NEUROSCIENCE

Directors of undergraduate studies: Damon Clark (neuroscience.dus@yale.edu) (MCDB), KBT 224; Nicholas Turk-Browne (neuroscience.dus@yale.edu) (Psychology), SSS 305; neuroscience.yale.edu

Neuroscience aims to understand how the brain produces the mind and behavior, with the goal of advancing human understanding, improving physical and mental health, and optimizing performance. This entails a broad, interdisciplinary effort that spans from molecules to minds. At one end, biology, chemistry, and physics are improving our understanding of the molecular and cellular mechanisms of neuronal signaling and development. At the other end, psychology, psychiatry, and computer science link neural processes and systems to the mind and behavior. At all levels, the rich array of methods and data analysis depends on a strong foundation in the basic sciences, mathematics, statistics, and computer science.

PREREQUISITES
The foundational biology courses required of all Neuroscience majors are BIOL 101, 102, 103, and 104. All majors must also complete one of the following: PSYC 200, S&DS 103, 105, 238.

PLACEMENT PROCEDURES
Students must apply to enter the major. Applications are reviewed at the end of each term; decisions are based on a cover letter, transcript, and completed Neuroscience major worksheet. More information regarding the application process is available on the program website.

REQUIREMENTS OF THE MAJOR
Both the B.S. and B.A. degree programs require a minimum of 18.5 credits, including the three prerequisites, 15 lecture or seminar courses (which include the senior requirement), and one laboratory, as follows:

1. Two neuroscience foundation courses, NSCI 160 and 320.
2. One neuroscience lab chosen from NSCI 229L, 235, 258, 260, 321L.
3. Eleven electives from the following core groupings, with a minimum of: two from the Systems/Circuits/Behavior Core, two from the Molecular/Cellular/Biological Core, one from the Quantitative Core, one from the Computational Core (previously Advanced Allied Core), and one from the Basic Allied Core. No more than two credits may be taken from the Other Allied Core.

Systems/Circuits/Behavior Core: NSCI 340, 341, 346, 352, 355, 360, 442, 445
Molecular/Cellular/Biological Core: NSCI 324, 325, 420; MCDB 200, 202, 205, 210, 310, 370, 450, 452; MB&B 300 or MCDB 300
Quantitative Core: MATH 112, 115, 116, 120, 222, 225, 230, 231, 244, 246, 247; ENAS 151; NSCI 324, 325; CPSC 202
Computational Core (previously Advanced Allied Core): CPSC 100, 112, 201, 223, 323, 365, 470, 475, 476; S&DS 123, CPSC 362, 361
Basic Allied Core: PHYS 170, 171, 180, 181, 200, 201, 260, 261; CHEM 161, 163, 165, 167, 174, 175, 220, 221
Other Allied Core: NSCI 141, 147, 161, 240; BENG 485; MCDB 250; CGSC 110; PSYC 110; one additional lab course from the list above

Credit/D/Fail No course taken Credit/D/Fail may be counted toward the major, including prerequisites.

Roadmap See visual roadmap of the requirements.

SENIOR REQUIREMENT
In addition to the course requirements described above, all students must satisfy a senior requirement undertaken during the senior year. All students must fill out a checklist of requirements and go over it with the undergraduate registrar by the spring term of the junior year.

B.S. degree program The B.S. degree program requires two course credits of empirical research, NSCI 490 and 491. These courses are only available to Neuroscience seniors and receive a letter grade. Students are expected to spend at least ten hours per week in the laboratory, to complete written assignments, and to make a presentation. In addition to time in the lab, and as part of NSCI 490 and 491, students are expected to attend a regular capstone seminar, to hear guest speakers and to discuss senior work progress with their peers and the directors of undergraduate studies (DUSes). Research can be conducted over original, archival, or consortium data sets. Written assignments include a short research proposal summary due at the beginning of the term, and a full research report due at the end of the term. Students are encouraged to pursue the same research project for two terms, in which case, the first term full research report acts as the second term proposal, and the second term research report covers the work done in both terms of research. Final papers are due by the stated deadline near the end of the second term; the second term proposal summary may be combined into a full research proposal due at the end of the first term. Final papers are due by the stated deadline near the end of the term. Seniors are also required to present their research in the spring term. Students should find a research laboratory during the term preceding the research. Yale College does not grant academic credit for summer research unless the student is enrolled in an independent research course in Yale Summer Session. To register for NSCI 490 and 491, students must submit a form and a written plan of study with bibliography, approved by the faculty research adviser and DUS, by the end of the first week of classes.
B.A. degree program The B.A. degree program requires two course credits in non-empirical research, NSCI 480 and 481; or one credit in non-empirical research, NSCI 480 or 481, and one credit in empirical research, NSCI 490 or 491. These courses are only open to Neuroscience seniors and receive a letter grade. Under faculty supervision, for NSCI 480 or 481, students are required to conduct a literature review, complete written assignments, and make a presentation. The final research paper is due to the sponsoring faculty member, with a copy submitted to the department, by the stated deadline near the end of the term. Seniors are also required to present their research in the spring term. To register, students must submit a form and a written plan of study with bibliography, approved by the faculty research adviser and DUS, by the end of the first week of classes.

More detailed guidelines, forms, and deadline information is available on the department website.

ADVISING

Departmental advisers Schedules for all majors must be discussed with, and approved by, one of the DUSes. Only then may a schedule be submitted to the residential college dean’s office. For questions concerning credits for courses taken at other institutions, or courses not listed in this bulletin, students should consult with one of the DUSes.

REQUIREMENTS OF THE MAJOR

Prerequisites BIOL 101, 102, 103, and 104; and one of PSYC 200, S&D 103, 105, 238
Number of courses 18.5 courses (incl prereqs and senior req)
Specific courses required 2 neuroscience foundation courses, NSCI 160 and 320
Distribution of courses B.S. or B.A. – 1 lab course; 11 electives incl at least: 2 Systems/Circuits/Behavior Core courses, 2 Molecular/Cellular/Biological Core courses, 1 Quantitative Core course, 1 Computational Core course, 1 Basic Allied Core course, and no more than 2 Other Allied Core courses
Senior requirement B.S. – 2 empirical research courses, NSCI 490 and 491; B.A. – 2 non-empirical research courses, NSCI 480 and 481, or 1 empirical research course (NSCI 490 or 491) and 1 non-empirical research course (NSCI 480 or 481)

FACULTY OF THE NEUROSCIENCE MAJOR

Professors †Amy Arnsten (School of Medicine, Psychology), Tom Brown (Psychology), Ty Cannon (Psychology), John Carlson (Molecular, Cellular, and Developmental Biology), B. J. Casey (Psychology), Marvin Chun (Psychology), Paul Forscher (Molecular, Cellular, and Developmental Biology), Jutta Joorman (Psychology), Douglas Kankel (Molecular, Cellular, and Developmental Biology), Haig Keshishian (Molecular, Cellular, and Developmental Biology), †John Krystal (School of Medicine, Psychology), †Daeyeol Lee (School of Medicine, Psychology), †Linda Mayes (School of Medicine, Psychology), Greg McCarthy (Psychology), Laurie Santos (Psychology), †Dana Small (School of Medicine, Psychology), †Jane Taylor (School of Medicine, Psychology), Nick Turk-Browne (Psychology), Robert Wyman (Molecular, Cellular, and Developmental Biology)

Associate Professors †Sreeganga Chandra (School of Medicine, Molecular, Cellular, and Developmental Biology), Damon Clark (Molecular, Cellular, and Developmental Biology), Thierry Emonet (Molecular, Cellular, and Developmental Biology), Weimin Zhong (Molecular, Cellular, and Developmental Biology)

Assistant Professors †Alan Anticevic (School of Medicine, Psychology), Arielle Baskin-Sommers (Psychology), Steve Chang (Psychology), †Philip Corlett (School of Medicine, Psychology), Molly Crockett (Psychology), Dylan Gee (Psychology), Avram Holmes (Psychology), †Hedy Kober (School of Medicine, Psychology), †Hit Levy (School of Medicine, Psychology), †James McPartland (School of Medicine, Psychology)

Lecturer Nelson Donegan (Psychology)

†A joint appointment with primary affiliation in another department or school.

Courses

NSCI 160a / PSYC 160a, The Human Brain  Gregory McCarthy
Introduction to the neural bases of human psychological function, including social, cognitive, and affective processing. Preparation for more advanced courses in cognitive and social neuroscience. Topics include memory, reward processing, neuroeconomics, individual differences, emotion, social inferences, and clinical disorders. Neuroanatomy, neurophysiology, and neuropharmacology are also introduced. sc

NSCI 161b / PSYC 161b, Drugs, Brain, and Behavior  Heddy Kober
An introduction to psychoactive drugs and their effects on both brain and behavior. Review of pharmacological and brain mechanisms of different classes of legal, illegal, and medicinal drugs, including alcohol, caffeine, tobacco, stimulants, depressants, antidepressants, and hallucinogens. Individual drugs’ pharmacokinetics, mechanisms of action, dosing, routes of administration, and patterns and effects of use and misuse. Some attention to substance use disorders/addictions, prevention, and treatment. sc

* NSCI 229Lb / PSYC 229Lb, Laboratory in Human Neuroscience  Gregory McCarthy
Instruction in the acquisition and analysis of human neuroscience data. This laboratory complements the lecture course "Methods in Human Neuroscience" (PSYC 230/NSCI 240). The main topics include structural, diffusion, and functional magnetic resonance imaging (MRI), electroencephalography (EEG), and event-related potentials. Students engage in laboratory exercises that illustrate the design and
analysis of experiments using each technique. These laboratory exercises involve acquiring, visualizing, and analyzing MRI and EEG data. Prerequisites: PSYC 160/NSCI 160, PSYC 200, PSYC 230/NSCI 240, or permission of the instructor.  

**NSCI 320a / MCB 320a, Neurobiology**  
Haig Keshishian and Paul Forscher  
The excitability of the nerve cell membrane as a starting point for the study of molecular, cellular, and systems-level mechanisms underlying the generation and control of behavior. Prerequisites: year of college-level chemistry; a course in physics is strongly recommended.  

**NSCI 321La / MCB 321La, Laboratory for Neurobiology**  
Haig Keshishian, Robert Wyman, and Paul Forscher  
Introduction to the neurosciences. Projects include the study of neuronal excitability, sensory transduction, CNS function, synaptic physiology, and neuroanatomy. Concurrently with or after MCB 320.  

**NSCI 324a / MB&B 330a / MCB 330a, Modeling Biological Systems I**  
Thierry Emonet and Kathryn Miller-Jensen  
Study of the analytic and computational skills needed to model genetic networks and protein signaling pathways. Review of basic biochemical concepts including chemical reactions, ligand binding to receptors, cooperativity, and Michaelis-Menten enzyme kinetics. Deep exploration of biological systems including: kinetics of RNA and protein synthesis and degradation; transcription activators and repressors; lyosogeny/lysis switch of lambda phage and the roles of cooperativity and feedback; network motifs such as feed-forward networks and how they shape response dynamics; cell signaling, MAP kinase networks and cell fate decisions; bacterial chemotaxis; and noise in gene expression and phenotypic variability. Students learn to model using MatLab in a series of in-class hackathons that illustrate biological examples discussed in lectures. Prerequisites: BIOL 101-104, or with permission of instructors.  

**NSCI 325b / BENG 465b / MB&B 361b / MCB 361b, Modeling Biological Systems II**  
Damon Clark, Thierry Emonet, and Jonathon Howard  
Advanced topics related to dynamical processes in biological systems. Processes by which cells compute, count, tell time, oscillate, and generate spatial patterns. Time-dependent dynamics in regulatory, signal-transduction, and neuronal networks; fluctuations, growth, and form. Comparisons between models and experimental data. Dynamical models applied to neurons, neural systems, and cellular biophysical processes. Use of MATLAB to create models. Prerequisite: MCB 330 or equivalent, or a 200-level biology course, or with permission of instructor.  

**NSCI 340b / PSYC 335b, Cognitive Neuroscience**  
Steve Wohng Chang  
This course covers how cognition is made by the brain. Students learn brain mechanisms underlying the generation and control of behavior. Prerequisites: year of college-level chemistry; a course in physics is strongly recommended.  

**NSCI 341a / PSYC 376a, Learning and Memory**  
Thomas Brown  
The basic facts, general principles, and theories that describe how higher animals, from mice to humans, are changed by their experiences. The historically separate fields of learning and memory research desegregated under a neuroscientific perspective that recognizes the evolutionary continuity among higher animals. Prerequisite: Introductory courses in biology and psychology, or permission of instructor.  

**NSCI 346b / PSYC 321b, Psychopharmacology**  
Thomas Brown  
Study of therapeutic and recreational drugs that affect the central nervous system and influence mood, cognition, perception, and behavior. Drugs considered vary from psychotropic to hypnotic to narcotic. Prerequisite: PSYC 160 or 170 or equivalent, or permission of instructor.  

**NSCI 352a / CGSC 352a / PSYC 352a, Arrested or Adaptive Development of the Adolescent Brain**  
BJ Casey  
Study of empirical and theoretical accounts of adolescent-specific changes in the brain and in behavior that relate to the development of self control. Discussions will focus on adaptive and arrested adolescent brain development in the context of relevant legal, social, and health policy issues.  

**NSCI 410b / CGSC 410b / PSYC 410b, Topics in Brain Development, Law, and Policy**  
BJ Casey  
Healthy development is a fundamental right of the individual, regardless of race, ethnicity, socioeconomic status, or gender. Youth require special protections of their rights due to vulnerabilities related to their physical and mental immaturity. These rights include, not only protections, but opportunities for building the cognitive, emotional, and social skills necessary for becoming a healthy adult and a contributing member of society. This seminar examines the extent to which legal policies and practices in the treatment of youths are consistent with scientific knowledge on psychological and brain development. Each class discusses one or more legal cases highlighted in the context of brain and psychological science and current laws and policies. Prerequisite: PSYC 110 and PSYC 160 preferred.  

**NSCI 440b / CGSC 420b / PSYC 420b, Topics in Clinical Neuroscience**  
Avram Holmes  
An overview and examination of the neuroscience of psychiatric illness. We focus on cutting-edge research in humans and animals aimed at understanding the biological mechanisms that underlie psychiatric illness. Although these questions date back to early philosophical texts, only recently have experimental psychologists and neuroscientists begun to explore this vast and exciting domain of study. We discuss the evolutionary and developmental origins of individual differences in human personality, measurement issues, fundamental dimensions of psychopathology, stability/plasticity, heritability, and implications therapeutic interventions as well as the associated
broader implications for public policy. A major focus is on the neurobiology of fear and anxiety, including brain circuits, molecular genetic pathways, and epigenetics. A secondary focus is on differences in behavior and biology that confer risk for the development of depression and addiction, including the biological systems involved in hedonic pleasure, motivated goal pursuit, and the regulation of impulses in the face of everyday temptation. Students should have some background in psychology; PSYC 110 and PSYC 160 preferred.

[ NSCI 445, Systems Neuroscience ]

* NSCI 470a or b and NSCI 471a or b, Independent Research  Damon Clark and Nicholas Turk-Browne
Research project under faculty supervision taken Pass/Fail; does not count toward the major, but does count toward graduation requirements. Students are expected to spend approximately ten hours per week in the laboratory. A final research report and/or presentation is required by end of term. Students who take this course more than once must reapply each term. To register, students must submit a form and written plan of study with bibliography, approved by the faculty research adviser and DUS, by the end of the first week of class. More detailed guidelines and forms can be obtained from http://neuroscience.yale.edu.

* NSCI 480a and NSCI 481b, Senior Non-empirical Research  Damon Clark and Nicholas Turk-Browne
Research survey under faculty supervision fulfills the senior requirement for the B.A. degree and awards a letter grade. For NSCI seniors only (and second term juniors with DUS permission). Students are expected to conduct a literature review, to complete written assignments, and to present their research once in either the fall or spring term. Students are encouraged to pursue the same research project for two terms. The final research paper is due in the hands of the sponsoring faculty member, with a copy submitted to the department, by the stated deadline near the end of the term. To register, students submit a form and written plan of study with bibliography, approved by the faculty research adviser and DUS, by the end of the first week of classes. More detailed guidelines and forms can be obtained from http://neuroscience.yale.edu.

* NSCI 490a and NSCI 491b, Senior Empirical Research  Damon Clark and Nicholas Turk-Browne
Laboratory or independent empirical research project under faculty supervision to fulfill the senior requirement for the B.S. degree. For NSCI seniors only (and second term juniors with DUS permission); this course awards a letter grade. Students are expected to spend at least ten hours per week in the laboratory, to complete written assignments, and to present their research once in either the fall or the spring term. Written assignments include a short research proposal summary due at the beginning of the term and a full research report due at the end of the term. Students are encouraged to pursue the same research project for two terms, in which case, the first term research report and the second term proposal summary may be combined into a full research proposal due at the end of the first term. Final papers are due by the stated deadline. Students should reserve a research laboratory during the term preceding the research. To register, students must submit a form and written plan of study with bibliography, approved by the faculty research adviser and DUS, by the end of the first week of classes. More detailed guidelines and forms can be obtained from http://neuroscience.yale.edu.