

## ARTICLE

# The New Blueprints: Undergraduate Neuroscience Education in the Twenty-First Century

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The Faculty for Undergraduate Neuroscience (FUN) has mounted many summer workshops since its first in 1995 held at Davidson College. An important outcome of the 1995 workshop was the development of four “blueprints” to help guide institutions in developing and maintaining undergraduate programs in neuroscience. Since then, at approximately ten-year intervals, participants at the FUN workshops have revisited and amended the Blueprints to better reflect best practices in undergraduate neuroscience education, including adding a fifth blueprint in 2005. In 2017,

participants at the FUN workshop held at Dominican University again conducted a review of the blueprints and amended each of the five. A significant change resulting from the 2017 discussions was revision of the neuroscience minor blueprint to reflect the evolution of this program type across institutions.

*Key words: neuroscience major; neuroscience minor; neuroscience studies; neuroscience emphasis in biology; neuroscience emphasis in psychology; core competencies*

It was well over twenty years ago that the Faculty for Undergraduate Neuroscience (FUN), then in partnership with Project Kaleidoscope (PKAL), convened the first of many summer workshops devoted to undergraduate neuroscience education. From the onset, these workshops have intended to promote best practices in curricular design; the participants at that first meeting undertook the task of examining the various forms that undergraduate neuroscience might take. What emerged from that meeting held in 1995 at Davidson College was a first set of guidelines for developing undergraduate programs in neuroscience—the original “blueprints” that served many institutions in the years following to help mold the future of programs across the United States.

Ten years after the Davidson Workshop, FUN hosted its fifth workshop in 2005 at Macalester College, which took as part of its mission to inaugurate a regular review of the blueprints with each passing decade at the workshops. The participants at that workshop found that after intensive exploration, what emerged were models of neuroscience education that expanded and updated those proposed at the 1995 meeting and added a new model of neuroscience studies alongside those.

In 2017, FUN held its ninth workshop at Dominican University, a meeting entitled “Undergraduate Neuroscience Education: Activities, Laboratories and Best Practices for Developing, Assessing and Sustaining Inclusive Curricula.” With over ten years having passed since the review of the curricular blueprints at the Macalester College workshop, at Dominican, participants and workshop leaders turned again to the task of exploring and discussing what forms an ideal undergraduate education in neuroscience might take. This article reflects the outcome of those discussions and revises earlier versions of the blueprints for programs as we move toward the third decade of the 21<sup>st</sup> century.

At the Dominican workshop, the value of the curricular blueprints was confirmed and the blueprints themselves further developed by participants coming from a variety of colleges and universities, representing a wide range of institutional strengths and resources, each with a vested interest in undergraduate neuroscience curricula. As in the earlier workshops, it remained clear that neuroscience educators agree to several fundamental principles that promote core competencies critical for effective undergraduate neuroscience education. These principles include:

- 1) promoting critical and integrative thinking;
  - 2) promoting communication skills orally and in writing;
  - 3) illustrating the interdependent nature of the sciences;
  - 4) imparting an understanding of the resources and limitations of the scientific enterprise as regards our society's biomedical, economic, and ethical challenges (Ramirez, 1997).
- In addition, participants at the Dominican workshop stressed:
- 5) the ongoing need to make diversifying the student body that is attracted to, and successful in, neuroscience programs a primary goal in developing neuroscience curricula; and
  - 6) the need to make the various career paths that exist for students completing neuroscience programs at the undergraduate level better understood by students, and better communicated by all programs.

These principles, when intentionally represented throughout the curriculum, can promote a number of specific core competencies (for a detailed discussion see Kerchner et al., 2012), namely:

- 1) independent thinking and self-motivated learning;
- 2) a basic foundation of knowledge across Neuroscience, Biology, Chemistry and Psychology;

- 3) the ability to integrate disparate information and think critically;
- 4) quantitative skills and familiarity with use of statistical applications and scientific programming/coding;
- 5) facility in the application of scientific inquiry, with analytic and research skills;
- 6) recognition of scientific rigor and the need for reproducibility;
- 7) development of a professional, ethical code of conduct; and
- 8) expertise across forms of communication skills.

In this article, we again update earlier versions of the “Blueprints for a Neuroscience Education” (as conveyed by Ramirez et al., 1998 and Wiertelak and Ramirez, 2008) guided in strong part by these core competencies. We also found considerable inspiration for our task in two recent *Neuron* articles. The outcomes and core competencies that emerge from well-structured programs should guide program development, and author Rae Nishi and colleagues (Nishi et al., 2016) provided granular detail on the approaches the Marine Biological Laboratory takes in its highly successful intensive summer programs. We should further incorporate the knowledge that students pursuing educations in Neuroscience at either the undergraduate or graduate level are more likely to head into non-academic rather than academic careers. Huda Akil and her co-authors (Akil et al., 2016; see also Ledbetter, 2012) articulate especially well that, although it is desirable to cover the various levels of analysis within neuroscience – at the molecular/cellular level, systems level, and behavioral neuroscience levels – it is also essential to impart critical thinking, computational, and communication skills that will serve the student well, no matter what career path they pursue. Adapting our undergraduate training to mesh well with changes in graduate training provided by such innovations as the Broadening Experiences in Scientific Training (BEST) programs at the National Institutes of Health could provide our students with a broader array of choices for their post-graduate work (for examples of such choices see figure 1 in Meyers et al., 2016). Readers may also be interested in a 2018 Society for Neuroscience Neuronline webinar focusing on best practices in undergraduate neuroscience pedagogy; two co-authors of this article (KP, JJR) served as speakers for that online event. For more information on this webinar see the Additional Resource section below.

In this update, we retain the five-blueprint structure, however, aspects of each blueprint have changed in the past decade. Perhaps most striking is the nature of the neuroscience minor; such minors now feature forms reflective of both neuroscience and neuroscience studies as majors. The five blueprints now are:

- 1) Neuroscience Emphasis in Psychology,
- 2) Neuroscience Emphasis in Biology,
- 3) Neuroscience as a (freestanding) Major,
- 4) Neuroscience Studies as a Major, and
- 5) Neuroscience or Neuroscience Studies as a Minor.

Although the blueprints each adopt different strategies in educating undergraduate students, the course sequences ultimately described below offer a progression from

introductory level courses through advanced level courses. To introduce these blueprints, we first discuss the underlying goals for the introductory, intermediate, and advanced levels.

*Note:* Regardless of which of the five blueprints a particular program may most closely align itself with, there are wide ranges of both course and laboratory experiences that could be featured in a neuroscience curriculum. Moreover, the mission, resources and faculties of specific institutions may further impart design characteristics related to the intended outcomes for graduates, including the forms and extent of laboratory research featured in the program (for a discussion of general characteristics of undergraduate neuroscience programs in the U. S., see Pinard-Welyczko et al., 2017). Further, while the discussions at the Dominican workshop did not format these goals as measurable student learning outcomes, educators developing or revising neuroscience programs should articulate their own student learning outcomes in ways that readily facilitate measurement and coordinate well with that institution’s assessment plan (Muir, 2015). We elucidate the principal goals of these levels, then with the intent to facilitate their thoughtful inclusion in course design across disparate institutional settings.

#### **Goals for the Introductory Level: Exposure to the Field.**

A dedicated and far-reaching introductory neuroscience course is the cornerstone of all the blueprints described below. The course should introduce students to both *what we know* in neuroscience, and *how we know it*. That is, introductory courses in neuroscience must discuss key findings across neurobiology, neurochemistry, neuroanatomy, and neurophysiology, and in doing so, expose students to classical approaches from psychology and biology, and the relevant quantitative and statistical analyses. The introductory level of the curriculum is also intended to *promote foundational learning* in the student of:

- The breadth of neuroscience
- The language of neuroscience
- The history of neuroscience
- The ethics of neuroscience
- The scientific questions of neuroscience
- Fundamental principles of neuroscience
- Methodologies of neuroscience
- The societal relevance of neuroscience

An emphasis on the societal relevance of Neuroscience can play an important role in attracting students to the discipline and can play an important role in improving retention of students under-represented in the sciences. An important decision in laying out your “blueprint” for Neuroscience at your institution is whether to place this introductory course before (or coinciding with) other foundational science courses, thus providing a “need to know” for basic chemistry, biology, psychology, etc., or placement of the course after certain foundational science courses have been mastered.

#### **Goals for the Intermediate Level: Explore the Field.**

- To have students explore neuroscience more deeply by:
- Increasing exposure to primary literature

- Engaging them in research design
- Engaging them in analysis of research and research findings
- Enlisting them in conducting research responsibly
- Providing experiences in presenting research findings, orally, visually, and in writing
- Involving them in more sophisticated analytic, quantitative, computational, and empirical work

#### **Goals for the Advanced Level: Expand Knowledge in the Field.**

- To promote students becoming independent investigators in neuroscience by gaining:
  - an in-depth understanding of primary literature;
  - extensive experience in design and analysis;
  - facility with sophisticated quantitative, computational and laboratory skills;
  - the ability to articulate how the interdisciplinary nature of neuroscience will facilitate solving problems facing science and society.

### **THE NEW BLUEPRINTS: NEUROSCIENCE EMPHASIS IN PSYCHOLOGY**

The curriculum designed for a neuroscience program nested in a psychology department remains structured into three levels, introductory, intermediate, and upper. Each of these levels has its own goals. The courses chosen to meet these goals are sometimes very specific, such as taking an experimental design and statistics course, and at other times may be accomplished by taking a few courses from a list of alternatives. There are also a number of collateral courses taken in other departments that should be included so that the interdisciplinary nature of neuroscience is fulfilled.

#### **Introductory Level**

Specific goals for the introductory level were to promote students' interest in neuroscience and to define the scope and terminology of it as a field of study. There are a number of introductory courses that could meet these goals and allow students to become familiar with the mode of inquiry used by neuroscientists. The participants at the workshop envisioned that a student would best accomplish the introductory goals of a neuroscience program nested within psychology by taking two courses at this level. A seminar focusing on topics related to neuroscience may be offered in addition to the required introductory courses.

#### **Courses for Introductory Level**

[two required; one or both with a laboratory component]

- Introduction to Neuroscience: The way in which students might be introduced to the study of neuroscience could be accomplished in several ways; for example, through a dedicated introductory course, behavioral neuroscience, physiological psychology, or through a general education course. Participants found it highly desirable for this course to be mounted by the psychology department to anchor the program, and for it to feature an extensive laboratory component.

- Introduction to Psychology: Although a general introduction to psychology is to be required, the biological basis of behavior should be well covered. One suggestion for achieving this was to adopt a modular approach to the course taught by several members of the department in turn, or to use guest lectures by neuroscience colleagues so that neuroscience is examined as fully as possible in the course.

#### **Intermediate Level**

The goals of the intermediate level—to explore the field—are intended to provide students with a deeper involvement in the content of neuroscience, as well as a greater understanding of the research perspectives used by neuroscientists. Such deeper involvement in content requires coursework drawn not only from the psychology curriculum, but that of biology, chemistry, and other fields. Intermediate-level students should gain experience with all phases of neuroscience investigations; including working both alone and in groups to conduct library research and design studies, carrying out physiological procedures important to the discipline and collecting data, and analyzing, summarizing and reporting findings in appropriate formats, such as oral presentations, visual display of data, and journal article preparation.

Multiple courses would be required in this level and it would be especially important to require coursework in research design, analysis, and statistics. If Behavioral Neuroscience was used as the introductory course, subsequent courses should build from that foundation and be designed to help students develop more advanced skills and provide them with the tools needed for deeper investigation of central themes across neuroscience. As featured in the previous blueprints, completion of organic chemistry and an associated lab was advised as a component of the curriculum (particularly for those students interested in the cellular/molecular end of neuroscience), and completion of biochemistry desirable. Within biology, completion of a general biology course with laboratory, and additional training in cellular, molecular, or other laboratory courses such as immunology, taken alongside coursework in genetics, evolution, or animal behavior will further acquaint students with overarching themes and research methodologies. Additional coursework in psychology should also center on such laboratory-intensive study as sensation and perception, cognition, and importantly, principles of learning and behavior. Further psychology-based courses in abnormal, clinical, comparative, and health psychology were all seen as desirable additions to the curriculum as offered by individual institutions.

A further recommendation is that students consider completing one or more courses from a list including neurophilosophy or philosophy of the mind, artificial intelligence, and general physics. Depending on the particular institution and its faculty expertise, many more courses could be added to this latter group.

#### **Courses for Intermediate Level**

[four or more required]

Statistics and research design stands out as a feature, along with:

- Psychology courses, such as Behavioral Neuroscience, Principles of Learning, and Sensation and Perception.
- Biology courses, such as Cell Biology, Genetics, Immunology, and Cellular and Molecular Neuroscience.
- Chemistry courses, such as General Chemistry, Organic Chemistry, and Biochemistry.
- Courses from other departments, such as Introductory Physics, Philosophy of Mind, Artificial Intelligence.

### Advanced Level

The goals of the advanced or upper level are consistent with those discussed at the earlier workshops: stated simply, work at the upper level should aid the student in becoming an independent scholar. As such, the courses taken should feature or focus on reading and analyzing primary literature, the completion of independent research projects that further develop laboratory skills, and make use of intimate course settings that emphasize student-directed learning. Students should be expected to articulate research findings in both written (APA format) and oral formats, and ideally to do so in a formal setting, perhaps through participation in a local, regional, or national conference. A second theme is to place emphasis on integrative capstone courses, such as a special topics or emerging trends seminar in behavioral, social, or cognitive neuroscience. In addition, some programs might make use of a senior thesis, independent study, or an internship that allows the student to both delve deeply into specific neuroscience content and reflect broadly on the field in general.

### Courses for Advanced Level

[two or more required]

Students completing a neuroscience program nested within psychology should consult closely with faculty advisors to ensure they fulfill both the requirements of a psychology major and the neuroscience program. Two or more courses at this level of study were suggested, to include a true research experience, advanced seminars in special topics, and/or a capstone experience that might be realized as a senior seminar, thesis, practicum or internship.

## NEUROSCIENCE EMPHASIS IN BIOLOGY

Participants at the Dominican University workshop discussed at length the interdisciplinarity of any neuroscience program. Although many participants came from biology departments, there was broad representation that reflects the move from a strictly “departmental” approach to a multi-departmental administration of neuroscience programs. Participants felt that students with a major in the natural sciences who want to emphasize neuroscience should include a research-based curriculum with investigative laboratories. The opportunity to engage in a more rigorous independent research is also highly valued when available. The specific requirements for any given major in the natural sciences are likely to vary widely, but there was consensus for strong preparation in chemistry, statistics, and computer science. Coursework in genomics or coding was seen as a plus for students looking to go on

to graduate programs. Participants at the Dominican workshop were also mindful of how majors vary from institution to institution depending on the goals of each Biology Department. A particular change was seen with regard to supporting coursework for the major; participants in 2017 did not explicitly call for requirements of physics, calculus, statistics, and an extensive chemistry background including biochemistry, as in 2005. This change, however may reflect participants’ implicit assumptions that such courses will be routinely included in the requirements for biology students, with or without an emphasis in neuroscience.

### Introductory Level

Specific goals for the introductory level were similar to that of the neuroscience emphasis in psychology; courses at the introductory level should interest students in further study and be structured to define the scope and terminology of neuroscience as a field of study. The participants at the Dominican workshop reasoned that introductory courses drawn from biology and psychology should be paired with a separate introduction to neuroscience when possible to meet these goals and allow students to become familiar with the modes of inquiry used by neuroscientists. The participants envisioned that a student would best accomplish the introductory goals of a neuroscience program nested within biology by taking three or four courses at this level.

### Courses for Introductory Level

[three or four required; one or more with a laboratory component]

- Introduction to Neuroscience: Participants agreed that this course, with or without a laboratory component, should be a requirement for the major/emphasis. At the same time, there was recognition that staffing and resources might not allow all programs to offer such a course. Although participants discussing the neuroscience emphasis within psychology had found it highly desirable for this course to be mounted by the psychology department to anchor the program, and for it to feature an extensive laboratory component, discussants of this blueprint were more flexible regarding this course and its structure.
- Introduction to Psychology: An introduction to psychology is to be required. As in the previous blueprint within psychology, it is important that in this course the biological basis of behavior is well covered.
- Introduction to Biology: A general introduction to the field of biology is to be required.
- First-Year Seminar: Participants involved in the discussion of this emphasis felt that a first-year seminar with a neuroscience focus would be beneficial to students and provides an opportunity for in depth exploration of neuroscience and even the opportunity to introduce students to the primary literature. Although only discussed by this group, the inclusion of a First-Year Seminar could serve this purpose for other versions of undergraduate neuroscience curricula as well.

### Intermediate Level

The goals of the intermediate level of the neuroscience emphasis in biology require the student to become more directly involved in the field of neuroscience. Such deeper involvement in content led to recommendation of courses not only from biology, but also other fields. Courses mounted at the intermediate level should allow students to build from their earlier introductory courses to engage with their peers in neuroscience investigations and laboratory-based courses that require students to collect, analyze, summarize, and report findings.

#### Courses for Intermediate Level

[one from Group A and one or more from Group B required]

Group A: a laboratory-based course on brain and behavior, such as Behavioral Neuroscience or Physiological Psychology.

Group B: Further foundational/supporting coursework

- Chemistry courses, such as Organic Chemistry and Biochemistry
- Genetics
- Cell Biology

### Advanced Level

As the student becomes an independent scholar, the completion of independent research projects that further develop laboratory skills is an important component of their education. Advanced seminars, journal clubs, and electives that bring students together from across different disciplines help emphasize student-directed learning at this level. As in the psychology-based emphasis, capstone courses such as a special topics or emerging trends seminars provide further depth in areas of particular student interests.

#### Courses for Advanced Level

[three or more required]

Students completing a neuroscience emphasis within biology will be challenged to fulfill both the requirements of a biology major and the neuroscience program. Although three or more courses were suggested, including an independent research experience, we note that advanced seminars in special topics and/or a capstone experience that might be realized as a senior seminar may also potentially serve to satisfy requirements of the biology major. Participants also emphasized the incorporation of the primary literature in both intermediate and advanced level classes.

- Directed or independent research
- Advanced neurobiology course (with or without lab)
- Potential electives (varies with institution)
- Interdisciplinary capstone, seminar or journal club

## NEUROSCIENCE AS A MAJOR

Participants at the Dominican workshop agreed that the goal of a freestanding neuroscience major is to provide students with a solid foundation and in-depth training in neuroscience and other sciences that may support multiple career trajectories. In many ways, this goal statement revalidated the contention of earlier workshops that the neuroscience

major is aimed primarily at students who desire to go on to further training in graduate school (in neuroscience or some related area), medical school, dental school, nursing school, veterinary school, or education, but with some flexibility built into the curriculum. Although the major is a rigorous course of study nested in the sciences, we should again recognize that even students pursuing graduate studies in Neuroscience are more likely to pursue non-academic rather than academic careers (Akil et al., 2016). A freestanding neuroscience major should not focus solely on the molecular/cellular, systems, and behavioral neuroscience levels; rather, it must also impart critical thinking, computational, and communication skills that will serve the student well, no matter what career choices they ultimately pursue.

At the Dominican workshop it was agreed that current disparate student needs require close advising—a critical and time-consuming faculty responsibility. For example, those students intending to satisfy pre-medical requirements as part of their neuroscience major may be best served by including physics and biochemistry classes, while other students with different goals may benefit by taking more electives in disciplinary areas more relevant to their particular post-college aspirations.

#### Courses for Introductory Level

[seven or more required]

- One-to-two semesters of Introductory Biology courses that feature genetics, basic cell chemistry, cellular/molecular biology, and physiology concepts with inquiry-based laboratories
- Two semesters of General Chemistry and one semester of Organic Chemistry, with laboratories
- Introductory Psychology
- Statistics
- One semester of Introductory Neuroscience, preferably with a laboratory component

Two further recommendations at the introductory level are calculus and computer science.

#### Courses for Intermediate Level

[three or four required]

- Cellular/Molecular Neuroscience with laboratory;
- Behavioral Neuroscience with laboratory;
- Systems-level Neuroscience (including, but not limited to sensory systems, motor systems, neural development, etc.)
- A research methods course or modules integrated into the other three intermediate-level laboratory courses that include more sophisticated data analysis skills as well as training in research ethics.

#### Courses for Advanced Level

[four or more required]

Advanced courses would be tailored to areas of faculty expertise but should include a research-oriented capstone experience (that could involve an independent study, a summer research experience, and/or senior experimental thesis work, drafting of a grant proposal, or a community-

based or clinically-based project), as well as one or more seminars or special topics courses in neuroscience. Discussants agreed that two to four electives should be chosen for inclusion in the student's major plan in consultation with the student's advisor.

A list of possible elective courses includes but is not limited to:

- Computational Neuroscience
- Developmental Neurobiology
- Learning and Memory
- Neuroanatomy
- Neurochemistry
- Neuroendocrinology
- Neuroethology
- Neuropharmacology
- Neural Networks/Modeling
- Social Neuroscience

Given the rapid changes within the field, it was stressed that the requirements for the major should be flexible enough that students can pursue a concentration or "track" of their choosing, such as cellular/molecular neuroscience, computational neuroscience, or cognitive neuroscience. The major requirements should allow room for students to choose associated courses such as molecular biology, computer science, and psychology, respectively, to match their particular interests. Such flexibility might also allow students the freedom to seek courses that speak to diversity and inclusivity, such as Neuroscience and Public Policy, Biology of Gender, and Cultural Neuroscience, if available.

## NEUROSCIENCE STUDIES AS A MAJOR

The goals of the neuroscience studies major vary by institution, but participants at the Dominican workshop agreed that the principle goals of this major are for students to develop critical thinking skills alongside core knowledge in neuroscience that can serve them on both scientific and non-scientific career trajectories, and to strongly integrate humanities and social sciences into this neuroscience curriculum. As such, the neuroscience studies major shares characteristics with neuroscience and neuroscience studies minors, concentrations, and emphases. As at the 2005 workshop, select faculty from primarily undergraduate institutions and liberal arts colleges expressed strong enthusiasm for this form of neuroscience education, which often describes the neuroscience curricula emerging at institutions with smaller faculties or with unique missions. Discussants of this curricular blueprint agreed that the courses included in neuroscience studies programs strongly supported a mission of educating a more scientifically literate populace while also serving the programs' core constituencies, the major, and/or minor students.

### Introductory Level

As for each of the blueprints, a dedicated and far-reaching introductory neuroscience course that introduces students to both *what we know* in neuroscience and *how we know it* is a critical component. In addition to discussing key findings across neurobiology, neurochemistry, neuroanatomy, and neurophysiology, and exposing students to research

methods and analyses, particular attention should be paid to how neuroscience informs, and is informed by, other sciences and the humanities. Providing students with ample in-class examples drawn from clinical neuroscience, neurophilosophy, artificial intelligence, and the neuroscience of dance or music were among the many suggestions participants made to promote this particular goal in neuroscience studies. The participants at the Dominican workshop reasoned that other introductory courses drawn from biology and psychology could be included alongside introduction to neuroscience, but agreed that local institutional interests and strengths, and the goals of that faculty, should drive which courses, laboratories, and other structures should be features of these programs. A major concern for the participants at the Dominican workshop was that these courses be conceived as discussions of both applications of neuroscientific findings and ways of knowing.

### Courses for Introductory Level

[one to four or more required]

- Introduction to Neuroscience: Participants agreed that this course, with or without a laboratory component, is a critical requirement for the major.

Other recommendations:

- Introduction to Psychology
- Introduction to Biology
- Statistics and Research Methods

### Intermediate Level, Advanced Level, and Disciplinary Emphasis

The goals of the intermediate level, and for the advanced level, require the student to become more deeply and directly acquainted with the broad field of neuroscience. In addition, this blueprint includes several courses in one field of study taken to create a disciplinary emphasis within the major.

### Courses for Intermediate Level

[three or more required]

- Behavioral Neuroscience
- Cellular/Molecular Neuroscience
- Neurophilosophy
- Neuroscience and Society
- Cognitive Neuroscience

### Advanced Level

Courses at the advanced level should provide students with opportunity to reflect on what is known in neuroscience, and challenge them to consider the ways in which one may come to know such information.

### Courses for Advanced Level

[two or more from Group A and one from Group B required]  
Group A: Special topics courses, such as but not limited to:

- Neuroscience of Dance
- Neuroscience of Music
- Neuroethics
- Neuroscience and Public Policy

- Social Neuroscience
- Neuroscience and Literature

Group B: Capstone or Senior Seminar: Participants at the Dominican workshop agreed that to complete the curriculum, a reflective, interdisciplinary capstone experience should be included. A seminar intended to return the students to the themes of what we know, and how we know it could be seen as one form of such a capstone; alternately, a history of neuroscience course might serve well for this purpose.

### **Disciplinary Emphasis**

[four or more courses required]

Students should choose courses to be included in disciplinary emphases in consultation with advisors to develop specific disciplinary knowledge and methodological expertise in a discipline that intersects with neuroscience. Such areas as philosophy, mathematics, computer science, psychology, or cognitive studies might be seen as just a partial list for inclusion here; but the primary goal for the student in neuroscience studies should be to return again and again to the themes of what is known in neuroscience and the ways in which one may come to know such information.

## **NEUROSCIENCE or NEUROSCIENCE STUDIES AS A MINOR**

Participants at the Dominican workshop engaged in discussion about the nature and mission of a minor program in neuroscience. In fact, participants in several blueprints discussions found themselves weighing in on the nature of the neuroscience minor. A persistent observation from past workshops was that minor programs were more often idiosyncratic to the particular institution, reflecting the strengths of local department and faculty groups though perhaps not offering as broad a collection of courses as might be found in institutions prepared to offer a neuroscience major. A major in neuroscience is highly recommended for those anticipating further study in neuroscience, i.e., continuing to a graduate school. That said, when combined with a traditional science major, such as biology, psychology, or chemistry, a neuroscience minor can provide a solid foundation for graduate or medical school preparation. Because many institutions may not have the broad faculty expertise or the specialized facilities to offer a full-bore neuroscience major, a minor would be a very appropriate and appealing addition to a liberal arts and sciences curriculum under these conditions. Indeed, as institutions explore the possibility of developing a neuroscience major as part of their curricular offerings, a minor may provide a reasonable first step in assessing student and faculty interest in crafting a neuroscience major.

Interestingly, discussants at the Dominican workshop observed that there seems little if any qualitative difference between a minor in neuroscience or what could be termed a minor in neuroscience studies. This observation led to proposal of a notable change in the curricular blueprints: the expansion of the minor concept to include both neuroscience and neuroscience studies as forms of the

minor. Discussants agreed that for either a neuroscience studies or neuroscience minor, there should be a strong introductory course that, although interdisciplinary in nature, takes as a primary goal to outline the various areas of neuroscience for the beginning student – introducing the student to the fundamental principles, language, and history of neuroscience. Similarly, either form of the minor should expose students to the modes of inquiry used in neuroscience, to its various research methodologies as well as to statistics and computational methods. Participants felt that such minors should culminate in a capstone (for example, a laboratory-based, research experience conducted over the course of a semester) or other final class (such as a seminar) that serves to pull together the various approaches and disciplines to which the student has been exposed (based on the coursework available at that institution) under the shared theme of neuroscience or neuroscience studies. The discussants were unanimous on two points in particular: First, a minor in neuroscience should not be able to be completed based on foundational courses in allied fields, such as introductory courses in biology, chemistry, or psychology, but rather, a substantial number of the courses in the minor must actually center on neuroscience. Second, immersing students in primary neuroscience literature at some point in their minor is essential, as the ability to read and critically assess the primary literature was regarded as a core competency for neuroscience minors.

As to the selection of courses that might support a minor, in general, relevant courses (such as those identified for the major in neuroscience or neuroscience studies – see sections above) from mathematics, computer science, across the natural and social sciences, and humanities were believed to constitute appropriate elective choices, especially when distributed both across the discipline and across introductory, intermediate, and advanced levels. Some discussion also supported the requirement of a research experience. One aspect of the discussion about the minor on which the discussants focused at Dominican warrants special attention: given the current concern regarding scientific rigor and reproducibility as well as responsible conduct of research, the courses that constitute a minor should significantly expose students to these central issues from the introductory to the advanced level.

A comparison of this combined neuroscience/neuroscience studies approach to the minor to earlier forms of the minor blueprint reveals enduring themes, despite perhaps the perception the minor blueprint was undergoing significant change. Consider that in 1995, the Davidson group had arrived at a model with the following characteristics: the minor should incorporate an introductory or capstone course, require a lab experience, contain courses from the social and natural sciences and the humanities, and include a substantial number of disciplines. Participants at the 2005 Macalester workshop expressed similar goals for the minor, suggesting a research experience alongside introductory and capstone coursework and other supporting courses from across disciplines. The redefinition of the minor blueprint here may now simply more accurately reflect the nature of the minor across a variety of

institutions. Importantly, the new emphasis on rigor and reproducibility, responsible conduct of research, and quantitative/computational skills reflect current conversations within the scientific community (e.g., Resnick and Stewart, 2014; Akil et al., 2016).

### General Characteristics of a Neuroscience/Neuroscience Studies Minor Program

- Foundational course in neuroscience
- Required neuroscience or cognitive science lab
- experience
- Contains elective neuroscience-relevant coursework from:
  - Mathematics
  - Computer Science
  - Natural Sciences
  - Social Sciences
  - Humanities
- Involves a substantial number of disciplines
- May include a capstone experience

### CONCLUSION

The years since the Davidson College Workshop in 1995 have seen the rise of neuroscience not only as a college major offered at many institutions (Ramos et al., 2016), but also as a significant cultural phenomenon in the 21<sup>st</sup> century. The increasing popularity of neuroscience is certainly due in no small part to the ever-expanding fund of knowledge from research activity around the globe, but also, the fuel this knowledge provides for the imagination—of what is known, and what is yet to be found. People from all walks of life—be they politicians, pundits, or poets—turn to neuroscience and its discoveries to seek answers that can provide hope and inspire dreams. We hope that these updated blueprints presented here will continue to serve the undergraduate neuroscience education community well, as faculty fine tune their programs and curricula to provide the next generation of neuroscientists with the wide-ranging foundation needed to fuel the great neuroscience discoveries yet to come. We close by again stating that we believe that providing a strong interdisciplinary education in neuroscience will also best serve society's needs by preparing our students to think critically, synthetically, and creatively about the problems facing humanity. Whether as neuroscientists or as informed citizens they will be well prepared to participate in the global dialogue securing a stable and fruitful future for us all.

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### ADDITIONAL RESOURCE

Neuroonline (<http://neuroonline.sfn.org/>), a Society for Neuroscience (SfN) website, helps neuroscientists advance in their training and career and connect with the global scientific community year-round. Anyone can access five resources every 30 days, while SfN members enjoy unlimited access, including participation in SfN webinars and community discussion forums. Register to watch the “Undergraduate Neuroscience Pedagogy: Perspectives From Different Institutions” webinar on demand on Neuroonline. In this webinar, undergraduate faculty - Julio Ramirez, Karen Parfitt, Gary Dunbar, and Laura Symonds - share best practices, many of which are discussed in this article, in undergraduate pedagogy implemented at a variety of institutions. They discuss features of neuroscience curricula at their colleges or universities and lessons they have learned from beginning and maintaining a neuroscience course of study. Registration link: <http://neuroonline.sfn.org/Articles/Program-Development/2018/Undergraduate-Neuroscience-Pedagogy-Perspectives-From-Different-Institutions>.

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