Neuroscience Research

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Neuroscience is a relatively young field, having emerged as a separate discipline within recent decades. Research in neuroscience encompasses all aspects of the nervous system from the cellular mechanisms of nerve cells to the brain's governance of behavior and cognition. Psychology, along with Biology, Physiology, and other disciplines is a major contributor to the interdisciplinary research of the field.

Indoctrination of students into neuroscience necessarily involves research experience. Directors of graduate and undergraduate Neuroscience programs agree that the most important preparation undergraduates can have for graduate school entry in neuroscience is research experience (Boitano, 2001). Indeed, a recent survey from the Association of Neuroscience Departments and Programs (ANDP) indicated that 95% of accepted students in neuroscience graduate programs have some research experience (Stricker, 2005). Students who plan to work in the neuroscience field immediately after graduation (e.g., lab technician, research assistant) also find applied research experience essential.

For a successful undergraduate research experience, the ideal interaction between teacher-student results in more than a simple transference of knowledge. Specifically, students in neuroscience are typically engaged in the discipline in an ever-increasingly independent and applied way. An apprenticeship model of learning fits well with student engagement in scientific application (Lave, 1996; Lave & Wenger, 1991). Apprenticeship as a model of learning puts greater emphasis on the student as a participant in the learning process. Essentially, learning becomes more self-directed as the student takes on a new identity while integrating into a community of practice (Lave & Wenger, 1991). In this case, the new identity is an actively engaged scientist within the neuroscience community of practice. The extraordinary growth of neuroscience research internationally has left students hungry for real experience (Mickley, Kenmuir, & Remmers-Roeber, 2003). The process of students developing a research partnership with their mentors in order to develop their research skills at all stages, from conception to publication, rather than simply joining the faculty members' existing project is the basis of a model neuroscience mentorship program described by Mickley et al. The outcome assessments have supported this model as an exceptionally good approach to undergraduate neuroscience education.

The apprenticeship model is student focused. Students gain independence as active neuroscientists as their skills, knowledge, and confidence develop. The teacher and the student become interactive partners in the learning process. Both the teacher and student, therefore, are learners in this dynamic (Lave, 1996). This partnership allows both parties to collaboratively formulate ways of applying the scientific method to answer a variety of questions, and transfers to the student the experience and confidence necessary to independently join the neuroscience community. I have personally found this approach to be extremely effective for engaging top caliber students in their chosen discipline early in their undergraduate years. After brainstorming through our mutual interests, for example, I have provided extra brain tissue from my own research for independently tailored analyses and have co-written a peer-reviewed grant proposal with an especially astute sophomore.

Given the heavy research focus and unique interdisciplinary blend of this particular community of practice, taking an active role in the neuroscience community requires research skills flexible enough to be applied to a variety of situations in a variety of scientific disciplines. The apprenticeship model is ideal for providing appropriate neuroscience training. Also, apprenticeship should be viewed as a process that requires time. This underscores the importance of undergraduate research in neuroscience. Ideally, students who become engaged in research early will be more confident, gain more skills, and integrate more smoothly into the community.

A unique challenge of student involvement in neuroscience research involves instruction flexibility. Interested students may be majors in a variety of disciplines, including Psychology, Biology, and Chemistry. The neuroscience community is primarily formed through a network of interactive, collaborative laboratories and departments. According to a recent survey, 64% of undergraduate

and graduate neuroscience programs involve multiple departments, whereas only 18% of these programs are housed specifically in neuroscience departments (Stricker, 2005). Given this unique environment, an important skill for undergraduate students is to gain the knowledge and confidence to seek out expertise as needed in a collaborative network of scientists. In other words, it is important to choose appropriate mentors and understand the scientific theories well enough to know which questions to ask and where to find the answers. Since most neuroscience training spans multiple departments, the expertise and interests of faculty are likely to depend on the institutional availability of faculty initially hired for a variety of positions. Specific student research interests and backgrounds may be equally as variable.

Successful navigation of the variability inherent to an interdisciplinary area such as neuroscience can be supported by promoting understanding among scientists regarding neuroscience research. It is not uncommon for physical science departments to be less than inclusive of psychology as a science. Likewise, psychologists may not fully grasp the complexities of engaging in neuroscience research or developing a multidisciplinary network. Methods of promoting open communication among departments and colleagues regarding the unique challenges of neuroscience research can be beneficial to faculty and students alike within the discipline. Examples of ways to open communication and promote understanding among faculty and students across multiple disciplines may include colloquia, open discussions, and formal or informal research presentations or journal clubs.

Although smaller undergraduate institutions are believed to be at a disadvantage to engage in undergraduate neuroscience research (Faculty for Undergraduate Neuroscience, n.d.), 69% of undergraduate neuroscience programs are at primarily undergraduate institutions (Stricker, 2005). Interviews with undergraduate students in several laboratories indicate that the success of the laboratory in engaging undergraduates in research depends on four important aspects: offering unique experiences and skills that cannot be found elsewhere; maintaining an open, collaborative atmosphere that values undergraduate input; clearly identifying the natural progression from mundane tasks to independent responsibility; and challenging critical, scientific thinking and ethical applications (Benson, 2002).

Setting up neuroscience research programs and opportunities for undergraduate students can be a daunting task, but resources are available to help. Project Kalaidoscope (PKAL) advocates for the development and support of undergraduate programs in science, technology, engineering and mathematics. Faculty for Undergraduate Neuroscience (FUN) provides a unique support system for undergraduate neuroscience programs and faculty. PKAL and FUN have collaborated in several workshops regarding the development of undergraduate neuroscience programs. The first of these workshops in 1995 resulted in specific goals for undergraduate neuroscience education. These goals include critical thinking, scientific communication skills, highlighting the interdependence of the discipline, and better understanding of science and its role in society (summarized in Kerchner, 2005; Ramirez, 2005). Specific resources associated with establishing and improving undergraduate neuroscience research can be found at:

- Faculty for Undergraduate Research (www.funfaculty.org) - FUN publishes the Journal of Undergraduate Neuroscience Education (JUNE), an online peer-reviewed mechanism for undergraduate neuroscience educators to share teaching techniques, curriculum development issues and laboratory exercises. (www.funjournal.org)
- Association of Neuroscience Departments and Programs (www.andp.org) - ANDP provides a discussion forum for neuroscience research and training issues and is a resource for neuroscience education information for undergraduate, graduate and postdoctoral students.
- Project Kaleidoscope (www.pkal.org) has published practical advice and best practices in undergraduate research in their yearly, internet-accessible *What Works* volumes since 2004.

Providing valuable research opportunities in undergraduate neuroscience involves three important but challenging components: space, time, and funding. One way to address these issues efficiently is to combine teaching and research space whenever possible. Adding lab components to biopsychology, psychopharmacology and other neuroscience-oriented courses can provide a reasonable mechanism for minimizing time and resource investment while maximizing space utilization. For strategic planning of research space, Project Kaleidoscope provides facilities planning resources and workshops and both Project Kaleidoscope's Keck consultation program and APA review consultants can provide on-site expert advice on facility development. Limited space need not preclude laboratory development though. Harrington (2006) provides a unique manual for focusing a course or laboratory on research methodology specific to neuroscience. In this type of course, student-designed projects and scientific papers can actively involve students in learning the

process of neuroscience research. Laboratory exercises can also be conducted easily within limited budgets. For example, sheep brains and cow eyes for dissection are inexpensive and are available from some online vendors formaldehyde-free for added safety and reduced disposal costs. Other laboratory projects and supplemental materials such as histology slides and electrophysiology manuals are available on the Journal of Undergraduate Neuroscience website. Online resources such as the mouse brain library (www.mbl.org) and the functional MRI data center (www.fmridc.org) provide easily accessible databases of animal and human brain images. Sinauer Associates have CD-ROM based activities in neurophysiology and are developing a database of NeuroLabs that will include affordable and accessible options for even the most limited budget and space considerations.

An important aspect of neuroscience research education is the ethical use of animal and human subjects. It is important to match subject use to the specific objectives of the laboratory or research project in order to balance educational value and subject utilization. Although Institutional Review Board (IRB) considerations are well known to most psychologists, a majority of neuroscience research involves animal (primarily rodent) rather than human subjects. While the IRB is charged with the protection of human participants in research, the use of animals is governed by Institutional Animal Care and Use Committees (IACUC). It is important in IACUC proposals to demonstrate consideration of the three R's (reduce, replace, refine) since every animal subject's use must be justified. To this end, when designing laboratory activities or training undergraduates in research techniques it is important to educate students about animal use, to provide as many options as possible that do not involve live animals (e.g., using tissue from a previous study or coding behavior using recordings of animals), and to thoroughly justify the number of animals necessary for the scientific goals of the project. Ethical considerations should be balanced against the irreplaceable value of training undergraduate students with neuroscience interests in live animal techniques. Students involved in animal research quickly gain greater understanding and respect for the research process as well as the time investment required for data collection. These skills are invaluable to students learning to design independent projects. I have found that even the most anxious and inexperienced students gain confidence and skill in handling animal subjects when appropriate training and individual attention is provided. The skills and confidence from this training contribute an important component to the development of the student as a member of the neuroscience community.

Another valuable option for students seeking experience in neuroscience research is involvement in one of the increasingly popular undergraduate summer research programs. It was only after completing one of these summer research programs that I realized I had finally found my niche in psychology. The program was instrumental in my acceptance to graduate school and my early involvement in the neuroscience community. According to self reports from summer research programs, 60% of perceived benefits involve growth toward becoming a member of the scientific community (Hunter, Laursen, & Seymour, 2007). High academic achievers should be encouraged to apply to these programs, which typically match students to available faculty with compatible interests. More information about undergraduate neuroscience summer research opportunities can be found at the following sites:

- Abbott Laboratories science internships for undergraduates (http://abbott.com/global/url/content/en_US/50.60.10.10:10/general_content/General_Content_00167.htm)
- National Science Foundation Research Experiences for Undergraduates program (www.nsf.gov/crssprgm/reu/reu_search.cfm)
- U.S. Department of Energy Science Undergraduate Laboratory Internships (www.scied.science.doe.gov/scied/erulf/about.html)
- American Physiology Society summer research opportunities, sorted by state and institution (www.theaps.org/education/ugsrf/SumResLINKs.htm)
- Westminster College Psychology Department list of neuroscience summer opportunities (www.psych.westminster.edu/psybio/internops.htm)
- Howard Hughes Medical Institute funded summer research in neuroscience (www.hhmi.org/grants/reports/scienceopp/main)
- Weizmann Institute of Science in Israel summer research opportunities for international students (www.weizmann.ac.il/ acadaff/kkiss.html)
- Harvard research opportunities for minority students underrepresented in the sciences (www.hms.harvard.edu/dms/diversity/shurpintro.html)
- New York University Center for Neural Science summer research program in neuroscience (www.cns.nyu.edu/undergrad/ surp)

Scientific discovery encompasses critical thinking and flexibility of application in order to apply classroom knowledge. Internationally, the

scientific community is highly skilled, making it especially important that our students not only integrate into the neuroscience community, but that their passion for discovery and science be stimulated. This is the only way to ensure the future generation of scientific advancement. Hands-on research experiences are essential to the development of critical scientific skills. We would not expect a surgeon to perform surgery without practice or an artist to learn to paint from a how-to book. Likewise, we cannot expect to produce proficient scientists without first having students train and practice the scientific method and basic research skills. Appropriate faculty-student collaborative experience is essential to the successful intromission of our undergraduate apprentices into the neuroscience community.

Additional resources for faculty and students:

- Society for Neuroscience (www.sfn.org) - SFN is world-wide professional organization with approximately 37,000 members (and still growing). SFN has links to resources for undergraduates, including summer training opportunities and undergraduate scholarships. SFN offers discounted rates for undergraduate student membership and there are numerous regional chapters of the society. FUN poster sessions for undergraduates are held during annual SFN meetings. ANDP is also closely affiliated with SFN.
- Web Guide to Research for Undergraduates (www.wbguru.neu.edu/devices) - hosted by Northeastern University, this site is an undergraduate student-oriented resource for research involvement. Although undergraduate students are the target audience, some information (e.g., learning contracts, keeping research journals) may be beneficial to faculty as well.
- Undergraduate journals for publishing neuroscience research (updated version of the journals listed in Willoughby & Lom, 2003)
  - *Journal of Young Investigators* (www.jyi.org) - JYI publishes under-graduate research in science, math and engineering
  - *Journal of Behavioral and Neuroscience Research* (http://academic2.strose.edu/Math_And_Science/flintr/jbnr) - JBNR is affiliated with the North East Undergraduate Research Organization for Neuroscience (NEURON). JBNR pub-lishes undergraduate research in neuro-science and psychology, and is especially interested in areas that utilize neuroscience, psychology, and behavioral techniques.
  - *IMPULSE* (http://impulse.schc.sc.edu) - IMPULSE is an international under-graduate journal. Accepted articles are published immediately online.
  - *Indiana Undergraduate Journal of Cognitive Science* (http://www.cogs.indiana.edu/iacs/journal.html) - online publication of under-graduate articles in any area of cognitive science.
  - *Journal of Undergraduate Sciences* (www.hcs.harvard.edu~jus/home.html) - JUS publishes undergraduate research in all areas of science

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