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APS undergraduate brainstorming summit report

Robert G. Carroll,¹ Marsha L. Matyas,² Anne E. Atwater,³ Van Doze,⁴ Richard Faircloth,⁵ Patricia Finkenstadt,⁶ Barbara Goodman,⁷ Erik J. Henriksen,³ Barbara Horwitz,⁸ Robin Looft-Wilson,⁹ Bob Madsen,¹⁰ Javanika Mody,⁵ Nancy Pelaez,¹¹ and Thomas A. Pressley¹²

¹Department of Physiology, East Carolina University, Greenville, North Carolina; ²American Physiological Society, Bethesda, Maryland; ³Department of Physiology, College of Medicine, University of Arizona, Tucson, Arizona; ⁴Department of Pharmacology, Physiology, and Therapeutics, University of North Dakota School of Medicine and Health Sciences, Grand Forks, North Dakota; ⁵Anne Arundel Community College, Arnold, Maryland; ⁶Phoenix College, Phoenix, Arizona; ⁷Division of Basic Biomedical Sciences, School of Medicine, University of South Dakota, Vermillion, South Dakota; ⁸Division of Biological Sciences, University of California, Davis, California; ⁹Department of Kinesiology, College of William & Mary, Williamsburg, Virginia; ¹⁰Chief Dull Knife College, Lame Deer, Montana; ¹¹Department of Biological Sciences, California State University, Fullerton, California; and ¹²Department of Physiology, Texas Tech University Health Sciences Center, Lubbock, Texas

IN 2004, the Education Committee was charged with seeking additional strategies to increase the exposure of undergraduate students to physiology studies and careers. Following a reaffirmation of this charge in the 2006 strategic plan, the American Physiological Society (APS) hosted an undergraduate brainstorming summit in late September of 2006.

Walter B. Cannon was a strong proponent of using the “wisdom of the body” to elucidate physiological function. For example, when attempting to pick up a glass of water, the sensory and planning areas of the cortex are activated before the motor cortex. It is essential to establish where in three-dimensional space the hand is at this moment, before deciding what combination of muscles needs to be activated to move your hand toward the glass. This article addresses the starting point for the planning process: Where are we now?

The 10 programs described represent a variety of undergraduate environments where physiology is taught. The diversity of settings in which physiology is currently taught provides many opportunities to enhance undergraduate exposure to physiology, as a biological science, as a biomedical science, and, most importantly, as an experimental science.

Programs described in this report are grouped as follows: community colleges, undergraduate colleges, and universities. A separate heading describes approaches that encourage undergraduate research (independent of the type of institution that houses them), as early exposure to research plays a key role in the development of scientists.

Community Colleges

The mission of community colleges is to provide a high-quality, low-cost education for members of the community. These institutions provide physiology instruction to a large number of students, particularly underrepresented minorities. Only a few of these institutions provide research opportunities, and the ones that do may provide models for attracting the best and brightest of that student population to pursue graduate study in physiology.

Physiology training for allied health professions. ANNE ARUNDEL COMMUNITY COLLEGE. Anne Arundel Community College (AACC) in Arnold, MD, teaches physiology to over 1,200 students each year, the majority of which enroll in a combined Anatomy and Physiology course in the Allied Health program. The main campus is ~3 miles north of Annapolis, MD; 20 miles south of Baltimore, MD; and 40 miles east of Washington, DC.

Established in 1961, AACC is a fully accredited, public, 2-yr institution offering credit programs leading to an associate (AA) degree, certificate, or letter of recognition. Students may prepare for transfer to a 4-yr institution or for an immediate career degree. AACC also offers a postbaccalaureate certification in the Physician’s Assistant Program, extensive lifelong learning opportunities, and noncredit continuing education to those seeking career training or retraining for individuals working to boost basic skills or pursuing new areas of interest.

There are three levels of anatomy and physiology courses geared to meet the needs of general education, allied health, and biology students. These courses are taught by eight full-time anatomy and physiology teachers of the total of 15 faculty members in the Biology Department and by 10 adjuncts in the same area in any one semester. Most Anatomy and Physiology courses are taught in an integrated lecture/laboratory format with a maximum of 24 students in a class. There are five laboratories dedicated to anatomy and physiology instruction scattered among three buildings at two locations.

Preparing disadvantaged students for allied health careers. PHOENIX COLLEGE. Phoenix College in Phoenix, AZ, is situated in an urban area and provides physiology instruction for over 1,600 students per year. The program seeks to address the shortage of nurses and other Allied Health practitioners in the community. Consequently, the majority of students enrolled in physiology-based courses at Phoenix College are pursuing a career in the Allied Health field.

Many students enrolled at Phoenix College are first-generation college students and/or considered disadvantaged or “at risk.” The Raising Expectations for Achievement and Community Service Through Higher Education program at Phoenix College is a federally funded program specifically designed to assist first-generation and low-income students with their transition into college.

Address for reprint requests and other correspondence: R. G. Carroll, Dept. of Physiology, East Carolina Univ., Brody Medical Sciences Bldg., 600 Moye Blvd., Greenville, NC 27834 (E-mail: carrollr@ecu.edu).

Phoenix College has several learning centers that offer tutoring, academic advisement, and other services. The Math/Science Center brings together services, resources, and programs to support Phoenix College students enrolled in math, science, and healthcare classes. Through its activities and events, the center provides opportunities for students who share similar academic interests to advance their education and become part of a learning community. The Learning Center is responsible for providing quality support services to the students at Phoenix College so they can develop the academic skills essential to successful learning.

Physiology instruction at a rural tribal college. CHIEF DULL KNIFE COLLEGE. Chief Dull Knife College (CDKC) is a small tribally controlled community college located on the Northern Cheyenne Reservation in southeastern Montana. CDKC's current enrollment is 185 students (110 full time and 75 part time). CDKC has 11 full-time faculty members, which includes 3 full-time science teachers and 3 full-time math teachers. The science students are usually women (75%), the average age is 26 yrs, and their math levels range from 8th to 10th grade. The science curriculum is designed to give students the basic courses they need to transfer to a 4-yr institution.

The college offers an AA degree in General Studies with options in Allied Health, Biology/Pre-Medicine, Agriculture, and Pre-Engineering. Transfer courses include the following: Biology of Cells and Organisms, Nursing and General Chemistry, Microbiology, Anatomy and Physiology, Pre-Calculus, and College Calculus. There are currently 25–30 students majoring in science, with the largest identified group of science majors in Allied Health.

The only formal instruction in physiology is in the Anatomy and Physiology course.

Biology/Pre-Medicine majors typically do not take Anatomy and Physiology but are required to take the 100-level biology sequence (Biology of Organisms and Cells), 1 yr of General Chemistry, Statistics, and Pre-Calculus.

Undergraduate Colleges

Undergraduate colleges generally provide a smaller educational setting where students have increased access to faculty. The graduate programs at colleges, if present at all, are small and often extend only to the Masters Degree. The lack of graduate programs limits the number of students who can serve as teaching assistants. Some colleges emphasize research as well as teaching, whereas others are primarily teaching institutions.

Physiology instruction at a liberal arts college. COLLEGE OF WILLIAM & MARY. The College of William & Mary, in Williamsburg, VA, is a primarily undergraduate liberal arts university. Physiology courses are taught in three different departments. The Department of Kinesiology teaches general physiology courses as well as specialized physiology courses including "Cardiovascular Physiology," "Exercise Physiology," "Physiology of Aging," "Environmental Human Physiology," "Cellular and Molecular Effects of Exercise," and "Diseases of Obesity and Inactivity." A new course has been added this year to expose freshman to the discipline, a freshman seminar entitled "The Physiology of Lance Armstrong." The physiology courses in this department are focused on human physi-

ology and cover aspects of physiological function from the systemic to the cellular/molecular.

The Department of Biology teaches physiology courses that have a more comparative approach, with a strong emphasis on the cellular aspects of physiology. More specialized courses on physiological topics include the following: "Vertebrate Biology," "General Endocrinology," "Neurobiology," "Neurophysiology," "Molecular Cell Biology," "Advanced Cell Biology," "Immunology," "Gene Regulation," and "Developmental Biology." Plant physiology is also taught in this department through the courses "Integrative Biology of Plants" and "Plant Development and Physiology."

The Department of Applied Science also teaches courses in the biophysical aspects of physiology, including the following: "Applied Cellular Neuroscience," "Applied Systems Neuroscience," "Networks in the Brain and Biology," and "Cellular Biophysics and Modeling." This department does not have an undergraduate program, but these courses are open to undergraduates, and undergraduates represent the majority of students that enroll in these courses.

Undergraduates who major in Kinesiology, Biology, or Neuroscience (an interdisciplinary major taught by the Departments of Biology, Psychology, Kinesiology, Applied Science, and Chemistry) are required to take one or more courses in physiology. In 2005, the combined number of declared majors in these programs was ~444 students, which represents ~16% of the juniors and seniors. While a small proportion of the upper-division undergraduates at the College of William & Mary are required to take physiology courses, the instruction in these majors typically involves in-depth training in one or more areas of physiology.

Universities

Universities provide physiology instruction in a large campus setting, with institutional emphasis on graduate programs as well as undergraduate programs. Generally, research demands place a significant burden on faculty instructional time, and students enrolled in graduate programs often make significant contributions to the instructional programs.

Physiology instruction at a state university. CALIFORNIA STATE UNIVERSITY-FULLERTON. At California State University-Fullerton, CA, undergraduate physiology is taught in the Department of Biological Sciences with several courses for biology majors as well as service courses for kinesiology, the teaching credential program, nursing, and the health professions program. Advanced exercise physiology courses are taught in the Kinesiology Department. The mammalian physiology course for biology majors also serves students in a popular postbaccalaureate program aimed at preparing students for admission to medical, dental, pharmacy, optometry, veterinary, physical therapy, physician assistant, and other health-related professions.

A separate Human Physiology course, with an optional laboratory, is taught for nonbiology majors. Laboratories emphasize functional aspects of each organ system through experimentation. The goal is to integrate learning of physiological concepts with use of the scientific method. Success in the course requires practice of experimental design, higher-order data analysis, use of a scientific laboratory notebook, use of primary literature in the interpretation of results, presentation

of work in a scientific symposium format, and the scientific give and take of in-depth feedback from peers.

Liberal studies or general education courses may also cover some physiology. Our general education course for K–6 teachers teaches human physiology for ~5 wk of the course. Reaching these teachers is an important aspect of increasing public awareness of physiology as a discipline, as one of every eight K–12 students in the United States attends school in California.

Undergraduate Physiology Major

Undergraduate physiology major through a college of medicine. UNIVERSITY OF ARIZONA. The Physiology Undergraduate Major at the University of Arizona is a comprehensive program of instruction providing undergraduate students with lecture courses and laboratories covering all of the major physiological systems of the body. This program is located administratively in the Department of Physiology and is the only undergraduate major currently offered through the College of Medicine. Graduates of the program receive a Bachelor of Science in Health Sciences degree with a major in Physiology. The major curriculum includes courses required for application and admission to schools of medicine, dentistry, pharmacy, physical therapy, occupational therapy, and physician assistant and effectively prepares the student for graduate training in the biological sciences.

The success of this integrative science major over the last 16 yr has been astounding, with huge increases in the number of freshman declaring prephysiology as their major. When physiology majors (upper division) are included with prephysiology majors (lower division), the number of undergraduate students currently enrolled in our program exceeds 1,000 students, up from 469 students in 2000–2001 and 872 students in 2005–2006. For the 2006–2007 academic year, prephysiology is the second largest major declared by incoming freshman at the University of Arizona, representing 5.6% of all majors declared by this class. Interestingly, majors in two other programs in the top five overall (Pre-Pharmacy and Pre-Nursing) must take the two-semester human anatomy and physiology course offered by the Department of Physiology.

There are several required core courses for all Physiology majors. The two-semester Human Anatomy and Physiology course is normally taken in the fall and spring of the student's sophomore year and provides the foundation for further, more-focused study of the various physiological systems of the body. This is also a service course for several science majors, such as Biology and Nutritional Sciences, and pre-professional majors, such as Pre-Pharmacy, Pre-Nursing, Pre-Health Education, and Pre-Physical Education. These courses enroll over 1000 students annually.

The Department of Physiology offers numerous elective courses that, in many cases, take advantage of the specific academic interests and research expertise of the faculty. Physiology majors must take a minimum of three of these three-unit lecture or laboratory courses. In addition, these majors can take one of several colloquia, which are two-unit discussion-based courses in which interactions among students and with faculty members are promoted in small-group settings. Topics include environmental physiology, metabolic regulation, reproductive

endocrinology, muscle biology, inflammation and disease, and others (Fig. 1).

UNIVERSITY OF CALIFORNIA-DAVIS. The University of California in Davis, CA, offers both physiology education and opportunities for student research involvement. Undergraduate physiology courses are taught through the Section of Neurobiology, Physiology, and Behavior (NPB) in the College of Biological Sciences. These courses serve NPB majors (~450 students in 2005–2006) and Exercise Biology (EXB) majors (~200 students in 2005–2006), both of which are overseen by the NPB, as well as students in other life science majors in the College of Biological Sciences, the College of Agricultural and Environmental Sciences, and the College of Letters and Sciences.

The NPB offers ~30 undergraduate physiology courses with most, but not all, being offered at least once per year. In addition, the EXB offers four undergraduate physiology courses. These courses include 1) lower-division lecture/podium courses designed for nonmajors and meeting the general education requirement for the campus, 2) lower-division seminar courses, 3) upper-division lecture/podium courses required for the NPB and/or EXB majors, 4) upper-division courses that meet the laboratory requirement for the NPB and/or EXB majors, and 5) 19 other upper-division courses that meet the elective requirement for the NPB major. In addition, undergraduates can work with any of the more than 70 University of California-Davis faculty members in the Physiology Graduate Program for academic credit with approval of the NPB Master Advisor. Graduation with Honors in Biological Sciences majors (including the NPB and EXB majors) requires a senior thesis, as does initiation into Phi Sigma (the National Honor Society in Biological Sciences). This goal entices many NPB students to engage in research.

UNIVERSITY OF SOUTH DAKOTA. The University of South Dakota has traditional undergraduate physiology courses but also provides research opportunities for students throughout the state. Undergraduate courses are offered through the Department of Biology in the College of Arts and Sciences. Over 1,000 students take physiology courses, most as part of a Biology major with either 1) a physiology and structure specialization or 2) an ecology and evolution specialization. Frequently, honor students and premedicine students who are not majoring in biology will only take Biology 163 and 164. This inquiry-

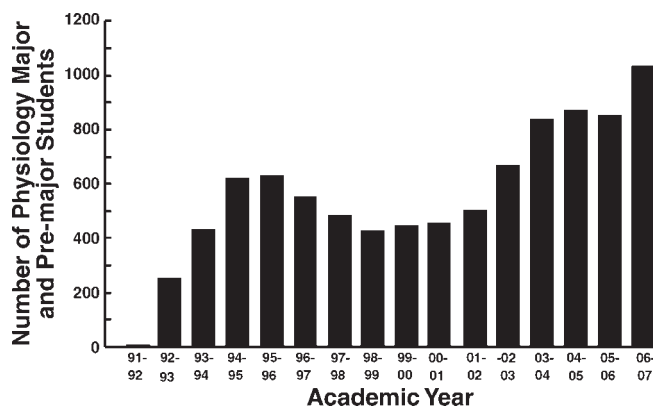


Fig. 1. Time course of enrollment of Pre-Physiology and Physiology majors at the University of Arizona from 1991 to 2007. From 1991 to 2004, the physiology undergraduate major (or its predecessors) was administratively located in the School of Health Professions. Since 2005, the major has been located in the College of Medicine.

based course (described in Ref. 1) incorporates various small-group and active-learning strategies during the lecture period, and the laboratories offer hands-on experience with the physiology that students are learning that week.

Programs to Encourage Undergraduate Research

There were numerous programs and approaches to encourage undergraduate participation in research activities, some collaborative and others self-contained. Below are descriptions of innovative programs along with potential funding models.

Independent programs. COLLEGE OF WILLIAM & MARY. Research experience for undergraduates is also a main element of the educational mission at The College of William and Mary. Many students perform research in faculty laboratories for 1 yr or more, which is facilitated by significant course credit for research projects and the Senior Honors Thesis program. Student research in the biological sciences, including physiology, is also supported by a grant from the Howard Hughes Medical Institute Undergraduate Biological Sciences Education Program, on a competitive basis. Additional student research support also comes from the College Honors Program, and the college provides free summer housing for students engaged in research. Students in all sciences have the opportunity to present their research at the annual Undergraduate Science Research Symposium, and the students in the Neuroscience program can also present at the annual Neuroscience Symposium.

UNIVERSITY OF ARIZONA. At the University of Arizona, students have the opportunity to earn credit for the completion of independent study projects and directed research projects in the laboratories of world-class investigators in the Department of Physiology and elsewhere at the College of Medicine or on main campus. In 2005–2006, ~200 physiology majors were enrolled in the Honors Program and 80% of the junior and senior honors students completed research projects with university faculty. Many of our majors complete their undergraduate careers as coauthors on peer-reviewed papers published in high-visibility research journals.

The undergraduate physiology major represents a successful model for how undergraduates at a *research I* university can be effectively educated in the fundamental concepts governing the function of the major physiological systems in humans while preparing these students for success in applying for positions in postbaccalaureate programs in health care and graduate school. The most serious challenges facing this program are 1) limitations in adequately funding this large and expanding undergraduate academic program in a College of Medicine (whose primary mission is the education of medical students) and 2) continuing to devote sufficient faculty time to teaching this increasing number of undergraduates in the face of expanding responsibilities in medical student and graduate student education. However, the department feels strongly that this type of comprehensive physiology undergraduate major is critical to successfully train the next generation of physiologists.

UNIVERSITY OF CALIFORNIA-DAVIS. Specific activities at the University of California-Davis are designed to increase the exposure of undergraduates to physiology and to involve students in physiological research. The NPB Club is a student group that meets once a month for social and informational events. The latter include informal discussions with faculty members about

their research, tours of laboratories, career options, etc. Club members meet with incoming freshman and transfer students to talk about NPB courses as well as club activities. Outstanding NPB seniors serve as discussion leaders in NPB 10, an introduction to human physiology for nonscience majors, as well as laboratory assistants in NPB 101L, a required systemic physiology laboratory course for NPB majors. Involving seniors in these capacities enhances their understanding of physiology as well as providing students taking these courses with peer role models.

Majors in NPB as well as other biological sciences are strongly encouraged by peer advisors, staff advisors, and faculty advisors to participate in research activities for academic credit. The College of Biological Sciences has a directory of faculty members who are willing to take undergraduates into their laboratory. This directory also provides a brief summary of the faculty members' ongoing projects.

President's Undergraduate Fellowships are available to help support the research of undergraduates across the campus. In addition, the NPB Chair provides undergraduates with partial support to attend a national meeting at which the student is presenting his/her research.

An Undergraduate Research Conference is held annually on campus and provides a very positive venue for students to present their research (either orally or as posters). The Chancellor, the Provost, and a number of deans and other administrators attend this conference and interact with students as they present their research. NPB majors demonstrate physiological principles on Picnic Day, the annual Open House for the campus. Picnic Day is entirely student run and is designed to showcase the diverse achievements of University of California-Davis students, staff, and faculty. NPB students organize and "man" displays/demonstrations for the public.

TEXAS TECH UNIVERSITY HEALTH SCIENCES CENTER. The Summer Accelerated Biomedical Research (SABR) program was developed by the Recruitment Committee of the Graduate School of Biomedical Sciences at Texas Tech University Health Sciences Center in 1998. This program identifies talented students in the early stages of their training and provides them with a productive research experience in the hope that they would consider careers as scientists. The program is intended for undergraduates in Biological Science degree programs and has attracted interns from all over the United States as well as from overseas. As a recruitment tool, the SABR program has been successful, with over 30% of the interns returning to Texas Tech as employees or students in one of our professional degree programs. The SABR program represents a model that is in use in many institutions and is easily adapted to suit local needs.

A good match between a trainee and the research laboratory is critical to the success of the program. Information about the SABR program is available on the web (<http://www.ttuhscc.edu/gsbbs/sabr/>), and students can download an application form. Selection of SABR interns from the pool of applicants is competitive, with an evaluation based on undergraduate courses and grades, a confidential letter of reference, and a statement of the student's interests and future goals. Faculty mentors are volunteers from the basic science departments who are interested in undergraduate research and the potential recruitment of talented students. The trainees are true contrib-

utors to the research, and they often appear as authors on abstracts and published papers.

To enable an intern to focus exclusively on the program, s/he receives financial support during the 10 wk in the laboratory. The \$3,800 stipend is shared between the Graduate School for Biomedical Sciences and the individual mentors, typically in a 50:50 split. For the graduate school, this represents a budget of about \$20,000. For the mentors, the costs are usually covered by extramural research grants or internal development funds. On occasion, we have also been successful in obtaining support from local and regional granting agencies.

Although the research experience is the most important component of the SABR program, there are also significant social and academic activities. With more than a dozen students each summer, we have a critical mass that produces a sense of community, and we encourage interaction and networking with events such as ice cream socials. The interns also participate in weekly research seminars presented by graduate students known for their excellent communication skills. These students introduce SABR trainees to areas of research outside those of the host laboratory and also provide outstanding role models. Workshops covering presentation skills, job hunting, and applications to professional school are conducted as well. The SABR seminars are designed as casual, nonintimidating experiences that encourage the lively exchange of questions and answers.

The conclusion of the SABR program is a symposium in which each intern presents their work. This is an opportunity for the intern to bring together the various aspects of the research experience, including the background, hypothesis or question being addressed, experimental approach, evaluation of the results, and conclusions to be drawn. It also encourages the development of communication skills. Because interns usually practice these presentations many times in front of their mentor and laboratory colleagues, they learn to receive and act on constructive criticism. As part of the audience during other presentations, they also have the chance to offer criticism in the same constructive spirit. These symposia are inevitably well attended, and they prove to be both a highlight of the SABR program and a rewarding way to conclude the summer.

Collaborative programs. CHIEF DULL KNIFE COLLEGE. CDKC has two long-term research projects that are collaborative projects with The University of Montana. The first research project was initiated in 1998 and investigates thermoregulation in honey bee colonies. This research has supported nine undergraduate students and has been supported by The University of Montana's Bridges to the Baccalaureate Program [National Institutes of Health (NIH)], APS's Explorations in Biomedicine Program (NIH), and CDKC's Research Initiative for Scientific Enhancement (RISE) Grant (NIH). Undergraduates have presented posters on this research at four scientific meetings (including 2 presentations at Experimental Biology meetings, supported by APS-National Institute of Diabetes and Digestive and Kidney Diseases Minority Travel Fellowships).

The second research project was initiated in 2006 and involves environmental microbiology research on the Nyack Microbial Observatory (just south of Glacier National Park). As part of this research, CDKC is developing a molecular microbiology laboratory. When this laboratory is completed, CDKC will be able to culture and characterize river bed bacteria and to identify bacterial species using PCR. This

research is currently supporting four undergraduate students and is supported by The University of Montana's Research Experience for Undergraduates program (National Science Foundation), The University of Montana's Bridges to the Baccalaureate Program (NIH), and CDKC's RISE Grant (NIH).

The college has participated in two short-term National Aeronautics and Space Administration (NASA)-supported student research programs through NASA's Reduced Gravity Student Flight Opportunities program. Through this program, teams of students design experiments that fly on NASA's "Vomit Comet" at The Johnson Space Center. The research involves teams of CDKC students, Montana State University engineering students, and 3rd–8th grade students on the Northern Cheyenne Reservation. In 2000, students flew an experiment on alfalfa leafcutting bee flight behavior in microgravity ("The Bee Gs"), and, in 2003, they flew an experiment on baking soda and vinegar reactions in microgravity ("The Fizz Kids"). These projects involved 9 CDKC students and 80 3rd–8th grade students.

CDKC international research is supported through a United States Department of Agriculture Challenge Grant and through a CDKC Tribal Colleges and Universities Program (TCUP) Grant (TCUP-NSF). Through this program, CDKC students travel to Mali, West Africa, to research the effectiveness of integrated pest management strategies delivered by Peace Corps Volunteers to Malian farmers. Students spend 10–12 days in Mali working with Malian agricultural researchers, Malian farmers, and Peace Corps Volunteers. Ten CDKC students have traveled to Mali as participants in this program (2003, 2005, 2006, and 2007).

UNIVERSITY OF SOUTH DAKOTA. The University of South Dakota also partners with predominantly undergraduate institutions to provide research opportunities for students across the state through the Biomedical Research Infrastructure Network (BRIN) program. The NIH's National Center for Research Resources (NCRR) funds Institutional Development Award programs, the Idea Networks of Biomedical Research Excellence (INBRE) in 23 states (and Puerto Rico), in which the aggregate success rate for applications to NIH has historically been low. INBRE requires partnerships between the lead research-intensive institutions and predominantly undergraduate institutions to enhance research opportunities for both faculty and students at the undergraduate institutions. The University of South Dakota BRIN program currently has partnerships with one state institution, four private institutions, and two tribal colleges throughout the state. The partnerships provide research core facilities in proteomics and genomics at the lead institution, expanded library science databases for all partners, release time and/or summer salaries for faculty members at the predominantly undergraduate institutions, equipment, supplies, and travel money for faculty and students at predominantly undergraduate institutions, funding for a summer (or academic year) research program for undergraduates of the predominantly undergraduate institution either at their home institution or affiliated with the lead institution, faculty development opportunities, etc. The partnerships with tribal colleges help support science and research there based on their needs. If a tribal college has a research faculty member, the same research support (library, staffing, equipment, supplies, travel, and student researchers) is available. If the tribal college does not have a research faculty member, financial support to hire more

science teaching faculty members and to purchase better and more equipment and supplies for the teaching laboratories is provided. One of the goals of INBRE is to encourage collaborations between faculty members at research-intensive institutions and predominantly undergraduate institutions; to date, three such interinstitutional collaborations have resulted from the University of South Dakota's network.

Another goal of INBRE is to entice students from predominantly undergraduate institutions into considering careers in biomedical research. In addition to the summer undergraduate research experience supported by the grant, at the end of the summer, a convocation for all undergraduate fellows of the predominantly undergraduate institutions is hosted by the graduate faculty of the Division of Basic Biomedical Sciences at the lead institution for them to be further introduced to health and research careers. During the convocation, the undergraduate fellows are honored at a reception while they present posters about their summer research experiences. Some of the former fellows are in graduate programs in the sciences, some are in medical school, some are working in research laboratories while applying to graduate or medical school, etc. One interesting aspect of the "pipeline" approach that has been noted is that more students of the predominantly undergraduate institutions who initially were straight premedical students are now saying that they see their careers including research or they are applying to MD/PhD programs.

UNIVERSITY OF NORTH DAKOTA. The University of North Dakota (UND) also has built institutional networks to promote research. The university was founded in 1883 by the Dakota Territorial Assembly and is located in Grand Forks, ND, a college town of 50,000 on the border separating North Dakota and Minnesota. It has a liberal arts foundation accompanied by a variety of professional and specialized programs. UND has the only law school and medical school in the state and is a national leader in rural health, aerospace studies, energy research, and educational programs for American Indians. The race/ethnicity makeup of students is as follows: 1.0% African-American, 1.1% Latino-American, 1.6% Asian-American, 2.7% international, and 3.0% American Indian. UND serves 388 American Indian students and offers a number of supportive programs, such as the Indians into Medicine (INMED) program.

UND is a participant in the North Dakota INBRE, which is supported by the NCCR. Goals of this program include enhancing biomedical research capacity at the predominantly undergraduate institutions within the state (see also the University of South Dakota INBRE) as well as increasing the number of tribal college students transitioning to 4-yr science programs. An Outreach Core is designed to link the five North Dakota tribal colleges and the North Dakota Association of Tribal Colleges to the UND INBRE program to empower tribal colleges to strengthen their introductory science curricula and to increase their students' exposure to information about biomedical graduate programs and research careers.

Undergraduate physiology education at UND is taught through the Department of Pharmacology, Physiology, and Therapeutics within the School of Medicine and Health Sciences as well as the Department of Biology in the College of Arts and Sciences and the Department of Physical Education and Exercise Science in the College of Education and Human Development. The majority of UND's physiology courses are

graduate level, with undergraduates having the option to enroll; however, few undergraduates actually take these courses.

Currently, there are at least four new undergraduate educational activities in development at UND, which are designed to increase the exposure of undergraduate students to neurophysiology as well as to encourage students to consider careers in physiology. The unique nature of these approaches is that they either 1) integrate hands-on research and teaching for undergraduates or 2) integrate undergraduate education and K-12 outreach.

Since 2001, 22 undergraduates participated in the Undergraduate Research Experiences in Neurophysiology Using Peer-Teaching program, including 17 women, of whom 4 were American Indian students from tribal colleges in North Dakota. These students have given 33 presentations at local/regional conferences. Of the eight students who have since graduated, four students have gone on to graduate studies in anatomy and physiology and four students are currently medical students. Of the 14 students who have not yet graduated, 4 students are planning to pursue graduate studies, another student intends to become a high school science teacher, and the others are undecided or considering careers in health care.

In our experience, peer teaching has proven to be a very effective teaching method in the research laboratory, and findings in the field of education support this observation.

A 3-yr, \$280,000 grant from the NSF supports a 10-wk summer research program in neurophysiology for undergraduate students from rural or tribal colleges who otherwise do not have access to research opportunities or who would be hesitant to pursue research activities/careers based on social demographics. The program is notable for award flexibility: the \$7,000 award is designed to cover a stipend, room and board, and travel to UND. Additional funding is available for child-care if needed. Nine students participated in the inaugural program, including three American Indian students (2 students from tribal colleges in North Dakota and 1 student from a 4-yr university), five undergraduate students from rural colleges without opportunities for research, and one local high school student. All the students who participated in this program have indicated that they are planning to attend either graduate or medical/dental school.

A second approach integrates undergraduate education and K-12 outreach. In conjunction with Biology faculty members, an experimental undergraduate course was designed to bring the Society for Neuroscience's Brain Awareness Week to our local schools. This spring will mark the third year of this course, in which undergraduates design grade-appropriate presentations of neuroscience material and visit local K-12 classrooms. This past year, we visited 25 classrooms, including grades 2, 4, 6, 7, 11, and 12. This involved 15 different teachers, and we reached approximately 485 K-12 students with our presentations. Feedback from the first 2 yr of visiting Greater Grand Forks K-12 schools was very positive. Undergraduates reported that the experience helped them to better understand the neuroscience material and that sharing excitement about science with children was a positive experience. K-12 teachers gave universally positive feedback about the experience.

In April 2006, we held the 1st Annual Greater Grand Forks Brain Bee competition. This is a question-and-answer neuroscience competition for high school students. Questions are

taken from *Brain Facts* (2), a publication of the Society for Neuroscience, and cover topics such as intelligence, memory, emotions, sensations, movement, stress, aging, sleep, and brain disorders (such as addiction, Alzheimer's disease, and stroke). The four high schools in the Greater Grand Forks area were invited to participate. Ultimately, we had seven participants from two high schools. The winner, a junior at the time, is now working in a research laboratory at UND, has been accepted to Harvard University, and plans to pursue a PhD in Molecular Neuroscience. We plan to expand this competition to the northeast region of the state and then statewide.

Common Themes

Even the limited sampling of institutions described here demonstrates that physiology is taught in a wide variety of programs and venues at the undergraduate level. Therefore, enhancing the quality of undergraduate physiology instruction will impact a large number of undergraduate students. There are common themes throughout these models that can help guide future programs and studies that seek to promote excellence in physiology at the undergraduate level. First, although community colleges do not significantly feed the PhD or MD/PhD physiologist pipeline, they play a critical role in providing physiology instruction to large numbers of students in general education, allied health, and biology. This is especially true for students traditionally underrepresented in the biomedical sciences: women and minorities. Community colleges often provide outreach to these group either by their location (for example, tribal colleges on Native American reservations) or via specific outreach programs. Involvement in physiology research is not typically a component in undergraduate physiology education at community colleges, but some have active and successful research programs, especially through specific federally funded initiatives.

Physiology education at undergraduate colleges and universities has a broader mission and institutional "footprint." Physiology courses are often taught in multiple departments, and elective courses are offered in addition to basic physiology courses. Students enrolled in physiology courses are not necessarily physiology majors but may be in kinesiology, neuroscience, nursing, or a wide variety of life science-related fields. Unlike most community colleges, physiology students at un-

dergraduate colleges and universities are more likely to have opportunities or even requirements to participate in student research.

Not surprisingly, at universities where research is a primary focus of the faculty, undergraduate student research programs are common and often serve significant numbers of students. They vary in how students and mentors are matched together and how student research areas are determined. However, most programs include more than just research activities; they also incorporate social and academic activities designed to develop skills in networking, presentation skills, and other professional skills. Some institutions, especially those in rural states, build multi-institution programs that draw on the resources and talent pool of diverse institutions (community colleges, undergraduate colleges and universities, and research universities) to offer research opportunities to a larger student community. These programs often take a "pipeline" approach, involving students not only at the undergraduate level but also at the K-12 level, recruiting students from diverse backgrounds and racial/ethnic groups, and providing career education as well as research experiences.

These models demonstrate that different institutions focus on different aspects of undergraduate physiology and research education and that all institutions can make a significant contribution toward excellence in physiology education at the undergraduate level. The APS is actively gathering information on models and resources to promote excellence in physiology education and involvement of undergraduates in physiology research; updates are available at the APS website (http://www.the-aps.org/education/edu_ugrad.html). These models can provide insight into the advantages and obstacles that characterize undergraduate involvement in physiology and can assist institutions to enhance their physiology instruction and expand student involvement in biomedical research.

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