"A community must have a common aim, and the common aim of the educational community must be the truth. It is not necessary that the members of the community agree with one another. It is necessary that they communicate with one another, for the basis of community is communication." This quote from Robert Hutchins has guided the work of Project Kaleidoscope (PKAL) from the very beginning in 1989, as the leaders of PKAL understood that as people begin to explore a common stock of ideas and a common vision about student learning, a community with a driving vision of what works could emerge. Thus, PKAL initiates a series of Occasional Papers; it is our hope that these papers foster informed conversations between individuals, as well as between institutions and associations, and that they contribute to building a sustained commitment to transforming undergraduate programs in mathematics and the various fields of science into the next century.

PROJECT ▪ KALEIDOSCOPE

Neuroscience

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Neuroscience

Project Kaleidoscope (PKAL) is an informal alliance of individuals and institutions engaged in the work of transforming undergraduate programs in science, mathematics, engineering, and technology.

Since its beginning in 1989 with support from the National Science Foundation, the work of PKAL has been kaleidoscopic, giving attention to all aspects of the undergraduate SME&T environment—faculty, curriculum, facilities, as well as to larger institutional and national issues. From an initial base of primarily liberal arts colleges, colleagues and partners from other kinds of institutions—public and private, large and small—have joined in the work of getting science education right. Since Phase II began in 1992, nearly 3400 individuals from over 660 colleges and universities have participated in one or more PKAL activity. Phase III began in 1998.

Current support for Project Kaleidoscope comes from:

- **The Exxon Education Foundation—**
  For the PKAL Faculty for the 21st Century Program

- **The National Science Foundation—**
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  For the Undergraduate Faculty Enhancement Workshops
  Office of Science and Technology Infrastructure—
  For the Facilities Committee of Visitors
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  For the PKAL F21 Leadership Institutes

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ICO/PKAL—Suite 803
1730 Rhode Island Avenue, NW
Washington, DC 20036
Phone: 202-232-1300
Fax: 202-331-1283
pkal@pkal.org
http://www.pkal.org

OCCASIONAL PAPER ON NEUROSCIENCE
from the PKAL Workshop
Interdisciplinary Connections:
Undergraduate Neuroscience Education

July 28-30, 1995
Davidson College
Davidson, North Carolina

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Questions asked at the workshop included:

- Given the range of undergraduate colleges and universities, what should a neuroscience curriculum look like in an undergraduate setting?
- What are we trying to accomplish by introducing neuroscience to undergraduates?
- What are the philosophical and logistical obstacles in setting up a neuroscience program in a liberal arts college? In a state university?
- How does a program in neuroscience get funding for program implementation, curricular development, and outfitting laboratories?
- What kinds of laboratory experiences are available that would facilitate student interest in neuroscience research and provide them with a sound basis in the fundamentals of neuroscience?
- Once a neuroscience program has been established, how do you maintain the momentum to sustain the program?

About the Workshop

One of the primary objectives of the PKAL workshop on neuroscience education was to bring neuroscience educators together to outline a coherent set of plans to assist institutions interested in developing undergraduate neuroscience programs. On the final day of the workshop, participants (70 faculty from 30 institutions) formed four subgroups to explore how undergraduate programs in neuroscience might be structured. We subsequently reconvened in plenary session to debate and discuss the four proposed blueprints. The material presented in the final chapter describes the conclusions drawn from these deliberations.

Workshop Leaders

Lin Aanonsen—*Macalester College*
Gary L. Dunbar—*Central Michigan University*
Leonard E. Jarrard—*Washington and Lee University*
Bruce R. Johnson—*Cornell University*
Israel I. Lederhendler—*National Institute of Mental Health*
Jeanne L. Narum—*Project Kaleidoscope, Independent Colleges Office*
Carol Ann Paul—*Wellesley College*
Julio J. Ramirez—*Davidson College*
Pamela E. Scott-Johnson—*Spelman College*
Dennison Smith—*Oberlin College*

GREETINGS

As part of its national series of workshops focusing on the reform of undergraduate education in the sciences and mathematics, Project Kaleidoscope (PKAL) held a workshop at Davidson College entitled “Interdisciplinary Connections: Undergraduate Education in Neuroscience.” This Occasional Paper is a collection of the presentations and stories about participants from the Davidson workshop.

As we approach the end of the “Decade of the Brain,” it is a good time to examine what an undergraduate neuroscience education should be. An explosive growth of information and technology and national attention to research advances has been accompanied by a dramatic increase in student interest in neuroscience. To nurture that interest, faculty are developing rich, state-of-the-art educational experiences in neuroscience for their students.

Because the field is in its infancy, there have been few occasions to examine the rationale for developing undergraduate neuroscience programs, or the objectives that neuroscience educators hope to achieve. Drawing on exemplary programs in undergraduate neuroscience education, the PKAL workshop at Davidson College focused on *what works*. Through case studies, plenary presentations, and small group sessions, participants explored the issues, challenges, and opportunities for building neuroscience programs. Their efforts are part of a continuing national dialogue sustained by PKAL on strengthening undergraduate science and mathematics education.

Workshop participants came from a broad range of institutions, departments, and subdisciplines within neuroscience. Dialogue ranged from ‘membrane biophysics’ to ‘the philosophy of mind.’ One of our major tasks during the weekend was to create models of neuroscience curricula that would help our colleagues across the nation develop programs informed by the PKAL vision, programs that emphasize interactive, research-based experiences.

On behalf of the PKAL Leadership Committee and the Workshop Leaders, I thank you for taking time to read this Occasional Paper and for having the courage to become involved in transforming undergraduate science and mathematics education. Our students and our nation will benefit tremendously from your commitment and efforts to improve science and mathematics education at the undergraduate level.

We sincerely hope that this PKAL Occasional Paper will be helpful as you respond to the challenges that lie ahead.

Julio J. Ramirez, Ph.D.
Davidson College
PKAL Workshop Coordinator

Scientists work mainly by metaphor…and the kinds of metaphors used to shape our thinking are changing. What we are coming to understand is that the process of reform is complex; it is messy; it is lively; it is an adventure…we are beginning to see the structures, form, and patterns in the work of reform, recognizing that things must always be in flux.

…the elements are always the same, but they keep rearranging themselves, so it's like a kaleidoscope: the world is a matter of patterns that change, that partly repeat, but never quite repeat. It is important to realize that the game you are in keeps changing, so that it is up to you to figure out the current rules of the game…as it is now being played. This means you can apply force to the maximum effect. You don't waste it…the idea is to observe, to act courageously, and to pick your timing extremely well.

— M. Mitchell Waldrop. Complexity.

A NEUROSCIENCE PROGRAM AT A COMPREHENSIVE STATE UNIVERSITY: THE CENTRAL MICHIGAN UNIVERSITY STORY

Gary L. Dunbar

Background

Central Michigan University (CMU) was established just over 100 years ago as a college for teachers. It is located in Mt. Pleasant, Michigan, a community of about 20,000 in rural mid-Michigan. Over the past century, the university has grown to be a comprehensive state university with an enrollment of 16,000 students. CMU operates under a student-credit-hour (SCH) model; departmental and programmatic resources are highly dependent upon the number of SCHs a department or program produces.

In the 100-year history of CMU, only a handful of students pursued graduate training in physiological psychology or other areas related to neuroscience. In 1987 there was no neuroscience program at CMU, nor any plans to establish one. There was limited interest in neuroscience among faculty and students; there was no working laboratory, and only a relatively limited infrastructure to begin building a productive research laboratory.

Two physiological psychology courses (a graduate course and an upper-level undergraduate/lowerlevel graduate course) were offered as service courses for the three Doctor of Psychology programs (clinical, school, and industrial/organizational psychology) and for the General Masters of Arts program in psychology. The two physiological psychology courses existed primarily to fulfill the APA accreditation requirements for the applied graduate programs. Most undergraduates taking the physiological psychology course did so as part of the required preparation for further study in some other area of psychology.

Establishing a Neuroscience Program

CMU took the first step in establishing a neuroscience program by creating a lower-level undergraduate course to generate student interest in neuroscience. Those of us involved recognized that the first key to creating a new program is to design a new class, and to convince your colleagues of the merits of providing a course that would, in essence, compete with their courses for students and student credit hours.

The course was designed as a lower-level interdisciplinary course for CMU's general education program. Because neuroscience is an exciting and fascinating subject, it is both a joy to teach and engenders a great deal of student interest and enthusiasm. The class is very successful. It has grown from one section of 35 students to four or five sections of 50 students each.

The first key in creating a new program . . . is to convince your colleagues of the merits of providing a course that would, in essence, compete with their courses for students and student credit hours.

The second step taken in establishing the neuroscience program was to create a working research/teaching laboratory in behavioral neuroscience, a task made more difficult because of severe space and resource limitations. (Start-up funds of $3,500 did not go very far in equipping the lab!) Through faculty efforts, the Dean became convinced of the need for certain safety equipment (flammable storage cabinets, acid cabinet) and for a new ventilation system for the animal lab.

The neuroscience major at CMU:

1) Biology 101, Introductory Biology

2) Psychology 100, Introductory Psychology

3) Chemistry 120, Survey of General Chemistry

4) Chemistry 127, Laboratory in General Chemistry

5) Psychology 211, Statistics; or Biology 500, Biostatistics

6) Psychology 387, Behavioral Neuroscience

7) Biology 392, Mammalian Physiology

8) Chemistry 342, Survey of Organic Chemistry

9) Chemistry 421, Survey of Biochemistry

10) Psychology 501, Laboratory in Behavioral Neuroscience

11) Biology 592, Neurophysiology

12) Biology 403, Independent Study; or Psychology 497, Independent Study (as capstone research experience)

13) a neuroscience seminar course (three semesters)

The biggest boost in starting the program came from two pharmaceutical companies in Michigan—Dow Chemical Company and Pharmacia & Upjohn. Dow donated several old, but useable items, including glassware, weigh scales, magnestirs, and an oven. The Upjohn Company supported the first research project, a collaboration between Dr. Dunbar and an Upjohn research scientist. This provided a good foundation for two Instrumentation and Laboratory Improvement grants (NSF-ILI) from the National Science Foundation, as well as for a Research Excellence Fund award from the state of Michigan.

The first NSF-ILI grant, which provided a computer and printer for a laboratory, was part of collaboration among five faculty members to upgrade our experimental curriculum to include computerized laboratory instruction. The second NSF-ILI grant funded a laboratory course in behavioral neuroscience. The course is very successful and is being integrated into the curriculum for our new neuroscience program.

Finally, Dr. Dunbar was awarded an Academic Research Enhancement Award (NIH-AREA) by the National Institute of Health. The NIH-AREA grants are targeted for institutions like CMU that are not research-intensive and have received only modest NIH support in the past.

An important ingredient in obtaining external funding is the involvement of undergraduates in research. The laboratory and research experience gained by the undergraduates in our program led to an increase in student demand to work in the lab and thus to the demand to formalize a neuroscience program. Thus, a second key to designing a new program is to generate student demand.

An important ingredient in obtaining external funding is the involvement of undergraduates in research.... A key to designing a new program is to generate student demand.

Formalizing the Neuroscience Program

Although CMU students can now major in neuroscience through an individualized studies degree, few students pursue this option. Most take a traditional degree in Biology, Chemistry, or Psychology with an emphasis in neuroscience. But the problem when we began was that the requirements for these degrees often leave little room for students to take more neuroscience courses.

For example, students in Biology are required to take botany and ecology, but would prefer to take behavioral neuroscience and the laboratory course in behavioral neuroscience. Conversely, taking mammalian physiology and neurophysiology may better serve students in Psychology who are taking abnormal psychology or social psychology courses.

This situation led colleagues in the Biology and Chemistry departments to begin the process of developing a formal interdisciplinary neuroscience program that would serve our students better.

Because many students at CMU do not decide to major until late in their sophomore year or early in their junior year, we designed our neuroscience curriculum to allow students to complete the major requirements within a two-year period. Designing the curriculum for the major was relatively easy because the courses were already being offered and many alternative courses (e.g., one-semester survey courses in chemistry) allowed for a great deal of flexibility in creating our curriculum.

In addition to the 13 required courses and 40 required credit hours, there are several alternative electives that students are strongly encouraged to take, ranging from electron microscopy to animal behavior.

The advantage of this curriculum is that it gives students a good background in key courses that will be useful for graduate training in neuroscience, and yet it allows them to finish the neuroscience program in two years. Our curriculum also provides a good balance of courses between the various departments (Chemistry, Biology, and Psychology), which is an important consideration for schools operating under the SCH model.

One of the major goals of our neuroscience program is to get students involved in laboratory research. As a capstone experience, all students are required to complete an independent research project. Students are encouraged to get as much laboratory experience as possible throughout their undergraduate years, and they all take a three-hour lab course in behavioral neuroscience *prior* to their independent research.

This lab course (developed with the help of an NSF-ILI grant) stresses the conceptual aspects of neuroscience inquiry in addition to teaching basic techniques used in behavioral neuroscience research. The focus of the lab course is on "why" certain procedures are used, rather than just "how" it is done. Students are given a class project to complete during the semester. Topics may vary from semester to semester, but in all cases the topics chosen emphasize an important conceptual issue that is to be addressed experimentally.

The focus of the lab course is on "why" certain procedures are used, rather than just "how" it is done.

For example, during one semester, students addressed the question of whether a double-dissociation of function exists following neurotoxic lesions (using ibotenic acid) to the medial septum and caudate nucleus. Previous work had indicated that electrolytic lesions of the caudate nucleus produce nonspatial memory deficits, but not spatial memory deficits, whereas electrolytic lesions of the fimbria-fornix cause spatial memory deficits without affecting nonspatial memory.

The course was structured as follows:

Weeks 1-3: the students read key articles and prepare the first draft of their research proposal, giving special emphasis on the rationale for the experiment

Weeks 4-6: the students learn surgical techniques and postoperative animal care procedures and revise and refine their research proposals

Weeks 7-9: students test the rats in spatial and nonspatial versions of a radial-arm water maze and assess spontaneous motor activity in an open field

Weeks 10-12: students perfuse the rats, section the brains, and process the tissue for Nissl, ChAT, and AChE

Weeks 13-15: the students do some morphometric analysis and cell counts, finish up their data analysis, and prepare their manuscripts.

The manuscripts are reviewed by peers (all are coded so that students do not know who is reviewing their manuscript). Each student then uses the reviews to revise their manuscript and submit it to the instructor. This course has been very helpful in preparing students for their independent research projects; it has been very well received by the students.

This program has been very successful in preparing CMU students for further training in neuroscience or health-related areas and for jobs in biotechnology and pharmaceutical companies. We have placed students in good Ph.D. programs in neuroscience and clinical neuropsychology, in professional schools (medical and veterinary), and in physical therapy and other allied health areas.

Presently, about 40 percent of our graduates go on for further graduate training in neuroscience at the doctorate level. We do expect that these demographics will shift, and many more of our majors may pursue careers that may not directly involve neuroscience research.

We continue to develop the program because we are convinced that neuroscience training at an undergraduate level can provide students with a broad background in many areas of science and equip them with an arsenal of skills that can be generalized to a variety of areas. Students majoring in neuroscience benefit from the interdisciplinary nature of the program. They not only get a healthy dose of a variety of science courses, but they learn how these diverse disciplines can be integrated to address important questions. This experience greatly augments our students' liberal arts education and enhances their ability to adapt to opportunities for further training or employment in many different fields. Some of our graduates have gone on to establish successful careers in business, law, and industry.

The interdisciplinary nature of the program . . . greatly augments our students' liberal arts education and enhances their ability to adapt to opportunities for further training or employment in many different fields.

That many of these students attributed their success to the education they received in our neuroscience program convinced us to pursue formalizing our major, despite the obvious decline in future opportunities for neuroscientists at the Ph.D. level. At the very least, we will continue to offer our program informally or as an emphasis in a more traditional biology, chemistry, or psychology major.

Establishing a neuroscience program at a time when many colleges and universities are "downsizing" may prove to be a daunting task, but the best ammunition we have at this point is an informal program that has been in place for several years and has proven to be very successful. Consequently, we are optimistic about getting our program formally approved by the various curricular committees in the department, college, and university.

Reflections

Although the process that we have gone through at CMU is somewhat arduous and time consuming, we are convinced that it was necessary to prove that our program will be successful before we could offer it formally. This may not be necessary at all mid-sized state universities or smaller colleges, but as it becomes more and more difficult to convince your colleagues of the merits of establishing a new program, it may be very beneficial to obtain some good test data to support your arguments.

Finally, establishing student interest in a program, involving students in a productive research program, and successfully placing students in graduate programs or professions are key ingredients in persuading your colleagues that an undergraduate neuroscience program would be an asset to your total institutional curricular offerings.

A neuroscience major can provide students with additional opportunities besides further neuroscience training at the Ph.D. level. It can greatly augment their liberal arts education and provide them with the interdisciplinary skills that are readily adaptable to a wide variety of areas. With a neuroscience major, students will be able to pursue successful careers in many diverse professions and occupations.

Grant money comes from taxes; taxes come from a lot of folks who don't have much money. Spend that money wisely.

To what degree should my choice of research work be governed by human needs, by social imperatives, and how am I going to justify spending all of my energies on any research that does not bear directly on pressing human problems?

. . . The solution, or rationalization, that I have finally come up with is that it is a perfectly worthwhile way of spending one's life to do your level best to increase human knowledge. It is not necessary nor is it always even desirable to be constrained by possible applicability of what you find to immediate problems. This may sound very peculiar to some young people, but it is a value judgement which I myself have made and which I can live with.

– Frank A. Beach
Biological Psychology, 6th Ed., James W. Kalat. 1998.

Minority Recruitment into Neuroscience

Pamela E. Scott-Johnson
Spelman College

Ensuring a fair representation of minorities in the scientific enterprise, including neuroscience, will be increasingly important in the years ahead. According to the authors of "Workforce 2000," by the Year 2000 white males will account for only 15 percent of the net addition to the U. S. work force. The other 85 percent will be females and males from other racial and ethnic backgrounds.

There are several issues that need to be addressed before we can effectively recruit and train minorities in neuroscience. Some of these issues include the need to understand:
- the current racial barriers in science education
- the value to minority students of mentoring
- the need to provide greater experience and exposure for minority students
- the need for a commitment to the success of all students.

Racial Barriers

We must recognize the racial barriers that have and continue to exist in science education, and recommit ourselves to the ideals of educating all peoples. These barriers include:
- lack of recognition of past and present participation of minorities within the sciences
- erroneous assumptions regarding minorities' capabilities in pursuing and conducting scientific research
- societal and economic barriers that force minorities into careers other than teaching or research.

Mentoring Students

Potential mentors must recognize and acknowledge the barriers for minorities in science education. Those of us responsible for training potential scientists must let go of erroneous assumptions and encourage the active participation of all willing and interested students. We must educate our students—all students—in such a way that they see themselves in the process and see how science relates to them with respect to their culture.

Faculty and administrators must provide . . . solid, consistent, and straightforward advice about how to succeed in the field of neuroscience.

Providing Experience and Exposure

Students must be exposed to and understand how their participation will contribute to sustaining the scientific and technical leadership of the United States. Faculty and administrators must provide apprenticeships, which must include solid, consistent, and straightforward advice about how to succeed in the field of neuroscience. This may be accomplished through basic course work, specific laboratory experiences and research projects in the natural and physiological sciences, informal discussions, and participation in scientific meetings and conferences.

Commit to Student Success

Faculty mentors and administrators must be committed to providing verbal and financial encouragement, and academic experiences and research exposure that will foster minority students' success.

A RESEARCH-ORIENTED PROGRAM IN UNDERGRADUATE NEUROSCIENCE EDUCATION

Julio J. Ramirez

Science education is typically divided into two components: *knowledge* and *experiential*. The lecture portion of science courses is designed to impart the fundamental knowledge that constitutes a scientific discipline. Lectures provide students with the language of the science, its history, the relevant phenomena, and its epistemology. The laboratory portion of a course is typically designed to teach students the experiential component: the scientific method, hypothesis testing, lab techniques, design and analysis.

Echoing the environmentalist's charge to "think globally, act locally," the Department of Psychology at Davidson College has implemented an educational program to enhance our students' experiences in psychology. We asked ourselves: are our students truly learning the science of psychology by taking standard laboratory courses?

The program we designed is Davidson College's attempt to develop a broad-based educational program emphasizing hands-on experience—*interactive education*. In our program, students do not simply replicate prepackaged experiments where the results are a foregone conclusion and easily interpreted. Rather, our program is designed to engage students in innovative and novel experimentation. We want our students to do neuroscience, not simply learn about it.

We want our students to do neuroscience, not simply learn about it.

Background

The College. Davidson College is a highly selective, liberal arts college founded in 1837. The College has a small student body (approximately 1,600 students) and a student-teacher ratio of 12:1.

The Students. The typical Davidson student has a combined SAT score of 1230. Thirty percent of the students come to Davidson from North Carolina, 40 percent come from other states in the Southeast, and the remaining 30 percent come from the rest of the United States and abroad.

The Department. The Department of Psychology consists of eight faculty members representing: Clinical, Developmental, Industrial/Organizational, Animal Learning, Behavioral Neuroscience, Psychometrics, Sensation & Cognition, and Social Psychology. The members of the department are actively involved in research or related scholarly endeavors within their subdisciplines.

The Students Served by the Project. The project we developed is designed to enhance the educational experience of student's interested in behavioral neuroscience: sophomore, junior, and senior level psychology majors, as well as advanced biology students.

Modern psychology takes completely for granted that behavior and neural function are perfectly correlated.... There is no separate soul or life force to stick a finger into the brain now and then and make neural cells do what they would not otherwise... It is quite conceivable that some day the assumption will have to be rejected. But it is important also to see that we have not reached that day yet...One cannot logically be a determinist in physics and chemistry and biology, and a mystic in psychology.

– Donald O. Hebb
Biological Psychology, *6th Ed., James W. Kalat. 1998.*

The Behavioral Neuroscience Program

Our overall plan is best described as a three-tiered program of instruction in behavioral neuroscience, within the department of psychology. This track emphasizes the theory and methodology of neuroscience as it pertains to neural phenomena reflected in behaving organisms. The three areas students receive exposure to are behavior, neuroanatomy, and neurophysiology.

Although students are not required to participate in all three levels of the neuroscience sequence, the first level is a prerequisite for participation in the second and third. Moreover, each advanced level is designed to elaborate on the neuroscience principles and methodologies of the lower levels. The ultimate goal of this three tiered approach is to train our students to think critically and creatively about the research they undertake, while gaining more independence from their instructors as they progress to their senior year.

Behavioral Neuroscience Track—Tier One. The first tier involves a beginning course in Behavioral Neuroscience, including a laboratory component. The maximum enrollment for this class is 15, and the two prerequisites are Introductory Psychology/Biology and Statistics. The book used for several years is *Biological Psychology* by James Kalat. The students find the content readily accessible and the writing enjoyable; the coverage is comprehensive and appropriate for a first course in behavioral neuroscience.

The students are trained in the lab in the fundamental procedures used by biopsychologists to study brainbehavior relationships, namely: research design, animal care, behavioral testing, surgery, and histology. The major emphasis is on the demonstration of structurefunction relationships in the Central Nervous System (CNS).

During a 15-week semester, the students have two assigned group research projects to examine how homeostatic, affective, and/or cognitive functioning are related to particular CNS areas. One project involves a traditional approach to laboratory training, in which the students examine fundamental, well-established principles in neuroscience (for example the role of the substantia nigra in motor behavior).

In the other project, the students are introduced to an area of research that has the potential to yield novel findings. For example, we have recently been investigating the role of the entorhinal cortex in operant behavior. Typically, the data the students collect during this group project serves as pilot data for work advanced student pursue later on. Our experience has been that several students who get particularly excited about the project follow up on their work in the following two levels.

Behavioral Neuroscience Track—Tier Two. The second tier involves upper-division courses that combine a lecture or seminar format with a lab and independent studies on topics of particular interest to certain students. The students enrolled in this sequence examine a current topic in seminar groups of 10 students or work with the instructor on an individual basis. Because of the more complex issues under examination, the undergraduates at this level of training are instructed in the use of more sophisticated experimental methodology as dictated by the topic under examination.

The primary pedagogical objective of Tier Two is to help the student recognize the complex nature of structure-function relationships in the CNS, as well as the obstacles encountered in studies attempting to elucidate these relationships. The readings in the courses typically include a range of more philosophical analyses, in addition to those usually covered in the textbook. Such analyses include in-depth examinations of the assumptions underlying the notion of behavioral function, the use of lesions to localize function, and the importance of multidisciplinary approaches in neuroscience investigations.

The textbooks used for the advanced neuroscience courses include *From Neuron to Brain: A Cellular and Molecular Approach to the Function of the Nervous System* by John Nicholls, Robert Martin, and Bruce Wallace, and *Correlative Neuroanatomy* by Stephen Waxman and Jack DeGroot.

We do not do human dissections in the seminar course on functional neuroanatomy. Students go on weekly field trips to the Carolinas Medical Center, where Dr. Ronald Follmer, an attending physician, takes them on neurology rounds. We also use the three-dimensional animation program *Human Brain Animations* by John Sundsten and Kenneth Kastella to help the students visualize the neuroanatomical pathways.

By the end of the neuroanatomy course, the students develop a particularly keen appreciation for the relationship between brain and behavior. For some students (usually about 3 to 4 a year), these courses become springboards for the highest tier of their education in neuroscience in our program.

Behavioral Neuroscience Track—Tier Three. This, the most advanced tier of the neuroscience track, involves a two-course sequence as a capstone experience for our most motivated and prepared senior students. Under the supervision of professors in neuroscience within the Psychology and Biology Departments, these students read intensively within a specific problem area and design original experiments. They then conduct the analysis and interpret the results. They prepare presentations for the Annual North Carolina Undergraduate Psychology Conference, the Annual National Conference in Undergraduate Research, and the Annual Meeting of the Society for Neuroscience. Students whose research and results are publishable are encouraged to submit their research for publication.

The goal of this capstone experience is to have the student become intimately familiar with the conceptual issues that engage neuroscientists, as well as with the day-to-day business of a neuroscientist.

Support Courses. In addition to the courses that form the core of our behavioral neuroscience track within the Department of Psychology, we recommend that our students take a variety of courses from other disciplines to strengthen and broaden their education in neuroscience. For example, students with an interest in neurobiology might emphasize the biology courses; students with an interest in psychobiology might emphasize the psychology courses.

List of Recommended Support Courses:

- Priniciples of Biology I & II
- Principles of Chemistry I & II
- Introductory Organic Chemistry I & II
- Calculus I & II
- General Physics (one year)
- Animal Behavior
- Biochemistry
- Genetics
- Molecular Biology
- Psychological Research
  - Design & Analysis
  - Sensation & Perception
  - Learning & Cognition
- Medical Ethics
- Philosophy of Psychology

A Feature Common to All Courses. A feature common to all courses in the First and Second Tiers is an extensive writing requirement, and at least half the total points in exams are linked to essays. With the exception of the first course in behavioral neuroscience, students are required to complete at least one 15-20 page research paper in all courses. Midway through the semester, students are required to hand in an annotated bibliography of articles they intend to include in their papers—typically a minimum of 20 references.

A feature common to all courses in the First and Second Tiers is an extensive writing requirement.

The Introductory Behavioral Neuroscience class requires two papers, and two sets of annotated bibliographies based on their research. Students include between 10 and 20 references in these papers. Because this is their first experience with behavioral neuroscience, they are given a lot of guidance in doing library research, choosing articles, writing sections of research reports, and analyzing the data.

Tier Three also emphasizes writing together with analysis, critical thinking, and synthesis. The students are required to prepare an annotated bibliography, which should have, depending on the area of study, between 50 and 70 references. The paper that students prepare generally serves as the introduction to their senior thesis. The Department of Psychology requires that three faculty members serve on a thesis student's committee.

The Evaluation of Our Program

We have used three indices to measure the success of the program:

- The number of students who have appeared as co-authors on presentations at undergraduate or professional meetings.
- The number of students who have pursued a Ph.D. in neuroscience after graduation.
- The number of publications that students have co-authored.

Reflections

We have concluded that a pedagogical model focusing on the student as a *participant in* rather than recipient of neuroscience has dramatically improved the educational program at Davidson College. Our undergraduate students are active in and committed to behavioral neuroscience. Before the end of their senior year, many of them will have truly experienced the academic life of a physiological psychologist.

We focus on four factors to enhance the educational experience of our students:

1) faculty commitment and enthusiasm;
2) faculty development;
3) student-teacher ratio;
4) equipment and facilities.

Faculty Commitment and Enthusiasm. Ultimately, the success of the program depends on the depth of faculty commitment to involving students in the learning enterprise. Teachers must provide a nurturing, supportive environment that encourages students' intellectual curiosity. They must allow their own passion for their discipline to surface in their dealings with their students, particularly when students are feeling less than passionate about neuroscience.

Ultimately, the success of the program depends on the depth of faculty commitment to involving students in the learning enterprise.

Faculty Development. To guarantee that the faculty members are energized while educating young neuroscientists, support for faculty development must be provided:

- The faculty should receive either release time or financial compensation for summer work dedicated to the creation of these interactive educational programs.
- The faculty should receive either release time or summer financial support to improve their own knowledge and skills within their discipline.
- The faculty of a given neuroscience program should regularly discuss how it is progressing and any problems encountered.

In other words, colleges and universities must provide the faculty with a nurturing and supportive environment so that students will receive a first-rate education.

Student-Teacher Ratio. On a campus like ours, maintaining a low student-teacher ratio is critical to the success of the program. Faculty members must give their students a great deal of individual attention; if the classes become too large this becomes practically impossible. The maximum number of students per class in the Behavioral Neuroscience sequence is 15, which may be difficult to accomplish in some institutions. If this is difficult, one strategy may be to use advanced students as teaching assistants.

Equipment and Facilities. Finally, an effective program requires adequate equipment and facilities. The two approaches that we have taken in our Behavioral Neuroscience lab are: 1) begging, borrowing, and building equipment; 2) proposal-writing. To date, our work has been supported by the National Institutes of Health, the National Science Foundation, the North Carolina Board of Science and Technology, The Pew Charitable Trusts, the Howard Hughes Medical Institute, and the Alfred P. Sloan Foundation.

One of the most effective ways to reverse the downward slide of science education is to incorporate *interactive education* into undergraduate curricula. If we are to improve science education at the elementary and high school levels, we must improve the quality of education in our colleges—the source of America's future teachers. If we are to attract students into the sciences, we must improve the quality of education in our colleges and universities—the source of our nation's future scientists.

One of the most effective ways to reverse the downward slide of science education is to incorporate interactive education broadly into the curricula.

A CASE STUDY: THE NEUROSCIENCE CURRICULUM AT MACALESTER COLLEGE

Lin Aanonsen

Strengths and Weaknesses of the Major

Strengths:

- Strong foundation courses in the sciences
- Depth in Neuroscience course offerings
- Broad selection of intermediate level courses
- Research-based curriculum

Weaknesses:

- Many course requirements
- Courses heavily weighted in the natural sciences
- Needs more interdisciplinary neuroscience connections beyond Biology and Psychology

Neuroscience has been a part of the science curriculum at Macalester since the 1970's, and has been a formal major since 1994. In developing the neuroscience curriculum together we reviewed programs from a number of undergraduate institutions, looked at the needs of our students, and examined the strengths of supporting programs at Macalester.

We came up with three major principles as the foundation for the neuroscience major on our campus. The major should:
- be rich in interdisciplinary connections
- prepare students for a number of neuroscience-related career paths
- have a research-based curriculum.

Interdisciplinary Connections

First, in acknowledging the fundamental interdisciplinary nature of neuroscience, we committed ourselves to developing a major that was rich in interdisciplinary connections.

At the most basic level, this interdisciplinary theme is reflected in the introductory course requirements for all majors in biology, chemistry, psychology and mathematics. A variety of required intermediate to upper-level courses more specifically related to neuroscience are truly interdisciplinary. They incorporate principles from the foundation areas of biology, chemistry, psychology and physics (courses include cellular and molecular neuroscience, behavioral neuroscience, neuroanatomy and neuropharmacology).

Finally, the interdisciplinary focus means that students are required to take at least one neuroscience related course outside the natural sciences, such as: Philosophy of Mind, Perception and the Senses, or Introduction to Artificial Intelligence. By having this requirement, our goal is that students (and faculty) will be able to make the natural and broader connections of neuroscience to the humanities, social sciences and computer science.

Finally, the interdisciplinary focus means that students are required to take at least one neurosciencerelated course outside the natural sciences...

Guiding Principle I. Rich Interdisciplinary Connections
- links between biology and psychology
- neuroscience-related courses outside the natural sciences
- developing neuroscience/chemistry labs.

Preparing Students for Neuroscience Careers

Our second guiding principle was to have course requirements for the major that prepare students for a number of neuroscience-related career paths, including: graduate programs in psychology, neuroscience and other biomedically-related fields, medicine, and technical positions requiring no further education.

Preparing student for this diversity of careers was particularly challenging and, as we discovered, is one of the more difficult tasks many institutions are facing in developing neuroscience majors.

In designing the major, we wanted all students to feel that the major was accessible whether they have a particular affinity toward biology, chemistry or psychology. At the same time, we wanted to be sure that the major could be a stepping stone for students who might be bound for graduate or medical school.

The best solution to this variety of issues was to have a curriculum that gave all neuroscience majors a common foundation, with the opportunity to focus their interests through either a cellular/molecular emphasis or an emphasis in psychology. These divergent paths come together again in the students' senior year when they participate in a senior seminar and share their research experiences.

Guiding Principle II. Course Requirements That Prepare Students for a Number of Neuroscience-Related Career Paths

- students choose a cellular/molecular or psychology emphasis depending on career interests

Research-based Curriculum

This final research experience is the culmination of our third principle in developing the major:
the curriculum should be research-based.

In the introductory biology labs (required for neuroscience majors), students pose their own scientific questions, then design, perform, and analyze their experiments. They also share their work with their classmates (orally and in writing). Similar efforts are underway in introductory psychology. These basic courses provide students with a solid foundation in research.

In the introductory biology labs required for neuroscience majors, students pose their own scientific questions, then design, perform, and analyze their experiments.

Some of the intermediate/upper level courses in neuroscience build on this foundation by exposing students to specific disciplinary research tools and by providing an opportunity to do independent research. In addition, students are required to have an in-depth research experience either through a specific upper-level research course, independent study or during the summer. The work is then shared with other neuroscience majors their senior year when they all participate in the senior seminar.

Thus, this final component of the program, the senior seminar, brings the divergent paths of the major back together in a format that enables students to share their experiences, further enhancing the interdisciplinary nature of the major.

Guiding Principle III. Train Students as Scientists—Research-Based Curriculum

- introductory biology and psychology have investigative laboratories
- in cellular/molecular neuroscience (and other intermediate level courses), students learn specific techniques and conduct a research project
- all students must participate in a "major" research project and senior seminar.

Proposing a Neuroscience Major at Berea College

"Berea could function quite well without a neuroscience major," says Megan Morgan-Carr, assistant professor of biology at Berea College. "But we have a few students a year coming in with an interest in the area, and neuroscience is exploding as a career field, so it would benefit our students to offer a degree in neuroscience."

After attending the PKAL workshop on the interdisciplinary nature of neuroscience, Morgan-Carr and Gene Chao (professor of psychology at Berea) realized that specialized neuroscience courses were not needed for a neuroscience major. Together, they developed an interdisciplinary neuroscience major (still under consideration in spring 1998) that fit in to Berea's existing curriculum—needing no new courses or faculty. "Given the fact of limited courses and faculty, and a dedication to the liberal arts, we designed an interdisciplinary major that offers students a strong undergraduate foundation in neuroscience."

Indeed, faculty who are thinking about developing and proposing neuroscience programs must ask some tough questions: Does the program fit in to the institution's overall educational mission? Does the program address real needs that cannot be met by other departments? For a proposal to succeed, administrators, departmental colleagues and faculty from other departments must be convinced of the need for programs. New proposals succeed partly because of their intrinsic merit, but also because of the effective leadership (marketing, lobbying) of those doing the proposing.

Morgan-Carr is aware of the challenges ahead. "As with any change in the status quo, there are sure to be obstacles to overcome in breaking new ground," she admits. "And while we hope the major will be judged on its own merits, it will unavoidably be a test case for the interdisciplinary major concept."

Intellectual questions aside, proposing a new program also raises more practical considerations. "Assuming no new faculty are added, how can we create new degree programs so that curricular and co-curricular 'maintenance' needs are addressed responsibly?" asks Steve Boyce, Provost and Academic Vice President at Berea. "We don't want to overload faculty by simply adding new program responsibilities, asking them to do the work as a generous—but unsustainable—labor of love."

Institutions across the country are becoming more open to the idea of interdisciplinary approaches. For Provost Boyce, much of the appeal of Morgan-Carr and Chao's proposed neuroscience program is its interdisciplinary approach.

Yet, even as he struggles with the answers to the practical issues, Boyce is optimistic. "In the last 20 years, Berea has established few new majors, and none that cut across department lines," he notes. "The neuroscience proposal is particularly intriguing in that it would be the first degree program at Berea that would not have a traditional departmental home.

"Indeed, the proposed major would provide a way for the college to be more responsive to the interests of faculty and students, and to the opportunities and needs that are developing in the world outside academia."

Interdisciplinary programs allow institutions to use resources in creative and efficient ways. More importantly, such programs open the frontier between disciplines for exploration, providing space for academics to reframe old questions and ask new questions.

In fact, Morgan-Carr believes the real purpose of the proposed major is to respond to changes in how scientists view, and do, science.

"I want to illustrate to students and colleagues that science is losing its disciplinary boundaries," says Morgan-Carr. "The more we learn about molecular biology, the more biologists must understand chemistry. As chemistry becomes increasing sub-molecular, chemists must understand physics. Neuroscience is a truly multidisciplinary or cross-disciplinary science, and can serve as an ideal example of the merging of the sciences."

A Brief Glimpse at Wellesley College

The Department of Biological Sciences at Wellesley College receives a lot of support for teaching, both financially and administratively. "We are fortunate to have a state-of-the-art facility, reasonable budgets and professional instructors for the laboratories," notes Carol Ann Paul, Senior Instructor in Biological Sciences. "Equipment has been acquired with the help of NSF/ILI and Hughes grants. We are able to teach students about the most recent techniques in neuroscience without too much worry about equipment or cost."

To add more rigor, the department is in the process of trying to change from a Psychobiology to a Neuroscience major. One way to make the major more rigorous would be to add required courses, such as chemistry. "Most of the science/pre-med students are already taking more chemistry, physics and math than is required, so such a change would make the requirements more uniform," said Paul.

Paul sees the following elements as essential components of "effective" labs:

- *Labs stretch over several weeks rather than a new lab every week.* Changing topics every weeks is confusing for students and does not allow for consolidation of ideas or an understanding of techniques and the principles behind them.

- *There is some component in which students design their own experiment.* This does not mean the student designs the entire lab, but rather designs part of a protocol to answer a specific question.

- *The lab produces a lot of data so students can begin to feel comfortable with data manipulation, graphing, statistics, and so on.* Mountains of data can overwhelm students. Learning to use spreadsheets, graphics and statistics software helps students feel more comfortable with data. It is especially exciting when they begin to transfer between applications to check out different aspects of the data.

- *There is an entire lab period set aside for discussion of data and report planning and writing.* Often lab time is reserved solely for "wet lab" activities, and students are expected to do all the data analysis and interpretation on their own. Unfortunately, this is exactly when they need assistance. And it is often where the connections between data and process are made—where the "Eureka" moment happens.

Paul believes following these elements will help students become more immersed in a topic, and will give them a more complete understanding of laboratory work. As she says, "the approach gives students memorable experiences and helps them learn valuable skills that can be applied to other projects and tasks."

INTRODUCTORY NEUROSCIENCE AT OBERLIN COLLEGE

Dennison Smith

Background

Oberlin's neuroscience program is one of the oldest and largest undergraduate neuroscience programs in the country. Neuroscience was first offered formally as a major in our curriculum in 1972 (the "Psychobiology major" introduced in 1972 emphasized work in behavioral neuroscience). Three other schools, Amherst, Wesleyan, and Colgate, also introduced neuroscience curriculums in 1972. By 1986 the major had been incorporated into our current neuroscience program, which now better represents the full range of interests associated with the neurosciences.

Oberlin's neuroscience program has two majors: neuroscience and biopsychology. The neuroscience major is designed for students interested in the biological, molecular, and chemical aspects of neuroscience. The biopsychology major is designed for students interested in the biological aspects of behavior. Both majors require, as a minimum, courses in introductory biology, chemistry, and statistics, as well as an introductory neuroscience course with lab and additional upper level work in neuroscience. We want all majors to have broad backgrounds in the sciences, as well as course work in neuroscience.

The curricula of the two majors differ in the amount of biology and chemistry required (neuroscience requires more), and the extent to which course work in psychology is required. Biopsychology requires four courses in psychology; neuroscience requires none. However, the two curricula are similar in that both emphasize:

- laboratory work;
- writing;
- reading and analyzing the primary literature.

Laboratory and research experiences are central in both majors, and in the way science is taught at Oberlin. All of our introductory and upper-level courses in neuroscience have labs that introduce students to modern laboratory approaches presented in an experimental context.

Many courses offer opportunities to read, analyze, and critique the original research of others.

Laboratory experiences are almost always designed so students have to collect and interpret data to answer questions posed by instructors. Other laboratories include sections in which students work in teams to develop experiments conducted using the techniques learned earlier in the course.

We also try to get our students to participate in independent research experiences. Because we can't accommodate all of our students in our Honors program or independent research courses, we encourage them to seek out research experiences at other institutions, either during the summer or during our winterterm in January. Nearly 80% of our students graduate with some intensive research experience.

The development of effective communication and analytic skills is emphasized in the program. Most courses require term papers; laboratory work is written up and presented formally. Many courses offer opportunities to read, analyze, and critique the original research of others.

There are two reasons our neuroscience program has two majors. First, it was clear that students would need too many courses if we provided only a single major in neuroscience, especially if they were to be properly prepared for work in the many different graduate programs in neuroscience (from molecular to behavioral). Accordingly, we designed one major, neuroscience, that would give students extensive course work in biology, chemistry and neuroscience. This approach prepares them for graduate work in biology or in medical science (medical school, pharmacology, immunology, molecular and cellular biology, neuroanatomy, physiology, etc.). The other major, biopsychology, requires less biology and chemistry, but requires students to take extensive work in psychology as well neuroscience.

The second reason for offering two majors is that the majors represent real differences in student interests. Some of our students relate best to the biological and chemical aspects of neuroscience, while others are drawn to the behavioral aspects.

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Introductory Neuroscience Courses

For the same reasons we offer two majors, we offer two versions of introductory neuroscience. One of the courses, *Introduction to Neuroscience*, is designed for students with interests and backgrounds in biology and chemistry. The other introductory course, *Human Neurobiology*, is designed for students interested in behavior and psychology.

In many ways these courses are identical. Both offer students a solid background in the basic subdisciplines of neuroscience (neuroanatomy, neurophysiology, neuropharmacology, cell and molecular neurobiology), which students need if they are to continue their education in this field. Introductory behavioral neuroscience courses typically do not include the extensive introduction to basic neuroscience that is included in both our courses. This is particularly true of behavioral neuroscience courses offered in psychology departments. Students taking neuroscience in psychology typically do not have extensive course work in biology and chemistry. As a result, behavioral neuroscience courses often minimize the amount of basic neuroscience students must learn, instead emphasizing the behavioral and applied issues in neuroscience relevant to the student course work in psychology.

At Oberlin we provide all majors with a strong background in basic neuroscience. We can do this because they have had at least one general biology course and because the courses we offered are for four credit hours. The increase in course credit over the standard three-credit course enabled us to cover introductory neuroscience, as well as to discuss the behavioral and applied elements of neuroscience.

Some psychologists may not believe so much neuroscience is needed. However, we believe that neuroscience is central to education in psychology and will become increasingly important. One indication is the impending change in the profession of clinical psychology, where clinicians may have the authority to prescribe drugs to their patients. Clearly, clinicians will need backgrounds in fields like neuroscience and pharmacology.

The question of how the brain organizes its subsystems to produce integrated behavior is perhaps the most challenging that can be posed.

– Patricia S. Goldman-Rakic
Biological Psychology, 6th Ed., James W. Kalat. 1998.

The two 4-credit introductory neuroscience courses on our campus differ in the material introduced beyond basic neuroscience. The *Human Neurobiology* course tends to place stronger emphasis on behavior, cognitive processes and applied issues. The *Introduction to Neuroscience* course is taught like a traditional course in neurobiology (emphasizing sensory and motor system physiology, endocrinology, developmental neurobiology, the physiology of eating, drinking and sleep, and synaptic plasticity). The *Human Neurobiology* course is also different in that students learn about neuroscience in a context that focuses on human behavior, clinical issues, and treatment. Instructors who have taught courses of this type to undergraduate psychology students know that a clinical/applied emphasis is invaluable to capture student interest.

Could we teach just one kind of neu-roscience course and not two? Probably, but we have been very successful using two qualitatively different approaches. Our success is at least in part indicated by the combined enrollment in the two courses, which is now over 150 students per year.

A Course for Nonmajors

While we can claim some success interesting Oberlin students in the neurosciences, our curriculum may be failing an entire segment of our student body. The two courses we offer are pre-professional. While they are excellent introductions to neuroscience for biology, chemistry, and psychology majors, they don't do a very good job meeting the needs of non-science majors.

We view neuroscience as having strong connections to many areas of the liberal arts curriculum not only Biology, Psychology, Chemistry, Physics, and Computer Science, but also Linguistics, Education, Anthropology, Philosophy, Public Policy, Women's Studies, etc. We are planning to offer a neuroscience course for students with little or no background in science. The course's main goal will be to illustrate the personal relevance of neuroscience and its connection to the wider liberal arts curriculum.

After some preliminary introduction to basic neuroscience, the proposed course would begin with a discussion of the mind, exploring the way neuroscientists, cognitive scientists, computer scientists and philosophers have attempted to explain perception, memory, consciousness and other cognitive processes. This section of the course would attempt to provide the context that underlies Ramon y Cajal's comment: "As long as the brain is a mystery, the universe, the reflection of the structure of the brain, will also be a mystery."

The second part of the course would deal with biology of individual differences in an attempt to illustrate that we all are, in part, a function of our unique biology. Physiological as well as evolutionary approaches to this issue would be included.

The last part of the course would center on the common diseases of the brain, and with the hopes for treating these conditions. The goal here would be to give students a better under-standing of these diseases and make them appreciative of the efforts of basic research scientists and clinicians. Issues regarding the use of animals in research would be discussed during this part of the course.

The common feature of the three topic areas is that they appeal to personal issues relevant to self-understanding, and as such should appeal to most students regardless of their scientific background. Moreover, most of the general issues involved can be understood without an extensive background in chemistry or biology.

Of course, the proposed course is only one solution for how neuroscience might be presented to nonscientists. I hope others will think of ways to accomplish this same goal. As it is, neuroscientists have not always done all they could to make neuroscience accessible to the lay public. It's something we need to do, particularly if neuroscientists expect public support for their efforts in the future.

[N]euroscientists have not always done all they could to make neuroscience accessible to the lay public. It's something we need to do, particularly if neuroscientists expect public support for their efforts in the future.

Approximately 75 junior and senior majors are currently enrolled in the program. If past patterns apply, 50-75 percent of the students will eventually pursue careers in medicine or academic careers (neuroscience, psychology, biology, etc.) involving teaching and research.

Our neuroscience majors are clearly organized as pre-professional courses of study, and therefore may not be models for all institutions. But we believe that the reasons why we offer two neuroscience majors apply to all institutions thinking about majors or programs in neuroscience.

A Brief Glimpse at Neurobiology and Behavior at Cornell University

"Our major provides the basic requirements in biology and then an intensive focus on neurobiology," says Bruce Johnson, Senior Research Associate in the Department of Neurobiology and Behavior at Cornell University. "The students may not be as broadly trained as some other biology majors, but they get the basics and benefit from an in-depth specialty.

"Cornell has research faculty also engaged in teaching, who bring an exciting and dynamic research perspective to the basic sciences," Johnson notes. "We also have an excellent staff of committed lecturers to teach larger laboratory and specialty courses not taught by research faculty. The students get the best of both worlds."

A unique offering is the department's "Crawdad Project" is a three-year project (1996-98) funded by the National Science Foundation. The project promotes the use of invertebrates in undergraduate physiology and neuroscience courses. The project has four parts:

- Production of laboratory manuals for students and instructors.
- Production of an instructional CD-ROM with video clips.
- Workshops for college teachers, held each of the three years.
- Ongoing support for instructors via the internet.

The laboratory exercises are inexpensive, easy to prepare, and straightforward. They use simple invertebrate preparations to illustrate fundamental processes of all nervous systems. The use of commercially cultured invertebrates (crayfish and snails) reduces cost and administrative overhead, and minimizes potential ethical and environmental objections of students. The workshops give teachers hands-on experience with invertebrate preparations so they can incorporate them into their classes, and allow for ongoing testing and evaluation of instructional materials.

MAINTAINING A RESEARCH-BASED NEUROSCIENCE PROGRAM

Leonard E. Jarrard

Maintaining an active, productive neuroscience research program at an undergraduate institution (small colleges and large universities) can be challenging. Below, I describe the issues we had maintaining a research-based neuroscience program at Washington and Lee University, a 4-year undergraduate college. Specifically, I address:

- the importance of institutional support;
- issues in establishing a research program at an undergraduate institution;
- the need to maintain contact with investigators at other institutions; and
- the importance of obtaining and maintaining outside support.

The Importance of Institutional Support

It is extremely important to have administrative support to maintain an active research-based neuroscience program. Without the encouragement and support of the administration, it is difficult for faculty to keep up with teaching, advising, and committee duties (scheduled, pressing commitments) while finding enough time to do the research.

The institutional benefits of science faculty maintaining active, visible research programs include:

- helping recruit topnotch students and faculty;
- promoting favorable publicity;
- improving the overall quality of the institution; and
- obtaining grants for research, equipment, and buildings.

Faculty members need good communication with the administrators who make decisions regarding teaching and other assignments. Administrators need to be informed about what faculty are doing, what they hope to do, and how important research activities are to the institution.

Establishing a Research Program at an Undergraduate Institution

Focus of Research. The focus of research at an undergraduate institution must be more limited than at larger research universities. There is a tendency, especially among new faculty members directly out of graduate school or postdoctoral training, to choose research topics that require specialized equipment and/or the involvement of others (graduate students, postdoctoral fellows, technicians). New faculty members must be realistic about what they can do.

There is also a real problem in the degree to which students are permitted to design and carry out research projects of their choosing, as opposed to limiting the projects to topics more in line with a faculty research.

Involvement of Undergraduate vs. Graduate Students vs. Postdoctoral Fellows. The advantages and/or disadvantages of having undergraduates involved in research compared to graduate students or postdoctoral fellows is a critical consideration. Undergraduate students seem more open to suggestions, and are more likely to try things that may not "pay off."

Undergraduate students seem more open to suggestions, and are more likely to try things that may not "pay off."

On the other hand, graduate students and postdocs are usually more dedicated, committed, and concerned that the results be significant and (hopefully) publishable. Having postdocs in a laboratory working side by side with undergraduate students can be very exciting. This kind of situation provides the undergraduate with a model who is knowledgeable and committed to research in the field.

Maintaining Contact with Investigators at Other Institutions

A problem often encountered at undergraduate institutions is the lack of contact with colleagues who do similar research investigators with whom one can interact to discuss ideas and problems. To avoid becoming isolated from the research area, faculty should attend professional meetings and workshops, take advantage of sabbatical leaves and other opportunities to meet others working in the same area.

Obtaining and Maintaining Outside Support

Most undergraduate institutions need to obtain outside support to establish and maintain an active, productive research program. Research grants provide funds for equipment, supplies, and student support, but can also fund technical assistance. There are many demands on faculty time; a technician can help keep research going and provide continuity. To maintain a funded research program, researchers need to demonstrate progress by presenting papers at professional meetings and by publishing papers in refereed journals.

Rewards

There are many problems associated with establishing and maintaining an active research program at an undergraduate institution, but there are also many rewards. One reward for science research faculty is the opportunity to be "doing science" and making original contributions to the field.

Thus, by having an active, productive laboratory, faculty members are not only able to maintain their own intellectual vitality and make contributions to the field, but they are also able to contribute in important ways to the development of students at a crucial point in their career.

Another reward is the opportunity to help students during a crucial period of their intellectual development—the three or four years of college. It is rewarding (and flattering) to have an outstanding student continue in one's area of expertise. But equally important to the individual and to society is having a student decide, from experience, that research (and maybe even science) is not a career path they want to follow. At the very least these students have an understanding of what research involves and (hopefully) the overall importance of science to society.

Thus, by having an active, productive laboratory, faculty members are not only able to maintain their own intellectual vitality and make contributions to the field, but they are also able to contribute in important ways to the development of students at crucial points in their careers.

A question to the Nobel laureates: If Albert Einstein were a young man just starting his career today, what field would he choose to work in?

"Einstein was not only a genius, he was a smart guy," replied one of the scientists. "I think he would choose a field of science with the greatest potential for dramatic advances in his lifetime, as he did at the start of the twentieth century by choosing physics."

"Which field would that be today?"

"Molecular biology."

"Ah," said a voice from one of the tables, "neuroscience. The brain."

Even the physicists and chemists and doctors in the room—pioneers in their chosen disciplines of some of the most exciting advances of our time—had to agree.

– David Mahoney & Richard Restak, M.D. The Longevity Strategy: How to Live to 100 Using the Brain—Body Connection.

Neuroscience at Lafayette College

Lafayette College's Behavioral Neuroscience major has just had its first birthday. According to Wendy Hill, Associate Professor and Chair of the Behavioral Neuroscience Program, the young major is off to a strong start.

"The major is only one-year old, and we already have nearly 20 majors. It is gratifying that so many students are eager and motivated to take on the challenge of this new program," she says. "The enthusiastic response of the students has contributed to our own excitement about the future of the program."

For Hill, it is the interdisciplinary nature of the major that attracts students. "They say it gives them the best of the many worlds of science. Because they are gaining a strong science background they feel they are prepared for a variety of career paths—medicine and health-related professions, pharmacology, and clinical psychology. They like this diversity."

But the interdisciplinary nature of the major—combining courses in biology, chemistry, and psychology—has created conflicts that Hill and her colleagues have needed to resolve. "It required perseverance mixed with a good dose of optimism and good will to get through some of the more difficult boundary disputes," Hill notes. "As the major grows, and we expect it will, these interdepartmental issues will continue to occupy our discussions."

In spite of the (not unexpected) inter-departmental turf wars, the Behavioral Neuroscience program at Lafayette has benefited from strong institutional support. "The administration recognizes the importance of the neuroscience major because it is a significant area of science, and because they value interdisciplinary approaches," Hill says.

"The neuroscience program exemplifies our commitment to student-centered learning," notes Jeff Bader, Associate Provost and Director of Research Services at Lafayette. "Students taking courses in neuroscience are immediately engaged in their learning through investigative laboratories and ample opportunities for undergraduate research."

The psychology department, part of the college's Natural Sciences Division, emphasizes a strong scientific approach to the study of behavior and mental processes; this emphasis (more than half the 16 courses required for the major have a lab component) was an important part of the success of the program.

"Given the emphasis on the scientific approach, my departmental colleagues were very much in favor of creating a Behavioral Neuroscience major," says Hill. "It fits perfectly into the educational philosophy of the department. In fact, all of my departmental colleagues, even those whose area of expertise falls outside the realm of neuroscience, were very supportive of the major."

Looking to the future, Hill believes it will be critical for the major to keep current with new findings and technical advances in neuroscience. "We want to ensure that our students are well prepared for the latest careers and the best graduate programs in neuroscience. Faculty will need to continue to keep up-to-date with the techniques and methods of inquiry being used by behavioral neuroscientists, and we will need up-to-date facilities and equipment as well."

Lafayette's reliance on the teacher-scholar model may help keep faculty current, but Hill cautions against a complacent attitude: "it certainly is not something we just can sit back and relax about." She also notes that keeping up with the latest technical advances will have a budgetary impact. Equipment and instrumentation can be very expensive and will demand careful use of funds.

Hill sees the neuroscience curriculum becoming more integrated within psychology and across other divisions at the college—not just the natural sciences—in the coming years. In particular, she would like to see connections made with the Engineering Division (especially electrical and chemical engineering) and the Humanities Division (such as through a Philosophy of Mind course).

"I see the Behavioral Neuroscience major taking advantage of what is unique about Lafayette. We offer strong programs in the liberal arts, sciences, and engineering. How wonderful it would be to create a major that truly bridges the different divisions. I can think of no other discipline that so readily offers such a possibility as does Behavioral Neuroscience."

UNDERGRADUATE EDUCATION IN THE NEUROSCIENCES: FOUR BLUEPRINTS[1]

Julio J. Ramirez, Lin Aanonsen, Gary Dunbar, Wendy Hill, Carol Ann Paul, Dennison Smith, and all Workshop Participants

Introduction

By virtue of its interdisciplinary nature, neuroscience is poised to serve as a model discipline, illustrating the importance of broad-based education in the humanities and the sciences. The achievement of synthetic and integrative thinking, a paramount objective of undergraduate education, is precisely the type of thinking that serves as the linchpin of neuroscientific work. The fundamental questions that neuroscience addresses can be properly addressed only by collaborative efforts of specialists in fields as diverse as computational neuroscience and philosophy. Moreover, as the field matures, it is becoming more evident that an appropriately educated neuroscientist must be fluent with the methodological and philosophical approaches of a number of scientific and humanistic disciplines.

Because questions about knowledge, the mind, and human nature are major questions common to many fields, there are rich possibilities for neuroscience to be a significant player in interdisciplinary education. There are a number of ways that neuroscience may become part of a college curriculum. At many schools, neuroscience may make its most important contribution to the curriculum as part of an interdisciplinary minor or concentration; other institutions may be able to implement a major or create a "track" in a psychology or biology program.

Recognizing the great diversity of institutions that may be interested in developing neuroscience programs, participants agreed that the curricula proposed should be flexible, allowing institutions to create programs that speak to their academic strengths and resources. The flexibility of the proposed curricula outlined below is reflected in the term *blueprint*. We assume they will provide a direction for program development, and incorporate a notion of adaptability to the needs and resources of a specific institution.

The four blueprints proposed:

- **Blueprint I:** neuroscience nested within a department of biology;
- **Blueprint II:** neuroscience nested within a department of psychology;
- **Blueprint III:** a neuroscience concentration/minor;
- **Blueprint IV:** a neuroscience major.

[1]This section quotes material appearing in: Julio Ramirez, "Undergraduate Neuroscience Education: A Model for Interdisciplinary Study," *The Neuroscientist*, 1997, Vol. 3, pp. 166-168.

Blueprint I: Neuroscience Nested in Biology

This major should fulfill the distribution requirements of a "regular" biology major (providing a foundation in all areas of biology from the molecular and cellular through systems to ecology and evolution). In addition, it should give students a solid foundation in neuroscience, including an introduction to neuroscience. Chemistry should also be required to support the major; students headed to graduate school should take one year of organic chemistry, in addition to physics and mathematics.

The neuroscience major nested in biology should:

- *Expose students to the process of neuroscience through a research-based curriculum.* This should include "doing" research, reading and discussing primary articles from the literature and writing about their work in a journal style format. Where possible, students should spend at least one semester doing independent research. Laboratories accompanying courses should be "investigative," encouraging students to design part of an experiment and collect novel data. Labs should extend over a period of weeks culminating in a journal style lab report.
- *Incorporate problem-based learning using case studies to illustrate issues in neuroscience, with students applying their knowledge by suggesting solutions.* Wherever possible, other instructors should include neuroscience examples in nonneuroscience courses such as statistics, physiology, genetics and cell biology.

Suggested courses include:

Required Courses to Provide a Broad Foundation in Biology

- Introductory Biology (2 semesters)
- Intermediate Level
- Genetics or Molecular Biology
- Cell Biology or Biochemistry
- Physiology or Anatomy
- Botany or Ecology or Evolution

Required Courses with a Neuroscience Focus

Introductory Level
- Introduction to Psychology
- Introduction to Neuroscience

Intermediate Level
- Behavioral Neuroscience or Physiological Psychology
- Neuroethology or Animal Behavior

Advanced Level
- One upper level course in a special field of Neuroscience
- Independent research with a writing requirement
- Seminar writing course using primary literature

Suitable Complementary Upper Level Courses
- Immunology
- Developmental Biology
- Endocrinology
- Advanced Psychology

Required Supporting Courses

- General Chemistry (2 semesters)
- Organic Chemistry (1 semester)

Recommended Supporting Courses

- Organic Chemistry (2nd semester)
- Physics (2 semesters)
- Statistics or Calculus

Other Suggested Electives

- Philosophy of Mind and Brain
- Bioethics
- Computer Science
- Artificial Intelligence

Blueprint II: Neuroscience Nested in Psychology

The curriculum designed for a neuroscience program nested in a Psychology department was structured into three levels: introductory, intermediate, and upper. Each level has its own goals. Courses chosen to meet these goals are sometimes very specific (an experimental design and statistics course), and at other times more generally accomplished by choosing from a list of alternatives. A number of collateral courses in other departments should be included so that the interdisciplinary nature of neuroscience is fulfilled.

Introductory Level

The goals for this first level are to attract interest and introduce students to the scope and terminology of the field of neuroscience. By taking the introductory course, the students become familiar with the mode of inquiry used by neuroscientists. A number of introductory courses would meet these goals. A student taking any one of the following three courses would meet the introductory goals of a neuroscience program nested within psychology.

Courses for Introductory Level [only 1 required]

- **Introduction to Neuroscience with lab:** crosslisted in the Psychology and the Biology department.
- **Introduction to Psychology:** the biological basis of behavior should be covered. If necessary, use guest lectures in this survey course.
- **General Education Course—Brain and Behavior:** If your college has an interdisciplinary course that explores neuroscience, it could also be used as an introduction to the major.

Intermediate Level

The goal here is to involve students more deeply in the content of neuroscience, and to give them a greater appreciation of the research perspectives of neuroscientists. Students should become facile with designing research, analyzing data, and carrying out physiological procedures important to the discipline. In addition, they should learn how to write in American Psychological Association (APA) format and to conduct library research.

Courses for Intermediate Level

At least two courses would be required in this level, Experimental Psychology [statistics and research methods covered] and Behavioral Neuroscience. The Behavioral Neuroscience course should have an active, hands-on lab associated with it. If your school does not offer a Behavioral Neuroscience course, or a similar course with a different rubric, then a series of courses might be required to cover subjects listed below.

- Experimental Psychology [required]
- Behavioral Neuroscience [required]

If you do offer Behavioral Neuroscience, the following topics might guide the content of your course:

Topics to Include:

- Cellular Mechanisms
- Neuroanatomy
- Psychopharmacology
- Sensory & Motor Systems
- Learning & Memory
- Cognitive Psychology
- Homeostatic Mechanisms
- Emotions
- Clinical Psychology

Upper Level

At the upper level the goal is to help the student become an independent scholar. Courses should include reading and analyzing primary literature, projects should further develop laboratory skills, and intimate course settings should emphasize student- directed learning. Students should be expected to articulate research findings in both written and oral formats. Capstone courses, such as a special topics seminar in behavioral neuroscience, senior thesis, or an internship, should be provided to give the student greater depth into behavioral neuroscience. To give the student a greater breadth of knowledge in the areas of psychology that are most likely to be influenced by a neuroscience perspective, other psychology courses should be taken.

Courses for Upper Level

Capstone courses—provide greater depth into behavioral neuroscience:

- Advanced Seminar
- Senior Thesis
- Honors Research
- Practicum, or Internship

Psychology courses—provide continuing breadth of the field:

- Abnormal
- Sensation and Perception
- Motivation and Emotion
- Health Psychology
- History and Theory
- Animal Learning
- Comparative
- Developmental
- Cognition
- Collateral Courses

Courses in other departments can contribute to a strong foundation in the sciences and are integral to the interdisciplinary nature of neuroscience:

- General Biology
- General Physics
- Biochemistry
- Neurobiology/Cell Biology
- Calculus
- Animal Behavior/Evolution
- Human Physiology
- Computer Science/Modeling
- General Chemistry with Lab
- Philosophy of Mind/Medical
- Ethics
- Organic Chemistry

Blueprint III: Neuroscience as a Minor

The major interdisciplinary themes that unite neuroscience with other parts of the curriculum are shared questions about the nature of mind and thought. These questions are most explicitly addressed in three fields: neuroscience, psychology, and philosophy. We therefore outlined a blueprint for a neuroscience minor as follows: an introductory course in neuroscience (either Neuroscience or Behavioral Neuroscience), a course in philosophy (Philosophy of Mind), and a course in the social/behavioral sciences (Cognition). With these as the core, scientific, humanistic, and social science views were given equal representation. A student taking the core would have a unique opportunity to compare and evaluate the approaches and perspectives of these different disciplines.

It could be that a course in computer science (Artificial Intelligence) should be part of the core. While there was little or no objection to this idea, the majority felt the barriers here are that such a course was either less likely to be available at most institutions, or might require an extensive background in computer science.

One important feature of this minor is that it should contain either an introductory or capstone course, or both. Introductory and capstone courses were envisioned to be ones in which the nature of mind and thought might be considered, and interdisciplinary connections examined. The capstone course was seen as an excellent way to tie together the material presented in the three core courses, but the introductory course would reach more students (although its coverage of the area would be less sophisticated). A cross-disciplinary team of teachers could teach both, and an individual with broad training could also teach the course.

This minor could include a wide range of supplementary courses that would enrich its content, based on local circumstances and strengths (how minors are defined, for example). Examples of courses that might be included were courses such as:

- Introductory Psychology
- Introductory Biology
- Philosophy of Science
- Linguistics
- Genetics
- Molecular Biology
- Physical Anthropology
- Abnormal Psychology
- Computer Science/Artificial
- Intelligence
- Chemistry
- Sociobiology
- Drugs and Behavior
- Sensation and Perception
- Health Psychology
- Human Sexuality
- Education and Learning
- Disabilities

In addition, courses in neuroscience, biology and psychology with a connection to the core theme of the minor could be included.

Blueprint IV: Neuroscience as a Major

There are at least as many ideas about what constitutes an ideal neuroscience major as there are neuroscientists. We focused on the goals of a neuroscience major, attempting to devise an outline that would best address these goals. As a starting point, participants assumed that a neuroscience major is aimed primarily at students who will seek further training in graduate school (in neuroscience or some related area), medical school, dental school, or veterinary school. Our ideal neuroscience major needed a strong general science core and a highly flexible structure. This approach would depend on strong advising to help the student construct a coherent program that best fit his or her specific goals.

Participants disagreed about the number and types of general science core courses that should be included in a neuroscience major. Some argued for a broad-based approach that included physics and calculus requirements, while others thought the core biological and chemistry courses would offer students more flexibility in choosing electives. Again, good advising is a key element here. Students who aspire to medical school or biotechnology areas may be better served by taking the physics and calculus classes. Students with different goals, such as further training in clinical neuropsychology, may benefit by taking more electives in psychology.

The idea of providing separate tracks, such as a cellular/molecular track and a behavioral neuroscience track, appealed to many. But there was general consensus that such an approach would not be critical (and for many smaller schools would be impractical). This is particularly true if students are given good advice in their course selection. Most participants thought the ideal neuroscience major would balance the cellular/molecular approach and the behavioral neuroscience approach.

The following courses are those that all participants agreed were vital for a good neuroscience major:

- Introductory Level
- Introductory Biology (2 semesters)
- General Chemistry (1-2 semesters)
- Introductory Psychology (1 semester).
- Intermediate Level
- Organic Chemistry (1-2 semesters)
- Cellular/molecular Neuroscience (1 semester)
- Behavioral Neuroscience (1 semester).
- Biochemistry (1 semester)
- Advanced Level
- Research-oriented courses (2 semesters; e.g. independent study or summer research)
- Special topics course or seminar (1 semester)

There was disagreement whether Physics and Calculus should be required. The addition of these courses to a neuroscience major should be a function of how many courses outside the major a student is required to take, and what the student's ultimate goals are. It was generally agreed that four to six electives should be taken in consultation with the student's advisor, with an attempt at balancing the cellular/molecular orientation with a behavioral orientation.

Several electives were suggested for the major, including:

- Developmental Neurobiology
- Neuroanatomy
- Immunology
- Cognition
- Perception
- Biochemistry
- Genetics
- Molecular Biology
- Health Psychology
- Learning and Memory
- Pharmacology
- Neural Networks/Modeling
- Ethology/Comparative Psychology

How many interesting facts fail to be converted into fertile discoveries because their first observers regard them as natural and ordinary things!...It is strange to see how the populace, which nourishes its imagination with tales of witches or saints, mysterious events and extraordinary occurrences, disdains the world around it as commonplace, monotonous and prosaic, without suspecting that at bottom it is all secret, mystery, and marvel.

– Santiago Ramon y Cajal Biological Psychology, 6th Ed., James W. Kalat. 1998.

The Overarching Objectives of a Neuroscience Education

An examination of the four blueprints reveals overarching objectives that educators developing neuroscience programs should consider. The educational objectives should be embedded in a laboratory-rich, inquiry-based academic curriculum. Resources available to institutions interested in neuroscience education vary. Therefore, the blueprints are designed to enable institutions to speak to their academic strengths, while being firmly established on a solid pedagogical and scientific base.

The principal objectives of an undergraduate education in neuroscience include:

Promoting critical and integrative thinking. Students need to learn the cornerstone of the scientific enterprise—thinking critically about the phenomena to which they are being introduced, about the arguments and principles they are studying, about the relationships among hypotheses, methods employed in scientific investigations, and the consequent interpretations of the data.

The nature of interdisciplinary sciences such as Neuroscience also demands that students cross the socalled boundaries separating the sciences. They need to recognize how the different levels of analysis crossing disciplinary borders can inform our efforts to understand natural phenomena.

Developing communication skills orally and in writing. Students are often under the mistaken impression that scientists conduct their work in laboratories in the bowels of science buildings and rarely interact with other human beings. Of course, Hollywood hasn't helped us dispel that image. Therefore, we must make every effort to engage students in writing projects and in making oral presentations of their projects at every level of their education. It is important to encourage them to discuss scientific issues among themselves and with their instructors. They may in fact learn more from one another than they do from us!

Illustrating the interdependent nature of the sciences. Because neuroscience is interdisciplinary, a background in the sciences and the humanities is necessary for undergraduate students to be properly prepared for an education in neuroscience. Although the courses can be tailored to the students' specific interests in neuroscience, a broad exposure to the sciences will prepare them for the study of neuroscience and reinforce the notion that the sciences are interconnected.

Imparting an understanding of the resources and limitations of the scientific enterprise regarding society's biomedical, economic, and ethical challenges. Most citizens recognize the importance of the biomedical sciences in defeating illness. But it is also clear that many do not recognize the complexity of the investigative work required in this endeavor. Many citizens do not know how science is conducted and do not have reasonable expectations about the pace of scientific research. Nor do they know what constitutes a valid scientific approach. In a democracy, citizens are key to the health and well being of the scientific enterprise. It is incumbent upon the scientific establishment to educate citizens and welcome them into our scientific deliberations.

The proposed educational experience can be divided into three levels, with each designed to satisfy a set of pedagogical goals. The higher levels build on the educational accomplishments of the lower levels and should continue to nurture the budding interest of students. Participants enthusiastically endorsed investigate laboratory experiences as opposed to pre-packaged laboratory exercises, and incorporating throughout the neuroscience curriculum a problem-based learning approach that relies on case studies.

Introductory Level

At the introductory level, the goal is to expose students to the history, language, scientific questions, fundamental principles, and methodology of neuroscience. Recognizing that this introductory course or course sequence may be the only experience students have with an interdisciplinary science, educators must make the integrative nature of neuroscience explicit.

Intermediate Level

The goal of the intermediate level is to have the students explore the content of neuroscience more deeply by introducing them to primary literature, engaging them more actively in research design and analysis, and having them present their research activities orally and in writing. Students should be capable of conducting library research and writing a scientific report of their experiments according to scientific journal standards. By the end of their education at the intermediate level, students should be capable of using basic laboratory techniques necessary to conduct neuroscience research in their area of interest.

Advanced Level

Finally, the goal of the advanced level is to help students become independent investigators. Greater emphasis should now be placed on having students read and critically assess the primary literature, design and analyze experiments that may yield novel findings, and develop more sophisticated laboratory skills. By this point in their education, undergraduate students should be able to articulate how the various disciplines contributing to neuroscience work together to address issues of fundamental importance to science and society. A capstone experience in the senior year, such as a research project, thesis, or special topics seminar, would help to promote such critical and integrative thinking.

Conclusion

There is probably no ideal neuroscience curriculum universally acceptable to all neuroscientists. Nevertheless, the courses incorporated into these Blueprints reflect what many of the conference participants considered as essential elements of a well-balanced, comprehensive neuroscience education. Collectively, the requirements for our neuroscience curricula ensure a broad-based education in the sciences and humanities appropriate for an undergraduate education, while at the same time providing a solid background in the fundamentals of neuroscience. However, it must be emphasized that a good program should provide adequate flexibility, and that good advising is an essential ingredient in making the neuroscience major an ideal one for each individual student.

The goal of educating young minds to prepare them for graduate and medical school is laudable. It is perhaps equally important to think about the pivotal role that neuroscience education can play in the general education of present-day college students. Our scientific and technological world continues to become more complex, and requires an educated citizenry to make informed decisions.

An education involving exposure to Neuroscience promotes the higher cognitive skills desirable in a well-educated public: analytic, integrative, and synthetic thinking. Neuroscience educators have an important role to play in preparing citizens to be full participants in the national dialogue that directly impacts their private lives as well as the scientific, ethical, and economic life of the nation.

To know the brain...is equivalent to ascertaining the material course of thought and will, to discovering the intimate history of life in its perpetual duel with external forces; a history summarized, and in a way engraved, in the defensive neuronal coordinations of the reflex, of instinct and of the association of ideas.

– Santiago Ramon y Cajal Recollections of My Life.

WORKSHOP PARTICIPANTS

Baldwin-Wallace College
Mark B. Gorman
Stephen D. Hilliard
G. Andrew Mickley
Carolyn F. Rogers

Bates College
John E. Kelsey
Nancy Kleckner
Cheryl McCormick

Berea College
Eugene T. Chao
Megan Morgan-Carr

Bowdoin College
Patsy S. Dickinson
Alfred Fuchs

The College of Wooster
James W. Jenness

Connecticut College
Marylynn Fallon
Cheryl A. Frye

DePauw University
B. L. Garrett
Robert Stark

Farleigh Dickinson University
Daniel Calcagnetti
Ronald Carlin

Franklin & Marshall College
Linda E. Muske
Charles N. Stewart

Gettysburg College
Kazuo Hiraizumi
Stephen M. Siviy

Hollins College
Bonnie Bowers
Harriet Gray
George Ledger

Indiana University of Pennsylvania
Dan Boone
Andrew C. Browe
Gary Patton

King's College
Joan Coffin
David Glick
William Shergalis

La Salle University
Gerald P. H. Ballough

Lafayette College
Dan Bauer
Wendy L. Hill
Curtis M. Loer

Lake Forest College
Robert B. Glassman

Trinity College
Priscilla Kehoe

University of Illinois at Chicago
Steve Kelso

Wake Forest University
Julie Cole
Wayne Silver

Washington and Lee University
W. Lad Sessions
Jeanine S. Stewart

Washington College
Michael Kerchner
Rick Locker
Kathleen Verville

Wheaton College
Kathleen Morgan

Project Kaleidoscope Staff:

Jeanne L. Narum
Director

Christina E. Hackmann
Executive Officer

Adrienne P. McHargue
Communications Officer/
Internet Coordinator

Diane M. Pimble
Assistant to the Director

David R. Narum
Writer

FROM THE DIRECTOR

What works has been the theme of PKAL since 1989, believing that it is more important to think about solutions than problems. Documenting successes in the work of transforming undergraduate programs in science and mathematics is much easier now than it was a decade ago. Programs like those described in this PKAL Occasional Paper demonstrate how careful and creative planning (together with some visionary thinking and much hard work) are beginning to change the learning environment for students.

There are many lessons to be learned from reading this PKAL Occasional Paper on Neuroscience.

If you are involved with neuroscience programs (or wish to be), the stories and blueprints will suggest approaches that might be adapted for your campus. Those outside the community of neuroscientists will gain a sense of the passion that drives the work of reform. It becomes clear also how successful reforms at the local level must be tied to broader concerns: that as the practice of science changes and becomes more interdisciplinary, so must the learning of science change. On these pages you will find some very practical advice on the politics of reform: generating student interest, taking small initial steps, building the search for external support into the agenda for change. The bottom line for all these stories, however, is a commitment to get students doing science as scientists do science–from the point of laboratory explorations and experiments to the communicating of the results that emerge from those explorations and experimentations.

Just as researchers share new insights and research results to further the advancement of knowledge, we believe that communicating and connecting is a key to reform of the learning environment. The more that is shared about what works and what does not work (identifying the right questions, understanding the changing context, reorienting institutional and departmental policies and structures, etc.), the more students and society will benefit from our efforts over the long-term.

This PKAL Occasional Paper is one of a series of PKAL publications designed to foster such conversations. We invite your thoughts about the future of undergraduate neuroscience in particular, and also about the larger undertaking of shaping the future of undergraduate programs in science, mathematics, engineering and technology education.

Jeanne L. Narum, Director
Project Kaleidoscope

ABOUT PROJECT KALEIDOSCOPE

From the beginning, Project Kaleidoscope (PKAL) has taken a kaleidoscopic approach to the work of transforming undergraduate education in mathematics and the various fields of science. This approach means that persons with a wide range of expertise and experience are brought to the table as questions of reform are discussed, and new programs developed and evaluated. Having faculty, deans, presidents and other senior administrators come to an agreement about goals for student learning, and about approaches to faculty and curricular development to achieve those goals is a key aim of all PKAL activities.

An operating premise of PKAL is that quality undergraduate SME&T education derives from faculty members who are intellectually vigorous, up-to-date in their fields, and experienced with research on learning and new pedagogies. We believe also that significant reform requires an institutional culture that rewards the considerable effort that productive change requires, one in which faculty across the campus collaborate, and in which institutional commitment is tangible. Finally, believing that significant reform cannot take place in isolation, PKAL encourages and supports connections within the undergraduate community.

For nearly a decade, PKAL has sponsored workshops and developed materials distributed in both print and electronic form that provide academic communities:

- information about promising new ideas about effective pedagogies and teaching technologies
- acquaintance with discovery-based learning experiences with documented success
- insights into the process and politics of reform
- connections to others who share their commitment to transforming undergraduate SME&T.

Over 600 colleges and universities, large and small, in all parts of the country have been involved with PKAL; institutional teams come together at workshops to wrestle with critical questions in regard to reform and have returned to their home campus to broaden the discussion and encourage informed action.

The challenge, of course, is to support the work of individuals and institutions so that their efforts succeed over the long-term. This suggests that continuing to provide a forum for the discussion and exchange of ideas, insights, and materials about *best practices* must be at the center of PKAL's endeavors. Thus, a new three-year series of workshops is now underway. However, this series, building on the structure and process of Phase II workshops, will address more directly some current critical themes. From the curricular perspective these will include integrating research and education, ensuring the success of all students, incorporating new technologies and new research on learning. From the institutional perspective, themes to be addressed include changes in policies and practices in regard to faculty roles and rewards, as well as budgets and finance. Attention to facilities planning will also be very prominent in all PKAL activities. The most visible new emphasis for PKAL in Phase III will be the expansion of the PKAL Web Site (http://www.pkal.org). Our goal is to make this Web Site a most useful resource. We invite you to join us there.

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Project Kaleidoscope
1730 Rhode Island Ave, N.W. ~ Suite 803
Washington, D.C. 20036

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