BOSTON UNIVERSITY

Undergraduate Program in Neuroscience

Program Catalog

2012 – 2013
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COVER ART: JIGAR PATEL ’13
TABLE OF CONTENTS ART: UNDERGRADUATE STUDENT, ANONYMOUS
THE UNDERGRADUATE PROGRAM IN NEUROSCIENCE is an interdisciplinary major leading to a Bachelor of Arts in Neuroscience. As a field that has grown considerably through integration across disciplines over the last few decades, a current understanding requires knowledge that spans traditional approaches. Our program combines breadth of exposure to the field with opportunities for more in depth study in several domains of neuroscience: Cell, Molecular, Systems, Cognition, Behavior, and Computational Neuroscience. Students have access to the extensive resources and expertise of faculty across multiple departments and colleges throughout the university. A wide array of courses are offered through the departments of Biology, Biomedical Engineering, Chemistry, Computer Science, Health Sciences, Mathematics & Statistics, Physics, and Psychology. Opportunities for independent laboratory research are available through multiple departments in the Colleges of Arts and Sciences, Engineering, Health and Rehabilitation Sciences, and at Boston University School of Medicine, including Anatomy and Neurobiology, Biochemistry, Neurology, Pathology, Pharmacology and Experimental Therapeutics, Physiology and Biophysics, and Psychiatry.

A total of 17 courses are required for the Neuroscience major, and are distributed among seven (7) basic science courses that will provide an appropriate background for neuroscience, five (5) core neuroscience courses, five (5) electives within the three principal domains, including at least one course from a second domain and no more than two courses from a restricted elective list. At least one upper level elective must include a lab component. Alternatives to the upper level lab course requirement include the following: 1) Successful completion of two consecutive semesters of faculty-mentored research during junior or senior year (through Directed Study: CAS NE 391, 392, 491, or 492; or Senior Work for Distinction: CAS NE 401/402); 2) Successful completion of CAS NE 102 and NE 203. A ‘C’ or higher is required in all 17 courses to receive credit toward the major.

In addition to the requirements of the major, students also must satisfy the requirement for general education through either the Core Curriculum (8) or the Divisional Studies Program (6), and the college language requirement (4). Information about how to satisfy the language requirement can be found at the following link: http://www.bu.edu/academics/cas/programs/foreign-language/. Both general education programs are designed to provide exposure to and perspective of topics beyond one’s major concentration and immediate academic focus, and to facilitate the acquisition of intellectual tools necessary for success in advanced study. The courses in the Core Curriculum integrate classic works in the humanities, important ideas in the natural sciences, and current topics within the social sciences. Each course consists of small seminar groups.
combined with a series of lectures; science core courses include both discussions and laboratories.

The Divisional Studies Program requires six one-semester divisional studies courses, two in each of the three divisions outside the division of one’s major concentration. Divisional studies courses are accessible to non-majors and effectively serve as a broad introduction to a specific discipline. Additional information about general education requirements and both the Core Curriculum and Divisional Studies Program can be found at the following link: http://www.bu.edu/academics/cas/programs/.

UNDERGRADUATE RESEARCH
The Boston University Neuroscience community is a hotbed of innovative, cutting-edge research, with opportunities for undergraduate participation in projects focused on addiction, aging, autism, learning and memory, neurodegenerative diseases, and neuroendocrinology, across multiple levels of analysis (in vitro slice physiology to neuropsychological assessment), techniques (single unit recording to behavioral studies), and experimental models (rodents to humans).

Students may receive credit, volunteer, or receive funding to work with faculty in the College of Arts and Sciences (Biology; Mathematics and Statistics; Psychology), Engineering (Biomedical Engineering; Electrical and Computer Engineering), Sargent (Health Sciences; Speech, Language, and Hearing Sciences), BU School of Medicine (Alzheimer’s Disease Center; Anatomy and Neurobiology; Biochemistry; Pharmacology; Neurology; Pathology; Physiology and Biophysics; Radiology), Maclean Hospital, or the Department of Anesthesiology at Massachusetts General Hospital.

Students may receive credit through Directed Study or Senior Work for Distinction, or apply for funding through grants awarded to the Undergraduate Program in Neuroscience (Howard Hughes Medical Institute, NIH; see below), or through UROP, faculty research grants, or Work Study.

Undergraduate Fellowships in Computational Neuroscience (NIH). Students will be trained in both computational and experimental approaches to studying the brain and will learn how to “translate” their research ideas from the laboratory to the clinic. The program integrates fundamental knowledge, interdisciplinary thinking, and translational skills to solve challenges in the neurosciences, as well as promote a strong community of faculty and students with similar interests. Our goal is to produce a new generation of neuroscientists who will combine experimental and theoretical techniques to increase our
understanding of the brain, to transition their discoveries from the lab bench to the clinic and to invent new technologies to restore lost brain function.

**HHMI (Howard Hughes Medical Institute) Summer Lab Experience.** Up to 26 rising sophomores who successfully complete NE 102 will receive a stipend to participate in a faculty-mentored research experience in a Boston University life-science laboratory during the summer between their freshman and sophomore years. In addition to a stipend, these students will receive several hundred dollars toward research supplies. A subset of these students will have an opportunity to apply for funding to travel to a scientific conference to help present the results of their research together with their research mentors. Grantees are expected to work 35 hours per week in the lab.

**CONTE (NIH) Summer Lab Experience.** Up to seven (7) students will be selected and funded through the CONTE Summer Lab Experience. Students may participate in a faculty-mentored research experience in, but not limited to, participating Boston University laboratories (see application for a complete list of lab placement options). Grantees are expected to work 35 hours per week in the lab.

**PEER LEARNING/EDUCATIONAL OPPORTUNITIES**

**Learning Assistant Program.** The focus of the LA Program is to allow high-performing former students to work alongside Graduate Teaching Fellows in laboratory sections. This program is used in colleges and universities all over the country and has benefited the participants, students and departments. We extend this opportunity only to a few deserving and capable students. Learning assistants will complete one mandatory, letter-grade seminar on teaching/learning techniques through the School of Education, attend weekly lab prep sessions, and assistant a Graduate Teaching Fellow in instructing one lab section per week.

**High School Outreach.** To enrich the pipeline of students from under-resourced backgrounds, we offer a hands-on after-school neuroscience lab course on campus for students enrolled in neighboring local Boston Public High Schools (Fenway, English, Brighton, and Charlestown), and host monthly, half-day laboratory experiences ("Neuroscience Day") for high school science classes from surrounding communities. A subset of students who successfully complete the after-school course are then given an opportunity to work in labs on campus during the summer.

**InterAxon.** First established at the University of Southern California, InterAxon is a program where BU undergraduate neuroscience majors visit local high schools to teach students about neuroscience. Through interactive presentations
and activities, the club strives to spark enthusiasm for the brain, and science in general, by offering a unique exposure to the field. InterAxon is a great opportunity for undergraduates interested neuroscience, psychology, and other sciences to offer and apply their knowledge in a rewarding experience. Members will receive hands-on teaching experience helping to design their own presentations, create posters and props, and join BU's larger mission to create a stronger bond to the Boston community.

**STUDENT LIFE – MIND AND BRAIN SOCIETY**

The Boston University Mind and Brain Sciences (MBS) was founded in the fall of 2008 in concert with BU’s incipient Undergraduate Program in Neuroscience. The group aims to create a network for undergraduate students who wish to take an active role in current issues and research. MBS serves as a hub for students interested in Neuroscience, Psychology, Biology, Philosophy, Computer Science, etc. Our goal is to support an eager multidisciplinary undergraduate community with conversations and resources fundamental to Neuroscience today.

Throughout the academic year, MBS hosts events spotlighting many different facets of Neuroscience. We hold “Brainstorm” sessions during which we informally discuss a topic of interest over coffee. Previous topics include “The Neuroscience of Religion” and “NeuroEthics.” The group also hosts research presentations by BU professors and screenings of thought-provoking films containing neuroscience motifs.

**The Nerve.** MBS members produce, edit and manage *The Nerve*, a student magazine published by the Undergraduate Program in Neuroscience. *The Nerve* features undergraduate essays on neuroscience and related fields and aims to spread awareness and ignite interest in the field while giving fellow students the opportunity to refine their writing skills and integrate what they learn in class. The first issue of *The Nerve* was released November 2009, and has recently produced its fifth issue. You can now read *The Nerve* online at [www.bu.edu/thenerve](http://www.bu.edu/thenerve).

**MBS Shadowing Program.** The MBS Shadowing program focuses on providing undergraduate Neuroscience majors and MBS members who are interested in medicine with opportunities to shadow neurologists, neurosurgeons, and psychiatrists in the Boston area. We have shadowing opportunities at BMC, MGH, Brigham and Women’s Hospital and Children’s Hospital Boston. MBS Shadowing is student run as a part of the Mind and Brain Society, and students are involved in every step of the process to set up shadowing opportunities and to connect students with doctors. If you are
interested in shadowing a physician or getting involved with the program, email mbsshadowing@gmail.com.

**CURRICULUM**

**Basic Science Requirements (7):**

<table>
<thead>
<tr>
<th>Course</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>CH 101/102</td>
<td>General Chemistry I/II (or equivalent)</td>
</tr>
<tr>
<td>PY 105/106</td>
<td>Physics I/II (or equivalent)</td>
</tr>
<tr>
<td>MA 123/124</td>
<td>Calculus I/II (or equivalent)</td>
</tr>
<tr>
<td>PS 211</td>
<td>Statistics (or MA 115/116 or MA 213/214)</td>
</tr>
</tbody>
</table>

**Core Courses (5):**

<table>
<thead>
<tr>
<th>Course</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>NE 101</td>
<td>Introduction to Neuroscience</td>
</tr>
<tr>
<td>NE 102*</td>
<td>Introduction to Cellular and Molecular Neurobiology</td>
</tr>
<tr>
<td>NE 202</td>
<td>Introduction to Cognitive Neuroscience</td>
</tr>
<tr>
<td>NE 203*</td>
<td>Principles of Neuroscience w/Lab</td>
</tr>
<tr>
<td>NE 204*</td>
<td>Introduction to Computational Models of Brain and Behavior</td>
</tr>
</tbody>
</table>

**Required Electives (5):**

1. One of the five required electives must contain a laboratory component if not met by the core laboratory courses (NE 102 and NE 203).
2. Breadth Requirement: One of the five required electives must come from a second group.
3. Up to two electives may come from the Restricted list (will not satisfy breadth or lab course requirement).
4. Two consecutive semesters of research during junior or senior year may satisfy the upper level lab course requirement.
5. Note: Course schedules vary by semester. Please check the Link for updated schedules.

**Group 1 – Cellular and Systems**

<table>
<thead>
<tr>
<th>Course</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>NE 230</td>
<td>Behavioral Endocrinology</td>
</tr>
<tr>
<td>NE 322*</td>
<td>Experimental Psych: Physiology</td>
</tr>
<tr>
<td>NE 444</td>
<td>Neuroethology</td>
</tr>
<tr>
<td>NE 445*</td>
<td>Cellular and Molecular Neurophysiology</td>
</tr>
<tr>
<td>NE 455</td>
<td>Developmental Neurobiology</td>
</tr>
<tr>
<td>NE 481</td>
<td>Molecular Biology of the Neuron</td>
</tr>
<tr>
<td>NE 520</td>
<td>Sensory Neurobiology</td>
</tr>
<tr>
<td>NE 545</td>
<td>Neurobiology of Motivated Behavior</td>
</tr>
<tr>
<td>NE 554</td>
<td>Neuroendocrinology</td>
</tr>
<tr>
<td>BI 599</td>
<td>Neurobiology of Synapses</td>
</tr>
</tbody>
</table>
Group 2 – Cognition and Behavior

PS 222  Perception
NE 234  Psychology of Learning
NE 323* Experimental Psych: Learning
NE 333  Drugs and Behavior
NE 337** Memory Systems
NE 338** Neuropsychology
NE 528  Human Brain Mapping
NE 529  Neuroplasticity
NE 544  Developmental Neuropsychology

Group 3 – Computation

NE 530  Neural Models of Memory
NE 330* Intro to Comp Models of Vision
NE 340* Intro to Comp Models of Skilled Action
SAR HS/NE 361* Intro to Comp Models Speech, Language, Hearing
BI 502  Topics in the Mathematical Structure of Biological Systems
MA 421  Modern Stat Modeling and Data Analysis
MA 565  Math Models in Life Sciences
MA 578  Bayesian Stats
CS 542  Machine Learning
CS 565  Data Mining
CN 500  Techniques in Modeling
CN 510/520 Principles & Methods of Cognition & Neural Models I/II
CN 530-570 Comp Models of Vision / Movement / Memory / Perception / Speech
CN 580  Introduction to Computational Modeling

* Lab course
** Students may elect to take only one of these courses toward the major

Restricted Electives:

BI 203  Cell Biology
BI 315  Systems Physiology
CH 203  Organic Chemistry I
MA 242  Linear Algebra
MA 226  Differential Equations
MA 416  Intermediate Stats
CS 111/112 Intro to Computer Science I/II
ENG EK 127 Engineering Computation
Research:
Senior Work for Distinction (2 Semesters: CAS NE 401/402)
Directed Study (CAS NE 391, 392, 491, 492)
Seminar: Nature of Science in Research (CAS NE 495)

REPRESENTATIVE COURSE SEQUENCING
The following are three sample course sequences representing a range of student interests: the generalist, specialist, and a thematic interest. Note that the first sequence incorporates CH 203 and CH 204 (Organic Chemistry) for those students who elect to complete the pre-med requirements. These sequences are consistent with other science degree programs in CAS, and none of these sequences assume AP credit for an incoming first year student.

Sample Course Sequence 1: A Generalist - Broad Survey of Neuroscience (Pre-Med).

<table>
<thead>
<tr>
<th>Fall</th>
<th>Freshman</th>
<th>Spring</th>
</tr>
</thead>
<tbody>
<tr>
<td>NE 101</td>
<td>NE 102*</td>
<td>CH 102</td>
</tr>
<tr>
<td>CH 101</td>
<td></td>
<td>Calculus</td>
</tr>
<tr>
<td></td>
<td>Humanities 1</td>
<td>WR 150</td>
</tr>
<tr>
<td>WR 100</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Sophomore</td>
<td></td>
</tr>
<tr>
<td>NE 203*</td>
<td></td>
<td>NE 202</td>
</tr>
<tr>
<td>Calculus</td>
<td></td>
<td>Statistics</td>
</tr>
<tr>
<td>&lt;CH 203&gt;</td>
<td></td>
<td>(CH 204)</td>
</tr>
<tr>
<td>Language 1</td>
<td></td>
<td>Language 2</td>
</tr>
<tr>
<td>&lt;BI 203&gt;</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Physics</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Social Sci 1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Language 3</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Junior</td>
<td></td>
</tr>
<tr>
<td>&lt;BI 520&gt;</td>
<td></td>
<td>NE 204*</td>
</tr>
<tr>
<td>&lt;PS 338&gt;</td>
<td></td>
<td>Physics</td>
</tr>
<tr>
<td>Social Sci 2</td>
<td></td>
<td>(BI 315)</td>
</tr>
<tr>
<td></td>
<td>&lt;Senior</td>
<td>Language 4</td>
</tr>
<tr>
<td>Humanities 2</td>
<td></td>
<td></td>
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<td></td>
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<td></td>
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<tr>
<td></td>
<td>* Lab course</td>
<td></td>
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<tr>
<td>&lt;&gt; Satisfies elective requirement</td>
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</tr>
<tr>
<td>() Free electives</td>
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</tbody>
</table>
Sample Course Sequence 2: A Specialist – Focused on Computational Neuroscience.

<table>
<thead>
<tr>
<th>Fall</th>
<th>Spring</th>
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</thead>
<tbody>
<tr>
<td><strong>Freshman</strong></td>
<td></td>
</tr>
<tr>
<td>NE 101</td>
<td>NE 102*</td>
</tr>
<tr>
<td>CH 101</td>
<td>CH 102</td>
</tr>
<tr>
<td>Humanities 1</td>
<td>Calculus</td>
</tr>
<tr>
<td>WR 100</td>
<td>WR 150</td>
</tr>
<tr>
<td><strong>Sophomore</strong></td>
<td></td>
</tr>
<tr>
<td>NE 203*</td>
<td>NE 202</td>
</tr>
<tr>
<td>Calculus</td>
<td>NE 204*</td>
</tr>
<tr>
<td>Statistics</td>
<td>&lt;MA 242&gt;</td>
</tr>
<tr>
<td>Language 1</td>
<td>Language 2</td>
</tr>
<tr>
<td><strong>Junior</strong></td>
<td></td>
</tr>
<tr>
<td>&lt;ENG EK 127&gt;</td>
<td>&lt;NE 340*&gt;</td>
</tr>
<tr>
<td>Physics</td>
<td>Physics</td>
</tr>
<tr>
<td>Social Sci 1</td>
<td>(MA 225)</td>
</tr>
<tr>
<td>Language 3</td>
<td>Language 4</td>
</tr>
<tr>
<td><strong>Senior</strong></td>
<td></td>
</tr>
<tr>
<td>&lt;BI 520&gt;</td>
<td>&lt;PS 530&gt;</td>
</tr>
<tr>
<td>Social Sci 2</td>
<td>(               )</td>
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<tr>
<td>Humanities 2</td>
<td>(               )</td>
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</tbody>
</table>

* Lab course
<> Satisfies elective requirement
() Free electives

Sample Course Sequence 3: A Thematic Interest – Focused on Memory.

<table>
<thead>
<tr>
<th>Fall</th>
<th>Spring</th>
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<tbody>
<tr>
<td><strong>Freshman</strong></td>
<td></td>
</tr>
<tr>
<td>NE 101</td>
<td>NE 102*</td>
</tr>
<tr>
<td>CH 101</td>
<td>CH 102</td>
</tr>
<tr>
<td>Humanities 1</td>
<td>Calculus</td>
</tr>
<tr>
<td>WR 100</td>
<td>WR 150</td>
</tr>
<tr>
<td><strong>Sophomore</strong></td>
<td></td>
</tr>
<tr>
<td>NE 203*</td>
<td>NE 202</td>
</tr>
<tr>
<td>Calculus</td>
<td>NE 204*</td>
</tr>
<tr>
<td>Statistics</td>
<td>Social Sci 1</td>
</tr>
<tr>
<td>Language 1</td>
<td>Language 2</td>
</tr>
</tbody>
</table>
**Junior**

<table>
<thead>
<tr>
<th>Course</th>
<th>Course</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;PS 337&gt;</td>
<td>&lt;BI 545&gt;</td>
</tr>
<tr>
<td>Physics</td>
<td>Physics</td>
</tr>
<tr>
<td>&lt;PS 323*&gt;</td>
<td>Humanities 2</td>
</tr>
<tr>
<td>Language 3</td>
<td>Language 4</td>
</tr>
</tbody>
</table>

**Senior**

<table>
<thead>
<tr>
<th>Course</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;PS 529&gt;</td>
</tr>
<tr>
<td>Social Sci 2</td>
</tr>
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<td>(          )</td>
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<tr>
<td>(          )</td>
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<tr>
<td>(          )</td>
</tr>
</tbody>
</table>

* Lab course
<> Satisfies elective requirement
() Free electives

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**Undergraduate Program in Neuroscience – Participating Faculty**

**Biology**
- Jelle Atema
- Michael Baum
- Gloria Callard
- Ian Davison
- Vincent Dionne
- William Eldred
- Tim Gardner
- Jen-Wei Lin
- Hengye Man
- James Traniello

- Nancy Kopell
- Mark Kramer

**Psychology**
- Daniel Bullock
- James Cherry
- Alice Cronin-Golomb
- Howard Eichenbaum
- Catherine Harris
- Michael Hasselmo
- Fabio Idrobo
- Kathleen Kantak
- Jacquelyn Liederman

**Computer Science**
- George Kollios
- Stan Sclaroff

**Mathematics and Statistics**
- Robert Devaney
- Uri Eden
- Eric Kolaczyk

- Ennio Mingolla
- Michele Rucci
- David Somers
- Chantal Stern
- Helen Tager-Flusberg
- Amanda Tarullo
Undergraduate Program in Neuroscience – Research Faculty

Alzheimer’s Disease Center
Neil Kowall

Anatomy and Neurobiology
Gene J. Blatt
Robert Joseph
Thomas Kemper
Ronald Killiany
Jennifer Luebke
Mark Moss
Deepak N. Pandya

Neuromuscular Research Center
Carlo DeLuca
Donald Gilmore
Gerald Gottlieb
Serge Roy

Neurology
Martin L. Albert
Sanford H. Auerbach
Raymon Durso
Samuel Frank
Robert C. Green
Carols S. Kase
Kristine Lundgren
Richard H. Myers
Margaret A. Naeser
Roberta F. White
Mieke H. Verfaellie

Neurosurgery and Pharmacology
Zhigang Xie
Alan Peters
Douglas Rosene
Jean-Jacques Soghomonian
Louis J. Toth
Irina V. Zhdanova

Biochemistry
Carmela R. Abraham
Richard E. Fine

Biomedical Engineering
Steven Colburn
James Collins

Pathology and Laboratory Medicine
J. Krzysztof Blusztajn
Peter Bergethon

Pharmacology and Experimental Therapeutics
Pietro Cottone
David H. Farb
Shelley J. Russek
Benjamin Wolozin
Sabina Valentino

Physiology and Biophysics
Carter Cornwall
J. Fernando Garcia-Diaz
J. F. Head
Simon Levy
Enrico Nasi
Charles Delisi
Gerald Kidd, Jr.
David Mountain
Jason Ritt
Kamal Sen
Barbara Shinn-Cunningham
Lucia Vaina
Sandor Vajda
Herbert Voigt

Geriatrics
Conan Kornetsky
COURSE DESCRIPTIONS

Required Basic Science Courses

CAS CH 101, 102 General Chemistry. For science concentrators who require a two-semester general chemistry course. Stoichiometry, gases, liquids, solids, solutions, equilibrium, thermodynamics, electrochemistry, atomic structure and bonding, kinetics, and selected chemical systems. Laboratory exercises include qualitative analysis. Three hours lecture, one hour discussion, one hour postlab lecture, and three hours lab.

CAS PY 105, 106 General Physics. Sequence satisfies premedical requirements; presupposes algebra and trigonometry. Principles of classical and modern physics. Mechanics, conservation laws, heat, light, electricity and magnetism, waves, light and optics, atomic and nuclear physics.

CAS MA 123 Calculus I. Limits; derivatives; differentiation of algebraic functions. Applications to maxima, minima, and convexity of functions. The definite integral; the fundamental theorem of integral calculus; applications of integration.


CAS PS 211 Introduction to Experimental Design in Psychology. Concepts of experimental design in psychology, including the identification and control of bias, minimizing unsystematic error, the statistical description of data, elementary probability theory, and elementary statistical inference.

CAS MA 116 Statistics II. One- or two-sample inference for normal means and binomial probabilities, analysis of variance, simple linear regression, multiple regression, analysis of categorical data. Introduction to survey design and design of experiments. Primarily for students in the social sciences with limited mathematics preparation.

CAS MA 213 Basic Statistics and Probability. Elementary treatment of probability densities, means, variances, correlation, independence, the binomial distribution, the central limit theorem. Stresses understanding and theoretical manipulation of statistical concepts.

CAS MA 214 Applied Statistics. Inference about proportions, goodness of fit, student's t-distribution, tests for normality; two-sample comparisons, regression and correlation, tests for linearity and outliers, residual analysis, contingency tables, analysis of variance.

Required Core Courses

NE 101 Introduction to Neuroscience. An introduction to the biological basis of behavior and cognition. Includes theoretical and practical foundations rooted in psychology, neuropharmacology, and clinical sciences (e.g. neurology and neuropsychiatry). Neuroethical dilemmas will be highlighted and integrated when relevant to discussion topics.

NE 102 Introduction to Cellular and Molecular Neuroscience. A cellular and molecular approach to nervous system function. Includes molecular and genetic basis of neurons; structure and function of ion channels, synapses, and glia; mechanisms of signal transduction; neuroendocrinology; and sensory systems and transduction. Project labs focused on anatomy and physiology of neurons.

NE 202 Introduction to Cognitive Neuroscience. Toward an understanding of the brain basis of cognition. Introduces research methods and human neuroanatomy, and provides a survey of topics including learning and memory, attention, perception, language, social cognition, and executive function.

NE 203 Principles of Neuroscience with Lab. Fundamentals of the nervous system, emphasizing synaptic transmission; hierarchical organization;
autonomic nervous system; mechanisms of sensory perception; reflexes and motor function; biorhythms; and neural mechanisms of feeding, mating, learning, and memory. Project labs focused on animal models of learning and memory. Prerequisite: NE102

**NE 204 Introduction to Computational Models of Brain and Behavior.**
Introduces students to important concepts in cognitive neuroscience and computational modeling of biological neural systems. The course combines a systems-level overview of brain function with an introduction to modeling of brain and behavior using neural networks.

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**Research**

**CAS NE 401, 402 Independent Work for Distinction in Neuroscience.** Laboratory research project chosen and performed under supervision of an affiliated neuroscience faculty member. Research lab must be chosen and the project approved by the program and College by the time of registration. Course grade determined by laboratory participation, written report, and oral presentation.

**CAS NE 391, 392, 491, 492 Directed Study in Neuroscience.** Mentored research experience in the field of neuroscience conducted under supervision of a neuroscience affiliated faculty. Research lab must be chosen and the project must meet guidelines established by the program by the time of registration. Course grade determined by laboratory participation and written report.

**CAS NE 495.** Seminar on the nature of scientific research for undergraduates currently engaged in research: “normal” scientific research, role of models, functioning of the scientific community, how the public may perceive scientific research, what distinguishes science from other fields of inquiry or belief.

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**Electives**

**Cellular and Systems Group**

**CAS NE 230 Behavioral Endocrinology.** Hormonal control of reproductive behaviors and social affiliation, aggression, fluid homeostasis and feeding, biological rhythms including seasonal reproduction, stress, learning and memory, psychiatric illness, and steroid abuse.

**CAS NE 322 Experimental Psychology: Physiology.** Laboratory course in physiological psychology. Emphasis on neuroanatomical mechanisms involved in behavior. Experiments are performed on rats and resulting data is analyzed. Research reports required.
CAS NE 444 Neuroethology. Cellular and molecular basis of behavior, with emphasis on functional physiology of neurons, interactions among neurons, and the organization of sensory-motor systems.

CAS NE 445 Cellular and Molecular Neurophysiology. Cellular and molecular basis of neural excitability and synaptic transmission. The molecular understanding at the cellular level is extrapolated to higher brain functions such as learning, memory, and sleep.

CAS NE 455 Developmental Neurobiology. Fundamental principles of developmental neurobiology, stressing molecular mechanisms that underlie early neural development, differentiation, process outgrowth, and behavior.

CAS NE 520 Sensory Neurobiology. Neural organization and function of sensory systems, including vision, audition, somatosensation, olfaction, and taste. Detailed analysis of transduction, and processing from periphery through central representations of sensory space. Special emphasis on neural coding. Readings include current research from primary literature.

CAS NE 545 Neurobiology of Motivated Behavior. Molecular and neuroendocrine mechanisms controlling reproductive and parental behaviors, ingestive behaviors and metabolism, circadian rhythms, and pain perception in vertebrates.

CAS NE 481 Molecular Biology of the Neuron. The study of interactions between neurotransmitters and receptors in the nervous system. Topics include electrical properties of neurons, a survey of neurotransmitters, molecular structure and function of receptors, synaptic transmission, intracellular signaling, and the molecular biology of sensory transduction.

CAS NE 554 Neuroendocrinology. Interactions between the two major integrative organ systems of animals and the endocrine and nervous systems in controlling physiological and behavioral aspects of reproduction, development, growth, biological rhythms, and homeostasis.

CAS BI 599 Neurobiology of Synapses. Structure, function, and composition of different types of synapses in the nervous system. Changes in synapse structure during synaptogenesis and plasticity as a cellular basis for higher brain functions such as learning and memory. Synaptic pathology in neural disease processes.
Cognitive Group

CAS PS 222 Perception and Behavior. Why do things look as they do? This question is examined with particular emphasis on experiments that clarify the relative contributions of nature and nurture, and structural and experiential factors.

CAS NE 234 Psychology of Learning. Survey of theory and techniques in learning and their applications in different settings. Topics include problem solving, memory, reward and punishment, and reinforcement schedules as studied in animals, normal classrooms, and remedial settings.

CAS NE 323 Experimental Psychology: Learning. Methodology, results, and interpretation of respondent and operant conditioning. Experimental analyses of selected topics in learning within the context of reinforcement theory. Required reports of instructor-planned and student-planned experiments using the albino rat.

CAS NE 333 Drugs and Behavior. Comprehensive survey of drug influences on behavior; introduces a neuroscience approach to behavior. Several classes of drugs discussed, including abused and addictive substances and psychoactive and therapeutic agents.

CAS NE 337 Memory Systems of the Brain. Survey of investigations into the brain systems and neurobiological mechanisms of memory. Includes experimental studies of amnesia in humans and experimental models of amnesia in animals. Focus on evidence for multiple forms of memory and distinct brain systems that mediate them.

CAS NE 338 Neuropsychology. Survey of theoretical aspects and major empirical findings in human neuropsychology, including memory, language, spatial function, attention, emotion, and abstract thought. Emphasis is on the relation between brain disorders (resulting from head injury, stroke, degenerative disease, etc.) and abnormal behavior.

CAS NE 528 Human Brain Mapping. Localization in the brain of human mental functions and the study of their neural mechanisms. Topics include methods (fMRI, PET, TMS, ERP), memory, perception, recognition, attention, and executive processes.

CAS NE 529 Neuroplasticity. Review of neurophysiological mechanisms underlying the astounding reorganizational capacity of the brain. Critical examination of ways to promote this plasticity: early childhood experiences,
positive thinking, meditation, exercise, visualization, physical therapy, computerized re-training, and sensory and motor prostheses.

**CAS NE 544 Developmental Neuropsychology.** Study of the neural mechanisms underlying behavioral development. Topics include the plasticity of the developing brain in response to deprivation or damage and mechanisms underlying specific syndromes (e.g., aphasia, dyslexia, learning disabilities, hyperactivity, autism, and Tourette's syndrome).

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**Computational Group**

**CAS NE 530 Neural Models of Memory Function.** Computational models of neurobiological mechanisms for memory function and spatial navigation, with a particular emphasis on cellular and circuit models of the hippocampus and related cortical structures.

**CAS NE 330 Introduction to Computational Models of Vision.** Explores the psychological, biological, mathematical, and computational foundations of visual perception. Mathematically specified neural and computational models elucidate the structure and dynamics of the mammalian visual system.

**CAS NE 340 Introduction to Computational Models of Skilled Action.** Humans are facile skill learners. What brain circuits and learning mechanisms enable skilled selection/choice of plans and skilled enactment of the plans chosen? This course integrates interdisciplinary efforts to understand brain functions well enough to allow accurate computer simulations of skill learning.

**SAR HS/NE 361 Introduction to Computational Neuroscience of Speech, Language, and Hearing.** Introduces the foundations of auditory perception including the mammalian auditory pathway, speech and language perception and links with speech production, auditory scene analysis, and music perception, from a computational perspective. Laboratory computer assignments elucidate functional properties of these systems.

**CAS BI 502: Topics in the Mathematical Structure of Biological Systems.** Examines mathematical principles for the control of biological systems, including themes of behavioral switching, adaptation, noise, and memory. Subjects range from bacteria to vertebrates. Assignments include student presentations on primary literature, and the option of computational modeling.

**CAS MA 421 Modern Statistical Modeling and Data Analysis.** Provides a non-technical descriptive introduction to modern techniques in data modeling via software Splus. Topics include linear and nonlinear, nonparametric and
semiparametric regression, Bayesian models and computations, introduction to data mining, association rules, decision trees, and neural network algorithms.

**CAS MA 565 Mathematical Models in the Life Sciences.** An introduction to mathematical modeling, using applications in the biological sciences. Mathematics includes linear difference and differential equations, and an introduction to nonlinear phenomena and qualitative methods. An elementary knowledge of differential equations and linear algebra is assumed.


**CAS CS 542 Machine Learning.** Familiarity with linear algebra, probability, and statistics. Introduction to modern machine learning concepts, techniques, and algorithms. Topics include regression, kernels, support vector machines, feature selection, boosting, clustering, hidden Markov models, and Bayesian networks. Programming assignments emphasize taking theory into practice, through applications on real-world data sets.

**CAS CS 565 Data Mining.** Familiarity with linear algebra, probability, and statistics. Introduction to data mining concepts and techniques. Topics include association and correlation discovery, classification and clustering of large datasets, outlier detection. Emphasis on the algorithmic aspects as well as the application of mining in real-world problems.

**CAS CN 500 Computational Methods in Cognitive and Neural Systems.** Introduction to mathematical methods and computer simulation for modeling cognitive and neural systems. Topics include computer simulation methods, control theory, difference and differential equations, digital signal processing, image processing, optimization, and statistics. Readings from current literature emphasize theory and applications relevant to the study of cognitive and neural systems.

**CAS CN 510 Principles and Methods of Cognitive and Neural Modeling I.** Explores psychological, biological, mathematical, and computational foundations of behavioral and brain modeling. Topics include organizational principles, mechanisms, local circuits, network architectures, cooperative and competitive non-linear feedback systems, associative learning systems, and self-organizing code-compression systems. The adaptive resonance theory model unifies many course themes. CAS CN 510 and 520 may be taken concurrently.
CAS CN 520 Principles and Methods of Cognitive and Neural Modeling II. Analyzes three main traditions in models of learning: unsupervised (self-organized) learning, supervised learning (learning with a teacher), and reinforcement learning. Architectures studied include adaptive filters, back propagation, competitive learning, self-organizing feature maps, gradient descent procedures, Boltzmann machines, simulated annealing, neocognitron, and gated dipoles. CAS CN 510 and 520 may be taken concurrently.

CAS CN 530 Neural and Computational Models of Vision. Current models of mammalian visual processes are constrained by experimental and theoretical results from psychology, physiology, computer science, and mathematics. The course evaluates the explanatory adequacy of competing neural and computational models of such processes as edge detection, textural grouping, shape-from-shading, stereopsis, motion detection, and color perception. Students perform computer simulations of some of the examined models.

CAS CN 540 Neural and Computational Models of Adaptive Movement Planning and Control. Neural models of eye, arm, hand, orofacial, and leg movements are presented and compared to reveal general organizational principles and specialized neural circuit designs for motor learning and performance. Issues include: trajectory formation, synchronization of synergists, variable velocity control, adaptive gain control, map formation, load compensation, serial order, and inflow versus outflow as sources of sensory-motor information.

CAS CN 550 Neural and Computational Models of Recognition, Memory, and Attention. Develops neural network models of how internal representations of sensory events and cognitive hypotheses are learned and remembered, and how such internal representations enable recognition and recall of these events to occur. Various neural pattern recognition models are analyzed. Special emphasis is placed on stable self-organization of pattern recognition and recall codes in unpredictable and noisy environments—notably by adaptive resonance theory models—and on how such codes direct attention toward predictively relevant combinations of features, while attenuating irrelevant background cues. Experimental data and theoretical predictions from cognitive psychology, neuropsychology, and neurophysiology of normal and abnormal individuals are analyzed.

CAS CN 560 Neural and Computational Models of Speech Perception and Production. Develops neural network models of speech perception and production processes. Emphasis is placed on the role of learning and on the specialized neural designs that have evolved for purposes of speech
communication. Practical, including industrial, applications of neural networks for speech processing are also reviewed.

**CAS CN 570 Neural and Computational Models of Conditioning, Reinforcement, Motivation, and Rhythm.** Develops neural and computational models of how humans and animals learn to successfully predict environmental events and generate behavioral actions that satisfy internally defined criteria of success or failure. Reinforcement learning and its homeostatic (drive, arousal, rhythm) and nonhomeostatic (reinforcement) modulators are analyzed in depth. Recognition learning and recall learning networks are joined to the reinforcement learning network to analyze how these several processes cooperate to generate successful goal-oriented behavior. Maladaptive behaviors and certain mental disorders are analyzed from a unified theoretical perspective. Applications to the design of freely moving adaptive robots are noted.

**CAS CN 580 Introduction to Computational Neuroscience.** This introductory level course focuses on building a background in neuroscience, but with emphasis on computational approaches. Topics include basic biophysics of ion channels, Hodgkin-Huxley theory, use of stimulators such as NEURON and GENESIS, recent applications of the compartmental modeling technique, and a survey of neuronal architectures of the retina, cerebellum, basal ganglia, and neocortex.

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**Restricted Electives**

**CAS BI 203 Cell Biology.** Principles of cellular organization and function: biological molecules, flow of genetic information, membranes and subcellular organelles, and cell regulation.

**CAS BI 315 Systems Physiology.** An introduction to physiological principles applied across all levels of organization (cell, tissue, organ system). Intended to prepare the student for more advanced courses in physiology. Topics include homeostasis and neural, muscle, cardiopulmonary, renal, endocrine, and metabolic physiology.

**CAS CH 203 Organic Chemistry.** Fundamentals of organic chemistry, including electronic structure, stereochemistry, and reactions of important functional groups. Laboratory includes extraction, distillation, and chromatography.

**CAS MA 226 Differential Equations.** First-order linear and separable equations. Second-order equations and first-order systems. Linear equations and


**CAS MA 416 Intermediate Statistical Methods.** Fundamental concepts and analytical skills in analysis of variance, including crossed and nested designs, as well as fixed- and random-effect models. Trend analysis for repeated measures, expected mean squares, and nonparametric techniques. SAS is used throughout the course.

**CAS CS 111 Introduction to Computer Science I.** The first course for computer science, mathematics, and physical science concentrators, and others wishing a more technical approach than CS 101 through CS 108. Develops basic skills in computer programming using the Java programming language.

**CAS CS 112 Introduction to Computer Science II.** Covers advanced programming techniques and data structures. Topics include recursion, algorithm analysis, linked lists, stacks, queues, trees, graphs, tables, searching, and sorting.

**ENG EK 127 Engineering Computation.** An introduction to engineering problem solving using a modern computational environment. Basic procedural programming concepts include input/output, branching, looping, functions, file input/output, and data structures such as arrays and structures. An introduction to basic linear algebra concepts such as matrix operations and solving sets of equations. Introduction to numerical methods, for example least squares solutions and their use for curve fitting. Programming projects provided by all College of Engineering departments will reinforce these concepts and introduce engineering freshmen to the various disciplines.
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