is one year.

Requirements for the Degree of Doctor of Philosophy

Program of Study
NBIO 140b (Principles of Neuroscience) is required along with at least five additional graduate-level courses relevant to the student's area of interest. First- and second-year students shall enroll in NBIO 250d (Neuroscience Proseminar) and all students should enroll in NBIO 306d (Topics in Neurobiology). All students are required to take CONT 300b (Ethical Practice in Health-Related Sciences), typically in the spring of their first year.

The suggested schedule of coursework for the first two years is the following:

First Year
Fall: NBIO 140b, NBIO 148b, NBIO 250d, NEUR 300d, and NBIO 306d.
Spring: CONT 300b, NBIO 145b, NBIO 250d, NEUR 300d, NBIO 306d, and one course selected from the Neuroscience Electives.

Second Year
Fall: NBIO 250d, NBIO 306d, and one course selected from the Neuroscience Electives.
Spring: NBIO 250d, NBIO 306d, and one course selected from the Neuroscience Electives.

Qualifying Examinations
This consists of two written propositions with accompanying oral exams. One of these shall be in the field of neuroscience, but not directly related to the student's thesis work (end of first year), and the other takes the form of a formal thesis proposal (end of the second year).

Teaching Requirement
As part of their Ph.D. training, students act as teaching fellows for two semesters, typically in their second year, in courses taught by neuroscience faculty.

Residence Requirement
The minimum residence requirement is three years.

Dissertation and Final Oral Examination
A thesis in the field of neurosicence is required for the Ph.D., normally carried out in the laboratory of one of the members of the neuroscience training faculty. After submission of the dissertation, the candidate gives a public seminar to the University community and then defends the work and its significance in an examination before a thesis committee.

Courses of Instruction

(1-99) Primarily for Undergraduate Students

NPSY 11b Introduction to Behavioral Neuroscience
[ss sn]
Prerequisite: PSYC 1a or MATH 10a or permission of the instructor. This course may not be repeated for credit by students who have taken PSYC 11b in previous years.
Data and theories regarding current conceptions of brain-behavior relationships. Begins with an introduction to neural systems as classically defined (sensory, association, motor, autonomic), and moves on to examination of the biological underpinnings of various behaviors, from those relating to basic drives (reproduction, feeding) to those with a cognitive flavor. Throughout, the accent is on interactions between organisms and environment (learning). Usually offered every year.
Mr. Katz

NPSY 12a Sensory Processes
[ss sn]
Prerequisites: Sophomore standing or MATH 10a or permission of the instructor.
Examines the human senses, emphasizing sight and hearing, studied from standpoints of anatomy, physiology, and psychophysics. Insights from the study of special observers including developmentally immature humans, members of nonhuman species, and people with abnormal sensory systems. Usually offered every year.
Mr. Sekuler

NPSY 22b Introduction to Cognitive Neuroscience
[ss sn]
Prerequisites: PSYC 1a or MATH 10a and sophomore standing in psychology or neuroscience.
Cognitive factors in sensory processes, attention, memory, motor control, plasticity, and language. Experimental and neuroimaging approaches are emphasized. Usually offered every year.
Mr. Sekuler

NEUR 90a Field Study: Neuroscience
Four semester course credits, of which a maximum of two may count toward the major.
Students proposing to take this course are expected to work out a detailed plan of study for one semester with the help of department faculty members. This plan is to be submitted to the department for its consideration before the end of the semester preceding the one in which 90a would be taken. Approval depends on the department's resources for supporting the student's plan as well as on the student's competence and the excellence of the plan itself. Usually offered every year.
Staff

NEUR 98a Readings in Neuroscience
Usually offered every year.
Staff

NEUR 98b Readings in Neuroscience
Usually offered every year.
Staff

NEUR 99d Senior Research
A year-long, two-semester course involving the student in an independent research project conducted under the supervision of a staff member and serving as an intensive introduction to specific methods of neuroscience research. In cases where students are able to do unusually long, intensive work in the laboratory, they may request a third course credit during the petition process; if this request is approved by the senior honors coordinator, students should register for NEUR 99d (fall) followed by NEUR 99e (spring). The combined enrollments for Senior Research may not exceed three semester course credits. To fulfill the NEUR 99 requirements, students must (1) submit to their research sponsor, at the conclusion of their first NEUR 99 semester, a paper that reviews the literature pertinent to their field of research, and (2) submit to their research sponsor, at the conclusion of their second NEUR 99 semester, a senior thesis that includes an abstract, an introduction, a review of materials and methods, results, discussion, and references. Usually offered every year.
Staff

NEUR 99e Senior Research
See NEUR 99d for course description.
Usually offered every year.
Staff

(100-199) For Both Undergraduate and Graduate Students

NPHY 115a Dynamical Systems, Chaos, and Fractals
[sn]
Prerequisite: PHYS 10a or 11a, MATH 21a, MATH 36a, or approved equivalents. This course may not be repeated for credit by students who have taken PHYS 115a in previous years.
Advanced introduction to the theory of nonlinear dynamical systems, bifurcations, chaotic behaviors, and fractal patterns. Concepts and analysis are illustrated by examples from physics, chemistry, and biology. The course will be complemented by a significant number of computer labs. Usually offered every second year.
Mr. Wang

NPSY 120b Man in Space
[ss sn]
Prerequisite: PHYS 10a.
Topics include how orbital flight is achieved, spacecraft life support systems, circulatory dynamics, sensory-motor control and vestibular function in free fall, the physiological and psychological adaptations necessary in space flight, and how astronauts must readapt on return to Earth. Usually offered every year.
Mr. Lackner

NPSY 125a Advanced Topics in Perception and Adaptation
[ss sn]
Prerequisites: MATH 10b, NBIO 104b, and PHYS 10a.
Covers current issues and theories in vision, vestibular function, proprioception, and adaptation to unusual force environments from psychological and biological perspectives. Usually offered every third year.
Mr. Lackner

NPSY 127a Motor Control
[ss sn]
Prerequisites: NPSY 11b (formerly PSYC 11b), or NPSY 12a, or permission of the instructor.
Surveys control of posture, movement, gesture, and speech from various perspectives including muscle properties, reflex organization, central neural mechanisms, spatial representations, learning, and development. Emphasizes research in physiology, psychology, biomechanics, and artificial intelligence. Usually offered every second year.
Mr. DiZio

NPSY 128b Motor Control, Orientation, and Adaptation
[ss sn]
Prerequisite: NBIO 140b.
A seminar critically reviewing and discussing current research about spatially adapted animal movement. The analysis focuses on behavioral properties, biophysics, and neural substrates. Topics include sensorimotor transformations, learning, memory, context specificity, and sensorimotor adaptation. Usually offered every second year.
Mr. DiZio

NBIO 136b Computational Neuroscience
[sn]
Prerequisites: MATH 10a or PHYS 10a or approved equivalents.
An introduction to concepts and methods in computer modeling of neural systems. Topics include the basic biophysics of ion conduction, single- and multi-compartment neuron models, information representation and processing in the visual system, and models of synaptic plasticity, working memory and decision making. Usually offered every second year.
Mr. Wang

NPSY 137b Cognitive Modeling
[ss sn]
Prerequisites: MATH 10b, and PSYC 51a or NBIO 136b.
A general introduction to the construction and simulation of mathematical models of human cognitive processes. The major emphasis will be on models of human learning and memory. Students will be expected to have some background in computer programming. Usually offered every second year.
Staff

NBIO 140b Principles of Neuroscience
[sn]
Prerequisite: BIOL 22b or permission of the instructor.
Basic principles of neurobiology. Topics include ion channels and their role in generating resting and action potentials; basics of synaptic physiology and pharmacology; neural circuits underlying behavior, learning, and mental illness. Usually offered every year.
Ms. Marder

NBIO 143b Developmental Neurobiology
[sn]
Prerequisite: BIOL 22b or permission of the instructor.
Discusses the mechanisms used in the development of the nervous system. Topics include determination of neuronal cell fates, neuronal differentiation and pattern formation, neuron survival and growth, and mechanisms responsible for generation of connectivity in the nervous system. Usually offered every second year.
Ms. Sengupta

NBIO 145b Systems Neuroscience
[sn]
Prerequisite: NBIO 140b.
A fundamental question regarding brain function is how we learn and remember. To understand this process, the underlying molecular, cellular, and network mechanisms have to be understood. These topics are reviewed, with emphasis on reading original papers and extensive class discussion. Usually offered every year.
Mr. Lisman

NBIO 146a The Neurobiology of Human Disease
[sn]
Prerequisite: NBIO 140b.
A lecture- and literature-based overview of the neurobiological underpinnings of neurological and psychiatric disorders including autism, mental retardation, schizophrenia, bipolar disorder, Alzheimer's Disease, Parkinson's Disease, and other neurodevelopment and neurodegenerative disorders. Usually offered every second year.
Mr. Nelson

NBIO 147a Neurogenetics
[sn]
Prerequisites: BIOL 18a and BIOL 22a.
Development and function of the nervous system and responses of excitable cells studied in neurological and behavioral mutants. Characterization and manipulation of genes, defined by these mutations and using molecular biological tools. Organisms: microbes, roundworms, fruit flies, mammals. Neurobiological areas: embryonic neural development, nerve cell differentiation and pattern formation, membrane excitability, responses to visual and chemical stimuli, biological rhythms, and reproductive behavior. Usually offered every third year.
Mr. Hall

NBIO 148b Cellular Neuroscience
[sn]
Prerequisite: NBIO 140b or permission of the instructor. May be taken concurrently with NBIO 140b. This course may not be repeated for credit by students who have taken NBCH 148b in previous years.
Focuses on cellular mechanisms of excitability and synaptic plasticity. Students examine classic experiments on action potentials and synaptic transmission and the original research literature dealing with the cellular mechanisms of developmental and learning-related plasticity. Usually offered every year.
Ms. Turrigiano

NBIO 150a Autism and Human Developmental Disorders
[sn]
Prerequisite: BIOL 22b.
Autism and other developmental disorders are characterized by abnormal brain development resulting in cognitive and behavioral deficits. Takes an integrative approach to investigate the biological, behavioral, medical, and social aspects of human developmental disorders. Usually offered every second year.
Ms. Birren

NPSY 154a Human Memory
[ss sn]
Prerequisite: NPSY 22b.
Presents a systematic analysis of current memory research and theory with an emphasis on list learning experiments and neural network models. Usually offered every third year.
Staff

NPSY 159a Advanced Topics in Episodic Memory
[ss sn]
Prerequisite: NBIO 140b or NPSY 154a and permission of the instructor.
Deals with current topics in the study of episodic memory. Discussions and readings on topics such as memory for temporal order, category learning, associative symmetry, item versus associative recognition, theories of search in free recall, and the memory systems controversy. Usually offered every second year.
Staff

NPSY 168b Electrophysiology of Human Memory
[ss sn]
Prerequisites: PSYC 51a, NBIO 140b, NPSY 22b.
Laboratory course covering experimental methods and data analysis of electroencephalographic recordings during memory tasks. Projects involve data collection using a 128 channel EEG system. Topics cover time- and frequency-based methods as well as source modeling. Usually offered every year.
Staff

NPSY 174b Visual Cognition
[ss sn]
Prerequisite: NPSY 12a or permission of the instructor.
Higher-order processes in vision. Visual impact of cognitive and other top-down influences, including attention, expectation, plasticity, and learning. Focus on visual recognition, contour formation, segmentation, temporal binding, and face and object perception. Studies of visual perception in brain-damaged individuals. Usually offered every second year.
Mr. Sekuler

NPSY 175b The Neuroscience of Vision
[ss sn]
Prerequisite: NPSY 12a or permission of the instructor.
Examines the neural basis of human vision from several complementary perspectives. Relates visual capacities of human observers to the structure and function of the visual system. Considers computational and functional neuroimaging approaches to vision. Usually offered every second year.
Mr. Sekuler

NPSY 196b Advanced Topics in Cognition
[ss sn]
Prerequisite: NPSY 159a or permission of the instructor.
This seminar covers current issues and research in memory, speech perception, and processing resource limitations. Emphasis will be placed on the current literature in the field. Usually offered every second year.
Mr. Wingfield

NPSY 197a Advanced Topics in Behavioral Neuroscience
[ss sn]
Prerequisites: NPSY 11b (formerly PSYC 11b) and NBIO 140b or permission of the instructor.
Covers current research and issues pertaining to the neurobiology of perception (focusing mainly but not exclusively on perception of chemosensory signals) as well as the neurobiology of simple learning. Usually offered every year.
Mr. Katz

NPSY 199a Human Neuropsychology
[ss sn]
Prerequisite: NPSY 22b, or NBIO 140b, or permission of the instructor.
Designed as an introduction to human neuropsychology. Topics include cerebral dominance, neuroanatomical mapping, and localization of function, with special reference to language, memory, and related cognitive function. Usually offered every year.
Mr. Wingfield

(200 and above) Primarily for Graduate Students

NPSY 207b Seminar in Perception
Prerequisites: MATH 10b, NBIO 140b, and PHYS 10a.
Examines the various aspects of visual, vestibular, motor, and proprioceptive information by which objects and events in three-dimensional space are perceived by human observers. Current research in psychology and artificial intelligence is considered. Usually offered every second year.
Mr. Lackner

NBIO 250d Neuroscience Proseminar
Limited to first- and second-year neuroscience Ph.D. students.
Required seminar for first- and second-year graduate students in the neuroscience Ph.D. program. Discusses relevant papers from the current literature with an emphasis on increasing oral presentation skills, experimental design, and proposal writing. Usually offered every year.
Mr. Nelson

NEUR 298a Readings in Neuroscience
Usually offered every year.
Staff

NEUR 298b Readings in Neuroscience
Usually offered every year.
Staff

NEUR 299a Master's Research Project
Usually offered every year.
Staff

NEUR 299b Master's Research Project
Usually offered every year.
Staff

NEUR 300d Laboratory Rotations
Staff

NBIO 306d Topics in Neurobiology
Usually offered every year.
Ms. Turrigiano

NBIO 340d Systems/Computational Neuroscience Journal Club
Usually offered every year.
Mr. Wang

NPHY 341b Neural Computation
An advanced graduate seminar course on current theoretical issues dealing with the dynamics and information processing of neural systems. Usually offered every year.
Mr. Wang

NEUR 401d Dissertation Research
Independent research for the Ph.D. degree. Specific sections for individual faculty members as requested.
Staff

CONT 300b Ethical Practice in Health-Related Sciences
Required of all first-year graduate students in health-related science programs. Not for credit.
Ethics is an essential aspect of scientific research. This course, taught by University faculty from several graduate disciplines, covers major ethical issues germane to the broader scientific enterprise, including areas or applications from a number of fields of study. Lectures and relevant case studies are complemented by two public lectures during the course. Usually offered every year.
Ms. Ringe

Cross-Listed Courses

BIOL 149b
Molecular Pharmacology