Undergraduate Program in Neuroscience and Cognitive Science

Overview

The undergraduate program in Neuroscience and Cognitive Science (NSCS) resides in the College of Science, in the School of Mind, Brain and Behavior. It has two parts: a lower-division pre-major and an upper-division major. Admission to the major is competitive and requires, at minimum, a grade of B in NSCS 200, Fundamentals of Neuroscience and Cognitive Science, and an average Chemistry/Biology GPA of at least 2.5. The admission process includes several short essays and may include an interview with one or more members of the NSCS Undergraduate Studies Committee.

Coursework in the upper division portion of the curriculum is divided into a set of core courses designed to provide students with a robust foundation in the principles, concepts, and technologies essential in neuroscience and cognitive science. Two methods courses are included in the core group so that students study not only the outcomes of research but also the methods commonly used in research in neuroscience and cognitive science. Students also choose a track, the cognitive-science track or the neuroscience track, which deepens their understanding of ideas and approaches used in studying the nervous system from one of the two perspectives. Electives in the major are organized into 6 major topic areas to allow students to customize the program to their own interests and delve deeply into a specific topic. Each topic area is associated with a menu of courses from which students choose, including research credits. Ethics, professionalism, critical thinking, and both writing and presentation skills are considered essential elements of the program and are addressed throughout the curriculum.

Coursework in the lower division is considered preparatory, providing students with the life- science, mathematics, and psychology foundation necessary to support study of the nervous system – both mind and brain.

The NSCS program also has three associated student organizations: the NSCS Association of Students, which is a student-led organization whose mission is to spread awareness of neuroscience and cognitive science to the UA student body and to the greater Tucson community; Nu Rho Psi - Alpha in Arizona, a chapter of the national neuroscience honorary organization; and the NSCS Ambassadors, student representatives of the NSCS program who act as liaisons of the program to the University of Arizona and Tucson community. Together, these organizations are key components of the NSCS community.

NSCS Program Learning Outcomes

The design of the NSCS major reflects a tiered approach. Students develop proficiency in the following abilities in core courses and enhance their competency in emphasis courses. The overarching goal is to provide graduates with a breadth and depth of understanding about the field of neuroscience and cognitive science that will render them well qualified for admission to graduate or professional schools such as medicine, dentistry, veterinary medicine, nursing, neuroscience, cognitive science, pharmacology, psychology, and related fields. They will be competitive for positions in a variety of health-related industries, in middle school, high school and adult education, and in disciplines that

increasingly require understanding of biology and biotechnology, including law, policy-making and business.

A. Core knowledge-specific content

Students will develop a firm understanding of the theories, fundamental principles and concepts, and technologies of brain organization and function from both neuroscience and cognitive science perspectives.

- Foundation, core and upper-division core courses will provide the theoretical and conceptual knowledge and the technological skills that form the basis of the field of Neuroscience and Cognitive Science
- Each course in the core builds on pre-requisite courses and on lower-level courses in the curriculum. Concepts are explored in greater depth at each level and course discussions, exams, and projects require increasing levels of knowledge, culminating at the upper-division level in assignments and exams that require synthesis, integration, critical evaluation, and experimental design. Assessment is primarily course-specific measures designed by the instructors but also includes pre- and post-program exams.

B. Scientific inquiry

Students will develop the capacity to think critically and flexibility about complex problems involving the brain and mind, and will develop the capacity to skillfully communicate concepts and research results to professionals and to the public.

- Students will acquire a solid foundation of content knowledge about the nervous system and cognitive processes through core courses; these courses will address the distinction between popular beliefs about the brain and mind and what can be concluded on the basis of current scientific knowledge.
- Upper-division core and elective courses will introduce students to current research issues, and course assignments will require critical analysis of situations and research, in both written and oral formats, and including statistical analyses. Assessment is accomplished primarily through direct measures as developed by course instructors.
- Students are strongly encouraged to take on a project in a research lab or to complete independent studies/directed research with faculty, and to present their work in one of several forums (e.g., UBRP poster sessions, NSCS research presentations, lab meetings.)

C. Ethics and professionalism

Students will apply ethical and professional standards to their evaluation of brain and mind-related research and technical development in the context of their own work and in the context of issues in the larger societal community.

- Students will successfully complete the CITI online courses on the principles of scientific research and on research with human subjects.

- Course-work throughout the curriculum will include discussion of ethics and science policy questions relevant to the course topic; assessment is accomplished primarily through direct measures as developed by course instructors.
- Students are required to attend ethics and science policy seminars.

Sub-outcomes

For each outcome, the course(s) in which the outcome is addressed are listed, those in bold indicating that the outcome is a major focus. The assessment activities for each course are shown in Table 1 under Assessment Activities.

A. Core knowledge-specific content. All NSCS students will be able to:

A.1) Describe the general organization of the brain and its relation to physiological and cognitive processes. Explain the fundamental principles of anatomical and functional organization of neuronal circuits and networks underlying the complex capacities of the mind. Analyze the inputs, outputs, and processes of the mind from different perspectives, including genetics, molecular and cellular mechanisms, systems-level and cognitive modes of processing, environmental or contextual considerations, and modeling.

- **NSCS 200, NROS 307,** NSCS 315B, NSCS 320

A.2) Explain, including diagrams, the basic molecular and cellular mechanisms underlying neural excitability and synaptic physiology. Predict the consequences of disrupting various elements of the underlying mechanisms.

- **NSCS 200, NROS 307, NROS 315B**

A.3) List and explain several common principles of sensory processing across modalities. Describe the basic features of the motor system and explain how sensory-motor signaling operates.

- **NSCS 200**, NROS 307

A.4) List and provide a basic explanation of the major foundations of cognitive science, including representation, computation, and functional analysis. Define the levels of explanation and explain the relationships between higher level and lower level explanations. Give examples.

- **NSCS 200**, **NSCS 320, NSCS 315A**

A.5) Give an overview of the concept of cognitive architecture and define the terms: modularity, domain specificity, distributed networks and central systems, and give examples.

- **NSCS 200, NSCS 320**

A.6) Summarize contemporary understanding of the biological bases of and the cognitive processes underlying behavior, including sensation, perception, language, attention, learning, memory, and action.

- **NSCS 200, NROS 307, NSCS 315A, NSCS 320**

A.7) Describe the basic cognitive processes and the primary circuitry involved in language, decision-making, thinking/reasoning, motivation, emotion, and consciousness. Give examples of normal range of cognitive, emotional and behavioral variability over the lifespan.

- **NSCS 200,** NSCS 320

A.8) Using an evolutionary perspective, outline evolutionary principles that support use of animal model systems and explain how innate/genetic factors and environment/experience are understood to interact in development. Explain the relationship between molecular genetics and epigenetics and provide examples.
- **NSCS 200,** NROS 307

A.9) List the basic steps in establishing the wiring plan of the nervous system, including common molecular signaling pathways. Differentiate activity-independent and -dependent steps.
- NSCS 200

A.10) Describe the cognitive, genetic, molecular and cellular bases of several common diseases and disorders of the nervous system. Discriminate among these disorders in terms of their presentation and include the clinical tools typically used in diagnosis.
- NSCS 200, NSCS 307

A.11) At a fundamental level, explain the common methodologies and experimental designs used in research in neuroscience and cognitive science. Evaluate the soundness of the methodological design of descriptive, correlational, and experimental research. Design, interpret, and evaluate simple cognitive, behavioral and cellular experiments. Synthesize research findings from the neuroscience and cognitive science literature in the evaluation of questions surrounding the neurophysiology, mind/brain or information processing. Explain how the study of atypical cases, either natural or accidental, has greatly enhanced our knowledge about mind-brain interactions.
- NSCS 200, NSCS 307, **NSCS 315A, NSCS 315B,** NSCS 320, upper-division courses

Core knowledge-specific content for Cognitive-Science track students

CS.12) Illustrate the complex relationship between mental faculties and brain structure, providing examples and comparing in several brain structures of how critical features of cognitive architecture, including modularity, domain specificity, distributed networks and central systems are organized.
- **NSCS 320,** PSYC 325**, and course selections from Philosophy and Cognitive Psychology menus**

CS.13) Describe the major principles of computational modeling, and compare and give an example of each of the following kinds of models: logic-based models, connectionist models, and Bayesian models.
- **NSCS 320,** PSYC 325**, course selection from Computational Methods menu,** and course selection from Philosophy, Linguistics and Cognitive Psychology menus

CS.14) Explain how perception of the world works and how the brain interprets the world from limited inputs and prior knowledge; construct examples.
- **PSYC 325, course selections from the Cognitive Psychology menu**, course selections from the Philosophy and Computational Methods menus

CS.15) Describe, providing examples, how cognitive function changes during development and during aging; apply poverty-of-the-stimulus arguments to cognitive development.

- NSCS 320**,** PSYC 325, **course selection from the Cognitive Psychology menu**, course selections from the Philosophy and Linguistics menus

CS.16) Explain what language is and explain the mechanisms underlying its acquisition. Analyze language samples, indicating examples of syntactic structure, word segmentation, recursion, language processing, word recognition, and indicating level of language acquisition.

- NSCS 320**, PSYC 325, course selection from Linguistics menu,** course selections from the Philosophy, Cognitive Psychology and Computational Methods menus

CS.17) Summarize what is currently understood about the cognitive processes involved in decision making, reasoning, moral judgment and action.

- **PSYC 325, course selection from the Philosophy menu,** course selection from the Cognitive Psychology menu

Core knowledge-specific content for Neuroscience-track students

NS.12) Describe the basic processes by which macromolecules are assembled and used to carry out common cellular processes (e.g. molecular genetics, signal transduction, second-messenger pathways, organelle assembly, cell division, cytoskeleton) as used in neurons and glial cells. Design an experiment to test involvement of various pathways in a particular process in neurons or glial cells.

- **NROS 310**

NS.13) Explain how neurons detect and process sensory information, including receptor function, transduction processes, and conduction properties. Compare and contrast these processes in various sensory modalities.

- **NROS 310, PSIO 465**

NS.14) Describe the anatomical organization (include diagrams) and functional properties of the somatosensory, visual, auditory/vestibular and olfactory and taste systems.

- **PSIO 465**

NS.15) Describe the anatomical organization (include diagrams) and network function of the circuits responsible for emotion and arousal.

- PSIO 465

NS.16) Explain how motor behaviors are generated, including the basic anatomy of reflex and descending motor pathways, central pattern generators, and regulation of motor activity by higher order circuits in the brain.

- **PSIO 465**

NS.17) For any of the pathways in NS.14-16, predict the consequences of lesions within those pathways.

- **PSIO 465**

NS.18) Explain the major mechanisms understood to underlie cortical plasticity. Use an example to illustrate at least two mechanisms.

- **NROS 310**

B. Scientific inquiry

B.1) Think critically about complex problems involving the brain and the mind.
- NSCS 200, **NROS 307, NSCSS 315A, NSCS 315B**, NSCS 320

B.2) Develop strategies to solve complex problems creatively and with cognitive flexibility.
- **NROS 307, NSCSS 315A, NSCS 315B**, NSCS 320; also research opportunities

B.3) Engage in self-initiated learning and discovery.
- All courses, **especially upper division ones**; also research opportunities

B.4) Read and critically evaluate both formal scientific literature and scientific results disseminated through the mass media.
- **NSCS 315A, NSCS 315B, all upper division courses including elective courses**

B.5) Effectively communicate (orally, written or electronic) the principles and concepts of biological and cognitive sciences to other scientists and to the public.
- NSCS 315A, NSCS 315B**,** upper division courses including elective courses

B.6) Analyze quantitative data, showing an understanding of fundamental concepts of statistics and computational approaches to data analysis.
- Pre-requisite statistics course, upper division courses including elective courses

C. Ethics and Professionalism

C.1) Apply ethical and professional standards to their own practice of research and to their evaluation of cases/situations.
- Students must complete the online course on Responsible Conduct of Research as part of their **NSCS 315B** course requirement.
- Students must attend an annual seminar on ethical issues.
- All courses address ethical and professional issues that arise in their content or discussions.

C.2) Articulate the complex interrelationship among science, technology, and society.
- Students must attend an annual seminar on science policy.
- Students will read Stine (2009) or another guide to the structure of the science-policy making enterprise in the US and must pass a short exam about the interrelationships among these elements.

Assessment activities

Direct Assessment

All courses use direct assessment strategies that include exams, quizzes, in-class presentations, homework, and projects. Table 1.
NSCS 200
NSCS 307

NSCS 315A
NSCS 315B
NSCS 320
The small size of the initial graduating class (2013) made it possible for the faculty members of the Curriculum Committee to design an exit interview focused on the knowledge-specific outcomes. The interviews were carried out by the Curriculum Committee members and additional faculty, with each interview lasting about 30 minutes. There was no consequence to the students, but even taking into account that some students clearly were not highly motivated, the interviews revealed gaps in the students' knowledge. This information was summarized and conveyed to the teaching faculty, who made small changes in their courses; because the number of students was small, and because the curriculum was changed to have two tracks, it was decided to wait and re-assess before making major changes.

At the program level beginning in AY2015/16, students will take a multiple-choice exam written by core teaching faculty to specifically assess core knowledge, scientific-inquiry skills, and ethical and professional behaviors. Students will take the exam at the beginning of their suite of core courses (NSCS 200) and will take the same exam at the end of their program as a requirement for graduation, allowing us to carry out both within and between-subject analyses of student achievement.

Indirect assessment

These assessments are carried out by faculty, the program director and program coordinator, the NSCS advisor, members of the Undergraduate Studies and the Curriculum Committees, and the chairs of each of the MBB departments. Extended discussion and evaluation is planned on a 3-year schedule; annual assessments identify short-term concerns that can be addressed rapidly and also identify areas for development or modification in the longer term. Surveys were designed by the program coordinator and the program director, the results are reviewed by the Curriculum Committee, and changes suggested in that review are incorporated into the following year's surveys.

Program integrity

- Annual documentation of learning objectives for each course (specified in course syllabi)
- Annual review of course content by review of syllabi
- Annual course listing updated (core, track and emphasis courses)
- Faculty/Student ratio to ensure accurate projections of resources needed
- Faculty teaching loads and faculty changes
- Annual faculty survey

Student characteristics and progress indicators

- Student demographics and characteristics
- Student recruitment, retention, time to degree completion, degree completion,
- Percent honors students, percent completing theses
- Student engagement
    - Percent students engaging in research, # of semesters of involvement
    - Labs taking undergraduate students for research
    - Attendance at local, regional, and national meetings
    - Authorship on publications
- Annual faculty survey

Student satisfaction

- Annual survey of students in the major to assess the goodness of student advising, teaching effectiveness, program supports, research experience and involvement in NSCS programs and outreach. These are subjective reports of their experiences and the results are used in program analysis and improvement. The instrument vary with the level of the student – pre-majors, full majors, graduating students and alumni. Examples of each: [link].

Alumni placement

- Alumni tracking will include job placement or continuing education, assessed at 1 and 5 years after graduation.

Course evaluation

- Within courses, students may be asked to evaluate their own and each other's projects using the same rubric or one similar to that used by the faculty. Instructors of all NSCS-program courses are strongly encouraged to regularly engage students in assessing their own learning.
- Every course provides students the opportunity to complete a course evaluation that includes an assessment of quality of instruction, at minimum the relatively generic online report that is provided by the University (TCE reports). Instructor-devised course-specific questions may be included on these reports. Instructors of NSCS and NROS also may have their own course-specific evaluation tools. Both are used by the instructors for course improvement. The TCE reports are available to the NSCS Curriculum Committee for use in curriculum review.

Curriculum assessment

- Annual assessments are carried out in the NSCS Curriculum Committee
- 3-year reviews. These sessions are attended by all core teaching faculty and by the heads of the departments comprising the School of Mind, Brain and Behavior.
- Annual faculty survey

First 3-year review

May 6, 2013 – three-year review session to discuss progress of the program, determine what changes needed to be made, and how to make those changes.

The 3rd-year review revealed a number of areas of concern. Changes in response to assessment findings are indicated in blue. These changes were made over the following two years.

Faculty reflection on the curriculum and student surveys indicated that a need to strengthen the cognitive-science portion of the curriculum needed to be strengthened. Cognitive-science and neuroscience tracks were created, available beginning in AY 2013/14 (and required of students admitted in Calendar year 2013/14), but all students must continue to take a common core of courses so that the program's unique focus bringing both perspectives to their study of the brain. Integration of the two remains simultaneously central and challenging.

- Students at all levels indicated via surveys a need to be better grounded in anatomy (A1-3, NS 14-17). More anatomy content was incorporated into NSCS 200 and an elective course, *Neuroanatomy* (NROS 330), was developed and offered first in Fall 2014.

- Students who responded to the surveys wanted more content on clinical disorders and diseases (A10, NS17). Faculty of the core courses agreed to incorporate more case studies and discussion of clinical disorders where possible, but this is an ongoing issue, made difficult because the major already has a large number of required units. Students in the Neuroscience track who are also in the Neurobiology emphasis may take *Neurogenetics* (NROS 430), which includes extended discussion of several neurological disorders, but does not address the clinical aspects of the disorders. Another course, NSCS 450, *Neurons and glia in health and disease*, does include more clinical aspects, but again is not a required core course.

- Students asked for Honors courses. As a new program, developing honors courses has not been a priority, but as faculty resources grow, we intend to add such courses. In the meantime, several of our courses have added honors discussion sections and many courses allow honors contracts.

- Faculty identified a concern that having NSCS 200 as the "gateway" course put too much grade pressure on both students and faculty. The requirement that students get a B in the course to be considered for admission to the major was retained, but students who achieved a high C can now petition the Undergraduate Studies Committee for a waiver of the requirement, thus allowing the committee to take into account the student's overall achievement. These students are specifically followed, both to track their progress (was the decision a good one) and to ensure that we provide guidance if they struggle.

- Faculty expressed concern about the availability of opportunities for research experiences. All students in the NSCS program who do research now must enroll in NSCS-designated independent study or directed-research courses, with faculty credit for the courses going to the faculty members' home department. This allows us to track our students, and their faculty mentors, to monitor both in what laboratories and when our students are engaging in research. To date the number of research-involved students has continued to increase. In addition, 3-year funding was obtained from a private Foundation to allow 15-18 students each year to engage in full-time summer research with a full stipend. With external funding resources at low levels, many of these positions would not have been available to our students.

- Faculty re-organized course sequencing for NROS 307, 310 and PSIO 465 with two goals in mind: 1) ensuring enough repetition of ideas to reinforce student learning while advancing the level of learning, and 2) ensuring that students in the cognitive-science track would not be disadvantaged by entering NROS 307 with neuroscience-track students who had a higher level of comprehension about molecular and cellular biology having taken NROS 310 first. This issue has been resolved (Catalog Year 13/14) by putting NROS 307 in the fall semester and NROS 310 in the spring, the new sequence also requiring some NROS 310 revision. In addition, the change allows students who wish to complete the required neuroscience-track core courses in one year to do so, as NROS 307 is a pre-requisite to PSIO 465, which is offered in the spring.

- Faculty expressed concern that NSCS 315, *Methods in Neuroscience and Cognitive Science*, would be a curricular bottleneck given the small size of its sections, and that the Cognitive Science material was not adequately addressed. Beginning in AY 14/15, NSCS 315 was split into a 1-credit NSCS 315A, *Methods in Cognitive Science*, and a 1-credit NSCS 315B, *Methods in Neuroscience*. NSCS 315B remains discussion-based, but will be offered both semesters with two discussion sections each semester to accommodate up to 120 students over the year.

- Faculty noted that the menu of courses for the Computational Emphasis was limited and that the emphasis required 18 units to complete instead of the 15 units for the other emphases. The higher unit requirement for the Computational Emphasis was reduced to 15 units (Catalog Year 13/14), made possible by the addition of a programming course to the list of NSCS program pre-requisites when the two tracks were created. Expanding the menu is an ongoing effort, requiring new faculty resources.

Annual review: 2014

The results of student surveys and faculty discussions in the Curriculum Committee indicated the following areas for concern:

- No capstone experiences available (A11). This is a resource issue that we will not be able to resolve in the short term. Students in the honors program must present their theses in the end-of-year poster session, but this is simply an opportunity for honors students to hone their ability to present their work to a mixed audience; the posters are not scored or evaluated. Students *can* take NSCS 498 as a capstone course, which requires a faculty advisor. But it would be good to have a capstone course related to each emphasis, which would allow students to integrate and share their knowledge about the emphasis topic.

- There is not enough neurodevelopment in the core curriculum, either from the neuroscience or the cognitive-science perspective (A9, CS15, NS18). Very basic neurodevelopment – initial embryonic events in formation of the nervous system – is addressed in NSCS 200, but further content is found only in elective courses, mainly in the Development and Aging Emphasis. Because neuro and cognitive development were considered important enough to be included among the learning objectives for the program, the curriculum committee will address the issue during AY 15/16.

- Faculty expressed concern, and students agreed, that the goals of the different emphases were not well defined. Most students choose the Cognition or the Neurobiology Emphases. At the annual majors meeting, each of the emphases was defined in terms of its goals, the careers it likely would support, and any student strengths that would be useful in pursuing it. When the new website is constructed, these descriptions will be highlighted.

Annual review: 2015

The results of student and faculty surveys and faculty discussions in the Curriculum Committee indicated the following areas for concern:

- The Neurobiology emphasis needs a neuropharmacology course. If the NSCS program's request for program fees is approved, the budget will allow hiring of an adjunct to teach a neuropharmacology course.

- Students continue to express a desire for more help with preparing for professional careers. If the NSCS program's request for program fees is approved, the addition of an administrative assistant for the Program Coordinator will allow time for development of NSCS-specific professional development opportunities, with the goal of enhancing student competitiveness for employment or postgraduate education.

- Lack of a capstone course. If program fees are approved, we will re-consider developing non-required capstone course(s) related to the emphases.