THE DEPARTMENT OF COGNITIVE AND NEURAL SYSTEMS

The Department of Cognitive and Neural Systems (CNS) provides advanced training and research experience for graduate students and qualified undergraduates interested in the neural and computational principles, mechanisms, and architectures that underlie human and animal behavior, and the application of neural network architectures to the solution of technological problems. The department's training and research focus on two broad questions. The first question is: *How does the brain control behavior?* This is a modern form of the Mind/Body Problem. The second question is: *How can technology emulate biological intelligence?* This question needs to be answered to develop intelligent technologies that are well suited to human societies. These goals are symbiotic because brains are unparalleled in their ability to intelligently adapt on their own to complex and novel environments. Models of how the brain accomplishes this are developed through systematic empirical, mathematical, and computational analysis in the department. Autonomous adaptation to a changing world is also needed to solve many of the outstanding problems in technology, and the biological models have inspired qualitatively new designs for applications. CNS is a world leader in developing biological models that can quantitatively simulate the dynamics of identified brain cells in identified neural circuits, *and* the behaviors that they control. This new level of understanding is producing comparable advances in intelligent technology.

CNS is a graduate department that is devoted to the interdisciplinary training of graduate students. The department offers MA, PhD, and BA/MA degree programs. Its students are trained in a broad range of areas concerning computational neuroscience, cognitive science, and neuromorphic systems. The biological training includes study of the brain mechanisms of vision and visual object recognition; audition, speech, and language understanding; recognition learning, categorization, and long-term memory; cognitive information processing; self-organization and development, navigation, planning, and spatial orientation; cooperative and competitive network dynamics and short-term memory; reinforcement and motivation; attention; adaptive sensory-motor planning, control, and robotics; biological rhythms; consciousness; mental disorders; and the mathematical and computational methods needed to support advanced modeling research and applications. Technological training includes methods and applications in image processing, multiple types of signal processing, adaptive pattern recognition and prediction, information fusion, and intelligent control and robotics.

The foundation of this broad training is the unique interdisciplinary curriculum of eighteen interdisciplinary graduate courses that have been developed at CNS. Each of these courses integrates the psychological, neurobiological, mathematical, and computational information needed to theoretically investigate fundamental issues concerning mind and brain processes and the applications of artificial neural networks and hybrid systems to technology. A student's curriculum is tailored to his or her career goals with academic and research advisors. In addition to taking interdisciplinary courses within CNS, students develop important disciplinary expertise by also taking courses in departments such as biology, computer science, engineering, mathematics, and psychology. In addition to these formal courses, students work individually with one or more research advisors to learn how to carry out advanced interdisciplinary research in their chosen research areas. As a result of this breadth and depth of training, CNS students have succeeded in finding excellent jobs in both academic and technological areas after graduation.

The CNS Department interacts with colleagues in several Boston University research centers, and with Boston-area scientists collaborating with these centers. The units most closely linked to the department are the Center for Adaptive Systems and the CNS Technology Laboratory. CNS is also part of a major NSF Center of Excellence for Learning in Education, Science, and Technology (CELEST); see http://www.cns.bu.edu/CELEST. Students interested in neural network hardware can work with researchers in CNS and at the College of Engineering. Other research resources include the campus-wide Program in Neuroscience, which unites cognitive neuroscience, neurophysiology, neuroanatomy, neuropharmacology, and neural modeling across the Charles River Campus and the School of Medicine; in sensory robotics, biomedical engineering, computer and systems engineering, and neuromuscular research within the College of Engineering; in dynamical systems within the Department of Mathematics; in theoretical computer science within the Department of Computer Science; and in biophysics and computational physics within the Department of Physics. Key colleagues in these units hold faculty appointments in CNS in order to expedite training and research interactions with CNS core faculty and students.

In addition to its basic research and training program, the department organizes an active colloquium series, various research and seminar series, and international conferences and symposia, to bring distinguished scientists from experimental, theoretical, and technological disciplines to the department.

The department is housed in its own four-story building, which includes ample space for faculty and student offices and laboratories (auditory neuroscience, computer vision and computational neuroscience, sensory-motor control, speech and language, technology, and visual psychophysics), as well as an auditorium, classroom, seminar rooms, a library, and a faculty-student lounge. A powerful computer network supports large-scale simulations of behavioral and brain models, as well as neural network applications and technology transfer.

THE CENTER FOR ADAPTIVE SYSTEMS

The Center for Adaptive Systems (CAS) is an interdisciplinary research and training center whose interests intersect the areas of biology, computer science, engineering, mathematics, and psychology. The Center performs interdisciplinary research aimed at discovering and developing principled theories of brain and behavior, notably concerning how individual humans and animals adapt so well on their own to rapidly changing environments that may include rare, ambiguous, and unexpected events. The Center also develops technological applications that are inspired by its biological models. Research and training are carried out both individually and through close collaborative relationships between faculty, students, and postdoctoral fellows. Research projects encompass a broad range of areas concerning cognitive and neural systems, including vision and image processing; audition, speech and language understanding; adaptive pattern recognition; cognitive information processing; self-organization and development; associative learning and long-term memory; reinforcement and motivation; attention; adaptive sensory-motor planning, control and robotics; navigation and spatial orientation; biological rhythms; consciousness; and the mathematical and computational methods needed to support advanced modeling research and applications. Both normal and abnormal behaviors are analyzed, including Parkinson's disease, attention deficit disorder, schizophrenia, and depression.

These investigations lead to neural network models that clarify the functional architecture of different brain regions. Recent models characterize the functional organization of such brain areas as the visual cortex, auditory cortex, temporal cortex, parietal cortex, motor cortex, prefrontal cortex, hippocampus, hypothalamus, cerebellum, superior colliculus, basal ganglia, reticular formation, thalamus, retina, and spinal cord.

General neural designs that realize specialized functional roles in distinct brain regions are clarified through such models. Different levels of organization are analyzed, ranging from neural systems and architectures to neural modules, local circuits, and cellular, biophysical, and biochemical mechanisms. For example, CAS and CNS have led the way in modeling how and why the architecture of all sensory and cognitive neocortex is organized into layered circuits. This research clarifies how "laminar computing" contributes to biological intelligence. Such cortical laminar cortical architectures are under investigation in vision, recognition learning and categorization, short-term memory, cognitive information processing, and sensory-motor planning. A typical example on the module level is opponent processing circuits by on-cells and off-cells. Specialized versions of this module play a key role in vision, biological rhythms, reinforcement learning, motor control, and cognitive information processing. Such a comparative analysis clarifies how a single modular design may be adapted to many different behavioral functions. A typical example on the mechanism level is associative learning, which plays a key role in such varied behaviors as recognition, spatial orientation, and sensory-motor control. Contributions of the specialized electrical and chemical dynamics of individual cells are analyzed in every model. The models also provide explanations and predictions of data that link the several levels of behavior, evoked potentials, neurophysiology, anatomy, biophysics, and biochemistry.

These neural models are typically naturally expressed as nonlinear dynamical systems. Numerical and analytical investigations of these systems lead to new mathematical results and problems, as well as to formal bridges to other biological and physical systems, notably dissipative systems that describe aspects of self-organization and nonequilibrium behavior. These formal investigations suggest new designs for computer vision, adaptive pattern recognition machines, autonomous robots, and massively parallel computers, thereby integrating basic science with the design of novel technologies. Faculty and students also interact with working engineers in companies and government laboratories to implement neural network designs in new hardware for technological applications.

As a part of Boston's large academic community, the Center has facilitated active collaborations among scientists at neighboring universities and research laboratories. In addition, Boston's prime location leads to a steady stream of national and international visitors.

LABORATORY AND COMPUTER FACILITIES

The department is funded by fellowships, grants, and contracts from federal agencies and private foundations that support research in life sciences, mathematics, artificial intelligence, and engineering. Facilities include laboratories for experimental research and computational modeling in visual perception; audition, speech and language processing; sensory-motor control and robotics; and technology transfer. Data analysis and numerical simulations are carried out on a state-of-the-art network comprises xeon-based workstations, Macintoshes, and both 32-bit and 64-bit PCs. A PC farm running BU's own version of Linux (BU Linux v5.3 based on CentOS 5) is available as a distributed computational environment. All students have department-supplied PCs on their desktops (running either Microsoft Windows or BU Linux) allowing them to run their simulations either locally or remotely on one of the department's workstations. Mathematical simulation and modeling are carried out using standard software packages such as Mathematica or Matlab, as well as SPlus and VisSim.

The department maintains a core collection of books and journals, and has access both to the Boston University libraries and to the many other collections of the Boston Library Consortium. In addition, several specialized facilities and software are available for use. These include:

Auditory Neuroscience Laboratory

The Auditory Neuroscience Laboratory is an experimental and theoretical laboratory focused on auditory perception, particular spatial perception, attentional processing, and neural plasticity. These questions are studied by running human behavioral experiments, neural imaging experiments (electro-encephalography or EEG), and computational models. The laboratory consists of three rooms, two of which are devoted to behavioral and computational studies (housing special-purpose signal processing and sound generating equipment, electromagnetic head-tracking systems, a two-channel spectrum analyzer, and other miscellaneous equipment for producing, measuring, analyzing, and monitoring auditory stimuli). A third room houses a 128-channel EEG system, along with additional control hardware for auditory signal generation and presentation. The Auditory Neuroscience Laboratory is located at 677 Beacon Street (the home of the CNS department).

Computer Vision and Computational Neuroscience Laboratory

The Computer Vision and Computational Neuroscience Laboratory consists of an electronics workshop, including a surface-mount workstation, PCD fabrication tools, and an Alterra EPLD design system; an active vision laboratory including actuators and video hardware; and systems for computer-aided neuroanatomy and application of computer graphics and image processing to brain sections and MRI images. The laboratory supports research in the areas of neural modeling, computational neuroscience, computer vision, robotics, and fMRI imaging. The major question being addressed is the nature of representation of the visual world in the brain, in terms of observable neural architectures such as topographic mapping and columnar architecture. The application of novel architectures for image processing for computer vision and robotics is also a major topic of interest. Recent work in this area has included the design and patenting of novel actuators for robotic active vision systems, the design of real-time algorithms for use in mobile robotic applications, and the design and construction of miniature autonomous vehicles using space-variant active vision design principles. Recently one such vehicle has successfully driven itself on the streets of Boston. Applications of fMRI imaging to measuring the topographic structure of human primary and extra-striate visual cortex are a current focus of research.

Sensory-Motor Control Laboratory

The Sensory-Motor Control Laboratory supports experimental studies of sensory-motor behavior and computational studies of neural circuits that enable learned voluntary action. Equipment includes a computer controlled, helmet-mounted, video-based, eye-head tracking system. The latter's camera samples eye position at 240Hz and also allows reconstruction of what subjects are attending to as they freely scan a scene under normal lighting. Thus the system affords a wide range of visuo-motor studies. To facilitate computational studies, the laboratory is connected to the Department's and University's extensive network of Linux and Windows workstations and Linux computational servers.

Speech and Language Laboratory

The Speech Laboratory includes facilities for analog-to-digital and digital-to-analog software conversion. Ariel equipment allows reliable synthesis and playback of speech waveforms. An Entropic signal-processing package provides facilities for detailed analysis, filtering, spectral construction, and formant tracking of the speech waveform. Various large databases, such as TIMIT and TIdigits, are available for testing algorithms of speech recognition. The laboratory also contains a network of Windows-based PC computers equipped with software for the analysis of functional magnetic resonance imaging (fMRI) data, including region-of-interest (ROI) based analyses involving software for the parcellation of cortical and subcortical brain regions in structural MRI images.

CNS Technology Laboratory

The CNS Technology Laboratory fosters the development of neural network models derived from basic scientific research and facilitates the transition of the resulting technologies to software and applications. The laboratory was established in 2001, with a grant from the Air Force Office of Scientific Research: "Information Fusion for Image Analysis: Neural Models and Technology Development." Current projects include multi-level fusion and data mining in a geospatial context, in collaboration with the Boston University Center for Remote Sensing; and collaboration with HRL for the DARPA SyNAPSE program, which focuses on neural model implementations in CMOS memristor hardware. This research and development effort builds on models of opponent-color visual processing, contour and texture processing, and Adaptive Resonance Theory (ART) pattern learning and recognition, as well as other models of vision, associative learning, and prediction. Associated basic research projects are conducted within the joint context of scientific data and technological constraints. Software, articles, and educational materials are available through the CNS Technology Website (http://cns.bu.edu/techlab/).

Visual Psychophysics Laboratory

The Visual Psychophysics Laboratory includes a group of faculty and graduate students that conducts psychophysical and computational modeling studies of many aspects of visual perception, including motion perception, shape-from-texture, contour extraction, and visual navigation. See: http://cns.bu.edu/vislab/. The laboratory occupies an 800-square-foot suite, including three dedicated rooms for data collection, and houses a variety of computer-controlled display platforms, including Macintosh, Windows and Linux workstations. Ancillary resources for visual psychophysics include an eye tracker, a computer-controlled video camera, stereo viewing devices, a photometer, and a variety of display-generation, data-collection, and data-analysis software.

Affiliated Laboratories

Affiliated CAS/CNS faculty members have additional laboratories ranging from visual and auditory psychophysics and neurophysiology, anatomy, and neuropsychology to engineering and chip design. These facilities are used in the context of faculty/student collaborations.

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Postdoctoral Fellow, Volen Center, Brandies University
PhD, Neuroscience, Australian National University
Mind-brain physics, mental disorders
http://brightnessdarkness.blogspot.com/

Takeo Watanabe
Professor of Psychology
Director, Vision Sciences Laboratory
PhD, Behavioral Sciences, University of Tokyo, Japan
Perception of objects and motion and effects of attention on perception using psychophysics and brain imaging (fMRI)
http://www.bu.edu/psych/faculty/takeo/

Jeremy Wolfe
Adjunct Professor of Cognitive and Neural Systems
Professor of Ophthalmology, Harvard Medical School
Director, Visual Attention Laboratory, Brigham & Women's Hospital
PhD, MIT
Visual attention, pre-attentive and attentive object representation
http://www.sleep.med.harvard.edu/people/faculty/215/Jeremy+M+Wolfe+PhD

Curtis Woodcock
Professor of Geography and Environment
PhD, University of California at Santa Barbara
Biophysical remote sensing, particularly of forests and natural vegetation, canopy reflectance models and their inversion, spatial modeling, and change detection; biogeography; spatial analysis; geographic information systems; digital image processing
http://www.bu.edu/cees/people/faculty/woodcock/

Arash Yazdanbakhsh
Research Assistant Professor of Cognitive and Neural Systems
Lecturer on Neurobiology, Harvard Medical School
PhD, Cognitive and Neural Systems, Boston University
Visual system, modeling, single cell electrophysiology, and psychophysics
http://www.cns.bu.edu/~yazdan/

Li Zhu
Visiting Researcher, Department of Cognitive and Neural Systems
PhD Candidate, Biomedical Engineering, Tsinghua University, P.R. China
Binaural signal processing and computational modeling, sound localization, cocktail party problem

Other Boston University faculty members who are affiliated with the CNS Department are listed at the end of the brochure.

MA IN COGNITIVE AND NEURAL SYSTEMS

Course Requirements

MA students are required to complete eight semester courses, at least six of which must be 500-level courses selected from the CNS curriculum (CN500, 510, 520, 530, 540, 550, 560, 570, 580). The remaining courses may be selected, with approval of the student's faculty advisor, from other CNS courses and from courses offered by the Departments of Biology, Computer Science, Engineering, Mathematics and Statistics, Medicine, Physics, Physiology, and Psychology.

MA Comprehensive Examination

The MA examination is offered each year in January and in May. A student must have passed at least four 500-level courses in the CNS curriculum to take the MA examination.

PhD IN COGNITIVE AND NEURAL SYSTEMS

Course Requirements

PhD students are required to complete at least sixteen semester courses as follows: at least ten courses chosen from the CNS Department's curriculum (CN500, 510, 520, 530, 540, 550, 560, 570, 580, 700, 710, 720, 730, 740, 760, 780, 810, 811) of which two must be 700 or 800 level; and the remaining courses chosen from other departments to form a coherent area of expertise. The latter courses will be selected in consultation with the student's faculty advisor.

Students who enter the PhD program with a Master's, MD, or PhD degree in one of these areas: biology, physiology, medicine, computer science, engineering, mathematics, statistics, physics, or psychology; are required to take eight courses chosen from the CNS Department's curriculum (CN500, 510, 520, 530, 540, 550, 560, 570, 580, 700, 710, 720, 730, 740, 760, 780, 810, 811), of which at least two must be 700 or 800 level; and to fulfill all other program requirements.

PhD Qualifying Examination

Students are required to pass a qualifying examination on the CNS curriculum, including their area of thesis concentration. The examination is offered each year in January and in May. A student must have passed eight courses in the CNS curriculum to take the PhD qualifying examination.

Dissertation Requirements

Before finalizing dissertation plans, students are required to submit a written prospectus. A dissertation and final oral examination must be completed in accordance with the general requirements for the PhD as outlined in the front section of the Graduate School Bulletin.

ADMISSION

Prospective applicants are urged to visit the Department of Cognitive and Neural Systems website http://www.cns.bu.edu/ for information which explains the requirements, practices, and offerings of the department in greater detail.

To apply, please visit http://www.bu.edu/cas/admissions/graduate/apply/.

Applications for admission and financial aid should be received in the Graduate School by December 15, but will be given full consideration if received by no later than January 15. Late applications will be considered until April 15. After that date, applications will be considered on a case-by-case basis. Late applicants should correspond directly with the department. Under certain circumstances, January admission may be possible, with an application deadline of October 15.

Applicants are required to submit undergraduate (and, if applicable, graduate) transcripts, three letters of recommendation, and Graduate Record Examination (GRE) scores. The Advanced Test should be in the candidate's area of departmental specialization. GRE scores may be waived for MA candidates and, in exceptional cases, for PhD candidates, but absence of these scores may decrease an applicant's chances for admission and financial aid.

All application materials must be submitted directly to the Graduate School Admissions Office.

Further information is available from the Department of Cognitive and Neural Systems,
677 Beacon Street, Boston University, Boston, MA 02215; phone: 617-353-9481;
fax: 617-353-7755; e-mail: ramos@cns.bu.edu.

FINANCIAL SUPPORT AND RELATED FACTORS

CNS Assistantships and Fellowships

The CNS Department offers full financial support, in the form of Research Assistantships and Teaching Assistantships, to qualified PhD candidates each year. In addition, top applicants are nominated for Presidential University Graduate Fellowships, Arts and Sciences Dean's Fellowships, Clare Boothe Luce Fellowships, and other prestigious awards.

Individual Graduate Fellowships

CNS applicants are also encouraged to apply to the NSF, other federal agencies, and foundations for graduate fellowship support. Many CNS students have competed successfully for such fellowships, using both their excellent academic records and the specific interest of some granting agencies in furthering development of neural network research to advance brain science and intelligent technology.

Part-Time and Full-Time Employment

Some CNS degree candidates support themselves by full-time or part-time employment in the Boston area. Many companies offer tuition payment as a benefit of employment. Most CNS courses meet once a week, from 5 p.m. to 8 p.m., to facilitate the participation of students with outside obligations.

International Students

International students enrolled in the CNS Department come from a variety of countries, including Australia, Austria, Brazil, Bulgaria, Canada, Colombia, England, France, Germany, Greece, Iceland, India, Iran, Ireland, Israel, Italy, Japan, Korea, Mexico, People's Republic of China, Peru, Republic of China, Russia, Singapore, Slovakia, Spain, Sweden, Turkey, and Venezuela. The department welcomes applicants from all countries. The types of financial aid the department can directly offer international students are sometimes limited, and visa restrictions may limit the types of part-time employment these students can obtain in the United States. Various CNS international students have obtained international fellowships prior to their arrival in the department. International students applying to the CNS Department are strongly encouraged to seek funding from their home countries.

Admission to the MA Program

A number of students are accepted to the MA program each year, usually without financial support. Students who do excellent work in the MA program and wish to work toward the PhD will be considered for admission to the PhD program upon written request.

BA/MA IN BIOLOGY AND COGNITIVE AND NEURAL SYSTEMS

The BA/MA in Biology and Cognitive and Neural Systems is an interdepartmental program in the College of Arts and Sciences and the Graduate School of Arts and Sciences. The program allows undergraduate majors in biology to begin working toward an MA in Cognitive and Neural Systems while still completing the Department of Biology BA requirements.

Admission to the BA/MA Program

College of Arts and Sciences students currently in or entering the junior year are eligible to apply for admission. Students must apply before March 1 of their junior year and must meet a GPA requirement of at least 3.0 through the end of their junior year. Students admitted to the BA/MA program will typically have completed at least one 300-level (or above) CNS course. In order to be admitted into the BA/MA program, students must have completed at least Calculus I and II (MA 123 and 124, or equivalent) and Linear Algebra (MA 242). The application should include a letter from the student's Department of Biology advisor. Application forms for admission to the BA/MA program may be obtained from the Graduate School of Arts and Sciences Office, Room 112, 705 Commonwealth Avenue, Boston, MA 02215.

Requirements

Students must complete all requirements for the BA in Biology as specified in the *Undergraduate Programs Bulletin*; plus all requirements for the MA in Cognitive and Neural Systems, as specified in the *Graduate School of Arts and Sciences Bulletin*. In particular, 32 courses (128 credits) are required for the BA and 8 courses (32 credits) are required for the MA degree. In total 40 courses (160 credits) are required. Students receive the BA and MA degrees simultaneously. Graduation applications must be submitted for both the BA and MA portions of the degree.

BA/MA IN COMPUTER SCIENCE AND COGNITIVE AND NEURAL SYSTEMS

The BA/MA in Computer Science and Cognitive and Neural Systems is an interdepartmental program in the College of Arts and Sciences and the Graduate School of Arts and Sciences. The program allows undergraduate majors in computer science to begin working toward an MA in Cognitive and Neural Systems while still completing the Department of Computer Science BA requirements.

Admission to the BA/MA Program

College of Arts and Sciences students currently in or entering the junior year are eligible to apply for admission. Students must apply before March 1 of their junior year and must meet a GPA requirement of at least 3.0 through the end of their junior year. Students admitted to the BA/MA program will typically have completed at least one 300-level (or above) CNS course. In order to be admitted into the BA/MA program, students must have completed at least Calculus I and II (MA 123 and 124, or equivalent) and Linear Algebra (MA 242). The application should include a letter from the student's Department of Computer Science advisor. Application forms for admission to the BA/MA program may be obtained from the Graduate School of Arts and Sciences Office, Room 112, 705 Commonwealth Avenue, Boston, MA 02215.

Requirements

Students are required to complete all requirements for the BA in Computer Science as specified in the *Undergraduate Programs Bulletin*; plus all requirements for the MA in Cognitive and Neural Systems, as specified in the *Graduate School of Arts and Sciences Bulletin*. In particular, 32 courses (128 credits) are required for the BA and 8 courses (32 credits) are required for the MA degree. In total 40 courses (160 credits) are required. Students receive the BA and MA degrees simultaneously. Graduation applications must be submitted for both the BA and MA portions of the degree.

BA/MA IN MATHEMATICS AND COGNITIVE AND NEURAL SYSTEMS

The BA/MA in Mathematics and Cognitive and Neural Systems is an interdepartmental program in the College of Arts and Sciences and the Graduate School of Arts and Sciences. The program allows undergraduate majors in mathematics to begin working toward an MA in Cognitive and Neural Systems while still completing the Department of Mathematics BA requirements.

Admission to the BA/MA Program

College of Arts and Sciences students currently in or entering the junior year are eligible to apply for admission. Students must apply before March 1 of their junior year and must meet a GPA requirement of at least 3.0 through the end of their junior year. Students admitted to the BA/MA program will typically have completed at least one 300-level (or above) CNS course. In order to be admitted into the BA/MA program, students must have completed at least Calculus I and II (MA 123 and 124, or equivalent) and Linear Algebra (MA 242). The application should include a letter from the student's Department of Mathematics advisor. Application forms for admission to the BA/MA program may be obtained from the Graduate School of Arts and Sciences Office, Room 112, 705 Commonwealth Avenue, Boston, MA 02215.

Requirements

Students are required to complete all requirements for the BA in Mathematics as specified in the *Undergraduate Programs Bulletin*; plus all requirements for the MA in Cognitive and Neural Systems, as specified in the *Graduate School of Arts and Sciences Bulletin*. In particular, 32 courses (128 credits) are required for the BA and 8 courses (32 credits) are required for the MA degree. In total 40 courses (160 credits) are required. Students receive the BA and MA degrees simultaneously. Graduation applications must be submitted for both the BA and MA portions of the degree.

BA/MA IN PSYCHOLOGY AND COGNITIVE AND NEURAL SYSTEMS

The BA/MA in psychology and cognitive and neural systems is an interdepartmental program in the College of Arts and Sciences and the Graduate School of Arts and Sciences. The program allows undergraduate majors in psychology to begin working toward an MA in cognitive and neural systems while still completing the Department of Psychology BA requirements.

Admission to the BA/MA Program

College of Arts and Sciences students currently in or entering the junior year are eligible to apply for admission. Students must apply before March 1 of their junior year and must meet a GPA requirement of at least 3.0 through the end of their junior year. Students admitted to the BA/MA program will typically have completed at least one 300-level (or above) CNS course. In order to be admitted into the BA/MA program, students must have completed at least Calculus I and II (MA 123 and 124, or equivalent) and Linear Algebra (MA 242). The application should include a letter from the student's Department of Psychology advisor. Application forms for admission to the BA/MA program may be obtained from the Graduate School of Arts and Sciences Office, Room 112, 705 Commonwealth Avenue, Boston, MA 02215.

Requirements

Students must complete all requirements for the BA in Psychology as specified in the *Undergraduate Programs Bulletin*; plus all requirements for the MA in Cognitive and Neural Systems, as specified in the *Graduate School of Arts and Sciences Bulletin*. In particular, 32 courses (128 credits) are required for the BA and 8 courses (32 credits) are required for the MA degree. In total 40 courses (160 credits) are required. Students receive the BA and MA degrees simultaneously. Graduation applications must be submitted for both the BA and MA portions of the degree.

CNS DEPARTMENT COURSE OFFERINGS

The courses offered by the CNS Department are described below. CNS students also take a wide variety of courses in related departments. In addition, students participate in a weekly colloquium series, an informal lecture series, as well as attend lectures and meetings throughout the Boston area; and advanced students work in small research groups.

CAS CN500 Computational Methods in Cognitive and Neural Systems

Prereq: One year of calculus or consent of instructor.
This course introduces students to computer and mathematical techniques spanning a variety of scientific areas that make use of theoretical and applied computational modeling, such as engineering, mathematics, computer science and computational neuroscience. Each topic is introduced through practical examples from the literature, combining theory and applications. Topics include basic and advanced computer skills, difference and differential equations, mathematical simulation techniques, statistics, digital signal processing, control theory and image processing. The course is designed with the flexibility required to account for the varied background of participating students. *Not offered in 2010-2011.*

CAS CN510 Principles and Methods of Cognitive and Neural Modeling I

Prereq: One year of calculus and consent of instructor.
Neural modeling is an interdisciplinary paradigm for discovering the computational designs that underlie human and animal learning and performance. This graduate-level course explores elements of the psychological, biological, mathematical, and computational foundations of behavioral and brain modeling. The course integrates experimental data and theoretical concepts in an interdisciplinary format. Mutually supportive constraints derived from several types and levels of analysis are used to discover organizational principles, mechanisms, local circuits, and system architectures that would otherwise be insufficiently constrained. The course presents a self-contained summary of relevant data to motivate and test key modeling ideas. Emphasis is given to analysis of the interactive, or emergent, functional properties generated by neural networks, since these properties control the behavioral success or failure of biological organisms in complex and unpredictable environments. The course presents a systematic introduction to basic mathematical principles, equations, and methods that provide a foundation for analyzing such emergent properties in key examples; notably, cooperative and competitive nonlinear feedback systems, associative learning systems, and self-organizing, self-stabilizing code-compression systems. Adaptive resonance theory is drawn upon for illustrative material because it unifies many of these themes and explains how a real-time cognitive system built from neural constituents can induce stable categories, which are fundamental for intelligent function by any cognitive system. *Gorchetchnikov. 4 cr., 1st sem.*

CAS CN520 Principles and Methods of Cognitive and Neural Modeling II

Prereq: One semester of linear algebra and consent of instructor.
This course complements CN510, and explores the psychological, biological, mathematical and computational foundation of behavioral and brain modeling. The course introduces and analyzes ideas from three main traditions in models of learning: unsupervised (self-organized) learning, supervised learning (learning with a teacher), and reinforcement learning. By studying all three traditions in a single course, the student gains a better understanding of the strengths and weaknesses of each. Architectures studied in detail include adaptive filters, back propagation, competitive learning, self-organizing feature maps, gradient descent procedures, the Boltzmann machine, simulated annealing, the Neocognitron, and gated dipole opponent processes. The

content of the course is distinct from that of CN510, and the two may be taken concurrently. *Not offered in 2010-2011.*

CAS CN530 Neural and Computational Models of Vision

Prereq: CN510 or consent of instructor.

The course acquaints advanced undergraduates and beginning graduate students with inter-disciplinary approaches to computational and neural network modeling of the functional, real-time processes of early primate vision. Topics include boundary detection, completion, and sharpening; textural segmentation and grouping; shape-from-texture and shape-from-shading; stereopsis; and motion analysis. For each process, key behavioral and physiological data will be analyzed from the standpoint of how the data constrain the computations carried out in network models of that process. Competing approaches to formal modeling will be discussed and students will carry out simulations of one or more such models on laboratory computer systems. *Yazdanbakhsh. 4 cr., 2nd sem.*

CAS CN540 Neural and Computational Models of Adaptive Movement Planning and Control

Prereq: CN510 or consent of instructor.

This course provides an integrative treatment of a large interdisciplinary database on sensory-motor planning and control in humans and other animals. In each segment, a behavioral competence, such as the ability to maintain a stable posture, or the ability to reach to a desired target, is carefully described. Then relevant parametric data from behavioral and neurophysio-logical experiments are studied, and quantitative theoretical models are compared on the basis of their ability to explain the basic competence as well as the associated parametric database. Special emphasis is placed on models of adaptive neural networks and thereby on the process of skill acquisition. *Bullock. 4 cr., 2nd sem.*

CAS CN550 Neural and Computational Models of Recognition, Memory and Attention

Prereq: CN510 or consent of instructor.

This course develops neural network models of how internal representations of sensory events and cognitive hypotheses are learned and remembered, and of how such representations enable recognition and recall of these events to occur. Various neural and statistical pattern recognition models are analyzed. Special attention is given to stable self-organization of pattern recognition and recall codes by Adaptive Resonance Theory (ART) models. Mathematical techniques and definitions to support fluent access to the neural network and pattern recognition literature are developed throughout the course. Experimental data and theoretical predictions from cognitive psychology, neuropsychology, and neurophysiology of normal and abnormal individuals are also analyzed. Course work emphasizes skill development, including writing, computational analysis, teamwork, and verbal communication. *Ames/Gorchetchnikov. 4 cr., 2nd sem.*

CAS CN560 Neural and Computational Models of Speech Perception and Production

Prereq: Consent of instructor.

This course surveys aspects of anatomy, physiology, and psychophysics important for modeling hearing and speech perception. The course follows the auditory pathway from external ear to cortex, introducing relevant research areas along the way. Intended as an introductory course for students interested in pursuing research in audition and/or speech perception, topics to be covered include masking, loudness, binaural processing, auditory localization, speech perception, and models of these perceptual processes. No prerequisite courses are required; however, the course is geared towards motivated graduate students with strong quantitative skills. Some rudimentary signal processing, probability, statistics, and decision theory will be introduced in order to allow students to understand the basic material to be covered. *Shinn-Cunningham. 4 cr., 1st sem. (meets with ENG BE509)*

CAS CN570 Neural and Computational Models of Conditioning, Reinforcement, Motivation and Rhythm

Prereq: CN510 or consent of instructor.

This course develops neural and computational models of how humans and animals learn to successfully predict environmental events and generate behavioral actions which satisfy internally defined criteria of success or failure. Reinforcement learning and its homeostatic (drive, arousal, rhythm) and non-homeostatic (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. *Tan. 4 cr., 2nd sem.*

CAS CN580 Introduction to Computational Neuroscience

Prereq: Senior standing in a Natural Science or Mathematics Department or consent of instructor.

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 simulators 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 neo-cortex. *Schwartz. 4 cr., 1st sem.*

GRS CN700 Computational and Mathematical Methods in Neural Modeling

Prereq: CN500 or consent of instructor.

This course introduces students to advanced techniques in computational and neural modeling. The techniques span a variety of disciplines including computer engineering, computational neuroscience, neural networks, statistics, applied mathematics, engineering, and physics. Topics such as use of simulation packages, numerical methods, statistics, control theory, differential equations, signal processing, statistical pattern recognition and vector quantization are treated on a more advanced level than in CN500. Where possible, this course has a tripartite organization. First, the theory is presented from a text or journal article. Second, students read and critique a paper that uses the technique. Finally, simulations and/or problem sets are assigned to fix the knowledge learned in the course. Pertinent examples will be drawn from research done by students and faculty in the CNS Department. *Cohen. 4 cr., 2nd sem.*

GRS CN710 Advanced Topics in Neural Modeling: Comparative Analysis of Learning Systems

Prereq: CN550 or consent of instructor.

This course considers the systematic analysis of supervised learning systems from neural networks, statistics, and artificial intelligence. Supervised learning systems include multi-layer perceptrons (MLP), ARTMAP, decision trees, and support vector machines. Working collaboratively, class members analyze many different algorithms and methods for pre- and post-processing data, and develop common benchmark problems and system evaluation criteria. *Not offered in 2010-2011.*

GRS CN720 Neural and Computational Models of Planning and Temporal Structure in Behavior

Prereq: CN510 or consent of instructor; CN540 is recommended.

Much of human activity consists of the formulation and execution of novel serial action plans. Serial plans are evident in all simple episodes involving preparatory actions undertaken to create the necessary conditions for a successful primary action, as well as in more complex episodes such as systematic search, communicative speech and gesture, handwriting, tool use, and object assembly. This course examines primary research literature from several relevant disciplines to identify replicable operating characteristics of serial plan formulation, choice, performance, and learning in human children and adults, with a focus on composition of novel serial plans that satisfy multiple constraints. It critically examines proposed principles governing these processes, as well as neural network (and when informative, other computationally-explicit) models that embody such principles. *Not offered in 2010-2011.*

GRS CN730 Models of Visual Perception

Prereq: CN530 and consent of instructor.

This course offers an advanced survey of selected topics of current interest in the neural and computational modeling of psychophysical and physiological data in mammalian vision. Examples of topics include visual object recognition, feature integration, computational maps, nonclassical receptive field characteristics, brightness perception, shape-from-shading, stereoscopic vision, motion perception, and optic flow. Students are expected to have a sufficient interdisciplinary grounding in the fundamentals of mammalian vision to read primary research sources extensively, and will be required to present short oral critiques of selected readings to the class. A term project that combines a literature review with formal or simulation analyses is also required. *Mingolla/Yazdanbakhsh. 4 cr., 2nd sem.*

GRS CN740 Topics in Sensory-Motor Control

Prereq: CN540 or consent of instructor.

This course covers three main topic areas: spatial representation, speech production, and rhythmic movement. Representations appropriate for handwriting, reaching, speaking, and walking are investigated with emphasis on different levels of representation and interactions between these levels. The course covers material from psychophysics, neuroanatomy, neurophysiology, and neural modeling. *Not offered in 2010-2011.*

GRS CN760 Topics in Speech Perception and Recognition

Prereq: CN560 or consent of instructor.

This course surveys advanced topics in automatic speech recognition and auditory representation of speech signals, especially as they relate to speech perception. The course is constructed around a thorough introduction to state-of-the-art techniques in automatic speech recognition. These techniques are also related to perspectives obtained from perceptual and neurophysiological research. The course begins with the necessary fundamentals in digital signal processing and statistical pattern recognition. These are followed by detailed discussion of the major techniques in automatic speech recognition, including neural networks, hidden Markov models, and dynamic programming. The relation of these techniques to neurophysiological processing and psycholinguistic data are explored. Neural models of auditory processing and speech perception are presented and evaluated. Modeling techniques, including parameter optimization and goodness-of-fit tests, are covered. *Cohen. 4 cr., 1st sem.*

GRS CN780 Topics in Computational Neuroscience

Prereq: CAS MA225 Multivariate Calculus and MA242 Linear Algebra or consent of instructor.
In this seminar, recent research papers and applications in computational neuroscience will be reviewed. Topics covered include cortical modeling, analog VLSI, active perception, robotic control, stereovision, and computer aided neuroanatomy. *Schwartz. 4 cr., 2nd sem.*

GRS CN810 Topics in Cognitive and Neural Systems: Adaptive Mobile Robotics

Prereq: Consent of instructor.
Offers a hands-on introduction to the challenges of implementing adaptive behavior on an iRobot Create platform. Using simple and reliable hardware, students design and implement computational models that allow the robot to perform behavioral functions, such as learning to approach or avoid objects and locations in its environment. Students are expected to have a sufficient interdisciplinary grounding in the fundamentals of computational modeling of mammalian vision, planning, and navigation to read primary research sources. A term project that combines a problem statement and an implementation of a behavioral task for the robot is required. Projects are executed by small groups. *Versace. 4 cr., 1st sem.*

GRS CN810 Topics in Cognitive and Neural Systems: Visual Event Perception

This course offers an advanced treatment of selected topics of current interest in the neural and computational modeling of mammalian vision. Examples of topics include visual object recognition, feature integration, computational maps, nonclassical receptive field characteristics, brightness perception, shape-from-shading, stereoscopic vision, motion perception, and optic flow. Topics vary each time the course is given. Students read primary research sources extensively, and are required to present short oral critiques of selected readings to the class. A term project that combines a literature review with model simulations or development of a psychophysical experiment is also required. *Not offered in 2010-2011.*

GRS CN811 Topics in Cognitive and Neural Systems: Visual Perception

Prereq: Consent of instructor.
This seminar deals with problems in visual perception. The topics are: visual analyzers, visual pathways, perceptual organization, shape description, object perception, size, shape and lightness constancy, motion perception, perceptual adaptation. *Not offered in 2010-2011.*

Research in Cognitive and Neural Systems

The variable-credit research courses listed below are normally open only to advanced PhD students and to students engaged in faculty-supervised research. These 900-level courses may not be used to fulfill minimum course requirements for a CNS degree.

GRS CN911, 912
Research in Neural Networks for Adaptive Pattern Recognition

GRS CN915, 916
Research in Neural Networks for Vision and Image Processing

GRS CN921, 922
Research in Neural Networks for Speech and Language Processing

GRS CN925, 926
Research in Neural Networks for Adaptive Sensory-Motor Planning
and Control

GRS CN931, 932
Research in Neural Networks for Conditioning and Reinforcement Learning

GRS CN935, 936
Research in Neural Networks for Cognitive Information Processing

GRS CN941, 942
Research in Nonlinear Dynamics of Neural Networks

GRS CN945, 946
Research in Technological Applications of Neural Networks

GRS CN951, 952
Research in Hardware Implementations of Neural Networks

COURSES IN RELATED DEPARTMENTS

The following courses are among those that may be useful to CNS students whose program of study includes courses outside the CNS curriculum. Other courses may be substituted with advisor's approval. Each course is described in the Graduate School Bulletin. Except as noted, each course carries 4 credits.

BIOLOGY
CAS BI 545 Neurobiology of Motivated Behavior
CAS BI 554 Neuroendocrinology
CAS BI 570 Cognitive Ethology
GRS BI 575 Techniques in Cellular and Molecular Neuroscience
GRS BI 644 Neuroethology
GRS BI 645 Cellular and Molecular Neurophysiology
GRS BI 655 Developmental Neurobiology
GRS BI 676 Neurobiology/Biophysics (not offered Fall 2010)
GRS BI 755 Cellular and Systems Neuroscience
GRS BI 756 Systems and Behavior Neuroscience

COMPUTER SCIENCE
CAS CS 535 Complexity Theory
CAS CS 537 Randomness in Computing (not offered 2010)
CAS CS 542 Machine Learning (not offered 2010)
CAS CS 580 Advanced Computer Graphics (not offered 2010)
CAS CS 585 Image and Video Computing
GRS CS 640 Artificial Intelligence (not offered 2010)
GRS CS 670 Performance Analysis of Computer Systems (not offered 2010)
GRS CS 680 Graduate Introduction to Computer Graphics

ENGINEERING
Biomedical Engineering
ENG BE 509 Quantitative Physiology of the Auditory System (meets with CN560)
ENG BE 515 Introduction to Medical Imaging
ENG BE 540 Bioelectrical Signals: Analysis and Interpretation (not offered 2010)
ENG BE 550 Bioelectromechanics (not offered 2010)
ENG BE 560 Biomolecular Architecture
ENG BE 563 Cellular and Molecular Systems Analysis (not offered 2010)
ENG BE 570 Introduction to Computational Vision
ENG BE 710 Neural Plasticity and Perceptual Learning (not offered 2010)
ENG BE 740 Parameter Estimation and Systems Identification (not offered 2010)
ENG BE 747 Advanced Signals and Systems Analysis for Biomedical Engineering

Mechanical Engineering
ENG ME 507 Process Modeling and Control
ENG ME 510 Production Systems Analysis
ENG ME 714 Advanced Stochastic Modeling and Simulation
ENG ME 720 Acoustics II
ENG ME 724 Advanced Optimization Theory and Methods (not offered 2010)
ENG ME 732 Combinatorial Optimization and Graph Algorithms (not offered 2010)
ENG ME 740 Vision, Robotics, and Planning
ENG ME 766 Advanced Scheduling Models and Methods (not offered 2010)

Electrical and Computer Engineering
ENG SC 516 Digital Signal Processing
ENG SC 520 Digital Image Processing and Communication
ENG SC 571 VLSI Principles and Applications
ENG SC 575 Semiconductor Devices
ENG SC 578 Fabrication Technology for Integrated Circuits
ENG SC 710 Dynamic Programming and Stochastic Control
ENG SC 716 Advanced Digital Signal Processing
ENG SC 717 Image Reconstruction and Restoration
ENG SC 719 Statistical Pattern Recognition
ENG SC 761 Information Theory and Coding
ENG SC 775 VLSI Devices and Device Models

HEALTH SCIENCES
SAR HS 550 Neural Systems
SAR HS 582 Neuroanatomy and Neurophysiology
SAR HS 755 Readings in Neuroscience

MATHEMATICS and STATISTICS
CAS MA 561 Methods of Applied Mathematics I
CAS MA 562 Methods of Applied Mathematics II
CAS MA 563 Introduction to Differential Geometry
CAS MA 565 Mathematical Models in the Life Sciences
CAS MA 570 Stochastic Methods of Operations Research (not offered 2010)
CAS MA 573 Qualitative Theory of Ordinary Differential Equations
CAS MA 574 Applied Nonlinear Dynamics (not offered 2010)
CAS MA 581 Probability
CAS MA 583 Introduction to Stochastic Processes
GRS MA 684 Applied Multiple Regression and Multivariate Analysis (not offered 2010)
GRS MA 685 Advanced Topics in Applied Statistical Analysis (not offered 2010)
GRS MA 717 Functional Analysis
GRS MA 771 Introduction to Dynamical Systems
GRS MA 775 Ordinary Differential Equations and Dynamical Systems
GRS MA 776 Partial Differential Equations
GRS MA 779 Probability Theory I
GRS MA 780 Probability Theory II
GRS MA 781 Estimation Theory
GRS MA 782 Hypothesis Testing
GRS MA 785 Time Series Modeling and Forecasting (not offered 2010)
GRS MA 861 Mathematical and Statistical Methods of Bioinformatics (not offered 2010)
GRS MA 881 Topics in High Dimensional Data Analysis

MEDICAL SCIENCES
(Please note: The Boston University Medical Campus follows a calendar that differs from that of the Charles River Campus.)

Anatomy and Neurobiology
GMS AN 702 Neurobiology of Learning and Memory
GMS AN 703 Neuroscience (not offered 2010)
GMS AN 802 Experimental Design and Statistics
GMS AN 807 Neurobiology of the Visual System
GMS AN 808 Neuroanatomical Basis of Neurologic Disorders

Behavioral Neuroscience
GMS BN 775 Human Neuropsychology I
GMS BN 776 Human Neuropsychology II
GMS BN 777, 778, 779 Basic Neuroscience
GMS BN 793 Adult Neurologic Communication Disorders
GMS BN 794 Brain Asymmetry
GMS BN 795 Neuropsychology of Perception and Memory
GMS BN 796 Neuropsychological Assessment I
GMS BN 797 Neuropsychological Assessment II
GMS BN 798 Functional Neuroanatomy in Neuropsychology
GMS BN 821 Seminar in Neuroimaging

PSYCHOLOGY
CAS PS 520 Research Methods in Perception and Cognition (not offered 2010)
CAS PS 524 Remembering the Past: The Psychology of Memory (not offered 2010)
CAS PS 525 Cognitive Science (not offered 2010)
CAS PS 528 Human Brain Mapping
CAS PS 530 Neural Models of Memory Function
CAS PS 544 Developmental Neuropsychology
CAS PS 545 Language Development (not offered 2010)
CAS PS 546 Cognitive Development
CAS PS 548 Perceptual Development (not offered 2010)
CAS PS 573 Abstract Thought (not offered 2010)
GRS PS 737 Memory Systems of the Brain (not offered 2010)
GRS PS 738 Techniques in Systems and Behavioral Neuroscience
GRS PS 821 Learning (not offered 2010)
GRS PS 822 Visual Perception (not offered 2010)
GRS PS 823 Verbal Processes (not offered 2010)
GRS PS 824 Cognitive Psychology
GRS PS 828 Seminar in Psycholinguistics (not offered 2010)
GRS PS 829 Principles in Neuropsychology
GRS PS 831 Seminar in Neuropsychology (not offered 2010)
GRS PS 832 Physiological Psychology (not offered 2010)
GRS PS 833 Advanced Physiological Psychology (not offered 2010)
GRS PS 835 Attention
GRS PS 844 Theories of Development (not offered 2010)
GRS PS 845 Topics in Perceptual Development (not offered 2010)
GRS PS 848 Developmental Psycholinguistics (not offered 2010)

AFFILIATED FACULTY

Anatomy and Neurobiology

Gene J. Blatt Associate Professor, School of Medicine (Neuropathology of autism studying both cerebellar and limbic systems). PhD, Thomas Jefferson University

Thomas L. Kemper Professor, School of Medicine (Aging in human and nonhuman primates, the effect of hypertension on the monkey brain; effect of protein deprivation on rat brain development and on the neuropathology of infantile autism). MD, University of Illinois

Mark B. Moss Professor, Chair, Anatomy and Neurobiology, School of Medicine (Neurological basis of memory: Studies of the basal forebrain and limbic system of humans and nonhuman primates, with particular regard to aging and age-related disease). PhD, Northeastern University

Deepak N. Pandya Professor, School of Medicine (Comparative brain architectonics in the monkey and human, as well as connectional studies in the monkey). MD, University of Gujarat (India)

Douglas L. Rosene Professor, School of Medicine (Morphology, connections, and neurotransmitter distribution of the olfactory and limbic systems in the brain of the Rhesus monkey). AB, Stanford University; PhD, University of Rochester

Julie Sandell Professor, School of Medicine (Anatomical remodeling in human retinas from patients with Retinitis Pigmentosa (RP), structural changes in the brain in aging Rhesus monkeys). PhD, Massachusetts Institute of Technology

Deborah W. Vaughan Professor, School of Medicine (Effects of age on peripheral nerve regeneration in the facial nucleus of the central nervous system). PhD, Boston University

Biology

Michael Baum Professor, Biology, College of Arts and Sciences (Behavioral and reproductive neuroendocrinology, brain sexual differentiation). BA, Carleton College; MA, PhD, McGill University (Canada)

Gloria V. Callard Professor, Biology, College of Arts and Sciences (Neuroendocrinology, reproductive endocrinology, environmental endocrine disruptors). BS, Tufts University; MS, PhD, Rutgers University

Robert E. Hausman Professor, Biology, College of Arts and Sciences (Developmental biology, cell-cell interactions). AB, MA, Case Western Reserve University; PhD, Northwestern University

Thomas H. Kunz Professor, Biology, College of Arts and Sciences (Physiological and behavioral ecology of mammals). BS, MS, Central Missouri State University; MA, PhD, University of Kansas

Sidney L. Tamm Professor, Biology, College of Arts and Sciences (Cell biology and motility, cytoskeleton, nervous and ionic control of cilia and behavior of gelatinous zooplankton, protozoan motility). BA, Cornell University; PhD, University of Chicago

James F.A. Traniello Professor, Biology, College of Arts and Sciences (Behavioral ecology and sociobiology of insects). BA, Boston University; MS, University of Massachusetts; PhD, Harvard University

Frederick E. Wasserman Associate Professor, Biology, College of Arts and Sciences (Animal behavior, bird song, territoriality). BS, State University of New York, Stony Brook; MS, PhD, University of Maryland

Eric P. Widmaier Professor, Biology, College of Arts and Sciences (Neuroendocrinology, developmental endocrinology, stress and adrenal function, endocrine control of body weight). BA, MS, Northwestern University; PhD, University of California, San Francisco

Biomedical Engineering

Charles R. Cantor Professor, Director, Department of Biomedical Engineering, College of Engineering; Professor of Biochemistry, School of Medicine. (Human genome analysis; molecular genetics; new biophysical tools and methodologies; genetic engineering). AB, Columbia University; PhD, University of California, Berkeley

James J. Collins Professor, Biomedical Engineering, College of Engineering. (Nonlinear dynamics in biology and physiology; synthetic gene networks; sensory prosthetics; human balance control). BS, College of the Holy Cross; DPhil, Oxford University (United Kingdom)

Carlo De Luca Professor, Biomedical Engineering, College of Engineering; Director, Neuromuscular Research Center, College of Engineering (Motor control of normal and abnormal muscles, human muscle fatigue, advanced technology for detecting and applying biosignals). BASc, University of British Columbia (Canada); HSc, University of New Brunswick (Canada); PhD, Queen’s University (Canada)

Charles DeLisi Dean Emeritus, College of Engineering; Metcalf Professor of Science and Engineering, College of Engineering (Analysis of DNA function, protein structure, optimization algorithms, neural network applications to molecular biology, drug and vaccine design, membrane biophysics). BA, City University of New York, City College; PhD, New York University

Solomon Eisenberg Professor, Chair, Biomedical Engineering, College of Engineering (Electrically mediated phenomena, tissue and bipolymers; cartilage biomechanics; computational modeling of electric field distributions in the human thorax and heart during electrical defibrillation; transcranial magnetic stimulation). SB, SM, ScD, Massachusetts Institute of Technology

David C. Mountain, Jr. Professor, Biomedical Engineering, College of Engineering; Assistant Research Professor of Otolaryngology, School of Medicine (Sensory biophysics, biomedical electronics and signal processing, auditory information processing). SM, Massachusetts Institute of Technology; MS, PhD, University of Wisconsin

Herbert F. Voigt Professor, Biomedical Engineering, College of Engineering; Associate Chair, Department of Biomedical Engineering, College of Engineering; Assistant Research Professor of Otolaryngology, School of Medicine (Auditory neurophysiology, neural circuitry, neural modeling). BE (EE), City College of New York; PhD, Johns Hopkins University

Computer Science

Peter Gacs Professor, Computer Science, College of Arts and Sciences (Cellular automata, fault-tolerant computing, and Algorithmic Information Theory). MS, Roland Eotvos University (Hungary); PhD, JW Goethe University (Hungary)

Steven Homer Professor, Co-Director, Computer Science, College of Arts and Sciences (Complexity theory, learning theory, parallel and probabilistic algorithms). AB, University of California, Berkeley; PhD, Massachusetts Institute of Technology

Assaf J. Kfoury Professor, Computer Science, College of Arts and Sciences (Programming languages and type theory). BS, MS, PhD, Massachusetts Institute of Technology

Leonid A. Levin Professor, Computer Science, College of Arts and Sciences (Computational theory). MS, PhD, Moscow State University (Russia), PhD, Massachusetts Institute of Technology

Electrical and Computer Engineering

Richard Brower Professor, Electrical and Computer Engineering, College of Engineering (Molecular dynamics simulation for biomolecules, lattices methods for QCD and statistical mechanics, quantum field theory of strings and particles). AB, MA, Harvard University, PhD, University of California, Berkeley

Roscoe Giles Professor, Deputy Director, Electrical and Computer Engineering, College of Engineering (Advanced computing architectures, distributed and parallel computing). BA, University of Chicago; MS, PhD, Stanford University

Mark Karpovsky Professor, Electrical and Computer Engineering, College of Engineering (Computer hardware, diagnostics, and fault detection). BS, MS, PhD, Leningrad Electrotechnical Institute (Russia)

Lev B. Levitin Distinguished Professor, Electrical and Computer Engineering, College of Engineering (Information theory; physics of communication and computing; complex and organized systems; quantum theory of measurement). MS, PhD, Moscow State University (Russia)

Syed Hamid Nawab Professor, Electrical and Computer Engineering; Assistant Professor of Biomedical Engineering, College of Engineering (Information and data extraction; algorithms/architectures with application to the analysis of brain to muscle communications). SB, SM, PhD, Massachusetts Institute of Technology

Mathematics and Statistics

Paul Blanchard Associate Professor, Mathematics and Statistics, College of Arts and Sciences (Dynamical systems, complex analytical dynamics). BA, Brown University; PhD, Yale University

Ralph B. D’Agostino Professor, Chair, Department of Mathematics and Statistics, College of Arts and Sciences (Longitudinal data analysis, multivariate data analysis, biostatistics, robust procedures). Director of Statistics and Consulting Unit and Research Associate, Center for Applied Social Science, Graduate School; Professor of Public Health, School of Public Health. Lecturer in Law, School of Law. BA, MA, Boston University; PhD, Harvard University

Robert L. Devaney Professor, Mathematics and Statistics, College of Arts and Sciences (Dynamical systems, classical mechanics, complex dynamics, computer experiments). AB, Holy Cross College; PhD, University of California, Berkeley

Ashis Gangopadhyay Associate Professor, Associate Chair, Mathematics and Statistics, College of Arts and Sciences (Statistics, stochastic processes, Toeplitz operators). BStat, MStat, Indian Statistical University (India); PhD, University of California, Davis

Glen Richard Hall Associate Professor, Mathematics and Statistics, College of Arts and Sciences (Dynamical systems, celestial mechanics). BA, Carleton College; PhD, University of Minnesota

Akihiro Kanamori Professor, Mathematics and Statistics, College of Arts and Sciences (Logic, set theory). BS, California Institute of Technology; DPhil, University of Cambridge (United Kingdom)

Tasso Kaper Professor, Mathematics and Statistics, College of Arts and Sciences. (Dynamical systems, applied mathematics). BS, MS, University of Chicago; PhD, California Institute of Technology

Murad Taqqu Professor, Mathematics and Statistics, College of Arts and Sciences (Probability, stochastic processes, statistics). License, Universite de Lausanne (Switzerland); MA, PhD, Columbia University

Psychology

Margaret Hagen Professor, Psychology, College of Arts and Sciences (Perception). BA, University of Washington; MA, PhD, University of Minnesota

Henry Marcucella Professor Emeritus, Psychology, Department of Psychology, College of Arts and Sciences (Sign tracking, discrimination learning, schedules of reinforcement, and animal models of alcoholism). BA, Northeastern University; MA, PhD, Boston University

David I. Mostofsky Professor, Psychology, College of Arts and Sciences (Operant conditioning, psychoimmunology, and fatty acid biochemistry). BA, Yeshiva University; MA, PhD, Boston University

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