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ABSTRACT

The Howard Hughes Medical Institute has as a major focus the improvement of science education at all levels. Each year the institute provides grants for competing organizations whose aim is educating the public in science and/or biomedical research. This document contains the proceedings of a conference that provided a forum for 98 representatives from institutions (public and private research universities, historically black institutions, and four-year liberal arts colleges) receiving undergraduate awards in the 1991 and 1992 competitions to convene and discuss institutional strategies for enhancing undergraduate science education. Topics discussed are as follows: (1) systemic reform; (2) enhancing the educational experience of American Indian students; (3) providing science education opportunities for traditionally underrepresented groups; (4) interdisciplinary studies in biochemistry and molecular Biology; (5) faculty development and high school enrichment; (6) computer use for the study of atomic, macromolecule, and organismic structures; (7) science curriculum development; (8) partnerships in education; and (9) teaching and learning strategies. Also included are: program profiles at selected institutions; four appendixes which contain details about the awardee institutions and a list of meeting attendees; a list of grants publications; lists of Howard Hughes Medical Institute trustees, officers, and principal staff members; and a subject index. (ZWH)

Howard Hughes Medical Institute

Institutional Strategies for Enhancing Undergraduate Science Education

Undergraduate Program Directors Meeting

October 4 – 6, 1993

Undergraduate Biological Sciences Education Program

Office of Grants and Special Programs

Howard Hughes Medical Institute

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The names of colleges and universities are listed as they appear in the *1993 Higher Education Directory.*

Howard Hughes Medical Institute

The Howard Hughes Medical Institute is a not-for-profit medical research organization dedicated to basic biomedical research and education. Its principal objectives are the advancement of fundamental knowledge in biomedical science and the application of new scientific knowledge to the alleviation of disease and the promotion of health. Through its program of direct conduct of medical research in conjunction with hospitals, the Institute employs over 220 independent investigators who conduct research at Institute laboratories in more than 50 leading academic medical centers, hospitals, and universities throughout the United States.

The Institute conducts research in five broad areas: cell biology and regulation, genetics, immunology, neuroscience, and structural biology.

To aid these research efforts, the Institute is involved in the training of pre- and postdoctoral scientists in the laboratories of Hughes investigators; has provided substantial support to the genome mapping program, which involves international collection, dissemination, and coordination of data; provides research training to medical students through the Research Scholars Program (conducted jointly with the National Institutes of Health); and organizes scientific conferences, workshops, and program reviews.

The Howard Hughes Medical Institute was founded in 1953 by aviator-industrialist Howard R. Hughes. Its charter, in part, reads:

The primary purpose and objective of the Howard Hughes Medical Institute shall be the promotion of human knowledge within the field of the basic sciences (principally the field of medical research and medical education) and the effective application thereof for the benefit of mankind.

In the fall of 1987, to complement its research program, the Institute launched a grants program to help strengthen education in the biological and related sciences. This program is administered through the Office of Grants and Special Programs and has as its primary objective the enhancement of science education at the graduate, undergraduate, and precollege levels, education of the public about science, and the promotion of fundamental research abroad. In addition, the Office of Grants and Special Programs is establishing a comprehensive assessment program. The Institute's grants program extends to a wide range of institutions involved in formal and informal science education, including colleges, universities, medical schools, research centers, elementary and secondary schools, and science museums.

Contents

Preface

Purnell W. Choppin, M.D. ■ President ■ Howard Hughes Medical Institute

A new bio-organic course at the University of Notre Dame now contains biological examples that illustrate the relevance of the course to biology majors. In the earlier organic course, says Dr. Morton Fuchs, Professor of Biological Sciences, "any resemblance between organic chemistry and biology was purely coincidental." At Gettysburg College, Institute funding has allowed biology and chemistry departments to develop a major in biochemistry and molecular biology. Says Dr. Ralph Sorenson, Chairman of the Department of Biology, "These two departments that were historically estranged got together and quickly designed the essential features of a new major." These are two examples of program presentations at the 1993 program directors meeting that addressed the major theme of institutional strategies for enhancing undergraduate science education.

The grants program of the Howard Hughes Medical Institute focuses on science education at all levels and in so doing complements the Institute's core programs in the direct conduct of biomedical research. The Institute's biomedical research activities involve some 225 investigators at more than 50 leading academic centers, hospitals, and research institutions around the United States. This research encompasses the fields of cell biology and regulation, genetics, immunology, neuroscience, and structural biology.

Since being launched six years ago, the grants initiative has grown to include support for graduate, undergraduate, and precollege programs as well as programs to educate the public about science primarily in the United States. In addition, biomedical research is supported in selected countries abroad. This array of programs is designed to help ensure the future quality and vitality of the scientific enterprise.

At the undergraduate level, the Institute has made a major commitment in support of programs to strengthen teaching in the biological sciences and other disciplines, including chemistry, physics, and mathematics, as they relate to biology. Another principal objective is to support programs that show promise of recruiting and retaining students in the sciences, particularly women and members of minority groups underrepresented in scientific areas. Rounds of competition for awards through the undergraduate program have been held in 1988, 1989, 1991, 1992, and 1993.

As part of its grants activities, the Institute also sponsors an annual meeting of undergraduate program directors from colleges and universities that have received awards in specific rounds of competition. On October 4–6, 1993, the Institute welcomed 98 program directors and

At the opening reception, Dr. Purnell Choppin, President of the Howard Hughes Medical Institute (*left*), and Dr. Frederick Eiserling, University of California–Los Angeles, discuss the development of undergraduate science programs at UCLA.

other representatives from institutions receiving undergraduate awards in the 1991 and 1992 competitions. The meeting provided an opportunity for attendees, including faculty members and administrators from public and private research universities, comprehensive institutions, historically black institutions, and four-year liberal arts colleges, to convene and discuss institutional strategies for enhancing undergraduate science education.

Changing the Way Science Is Conducted

The world of science is changing fundamentally. The rise of science as a profession in nineteenth century academia was accompanied by the development of departments, each based on a single scientific discipline. Today that older structure is giving way to a new arrangement. Changes in the academic organization of science are beginning to reflect what is taking place in the laboratories. Science departments such as microbiology or physiology are being reorganized at a number of academic institutions into broad new departments that emphasize, for example, cellular and molecular biology.

Because of the rapidity of scientific advances on the one hand and financial restraints on the other, science departments at colleges and universities are finding that they must quickly change what they teach and how they teach it. The growing interdisciplinary nature of science in general and the expanding overlap of biology and chemistry in particular mean that science departments must cooperate in developing curricula, integrating courses, and participating in other activities that tear down the traditionally high walls between scientific disciplines.

Institutional strategies for enhancing undergraduate science education, therefore, was a major theme of the 1993 program directors meeting. In particular, participants offered a variety of approaches to integrating biology and chemistry through Institute-funded programs. Stronger ties can be forged between the biology and chemistry departments through joint faculty appointments and research seminars, interdepartmental student exchanges, and team-teaching of science courses. In other cases, majors in cellular and molecular biology can be developed and courses revised to integrate biology-based problems into chemistry courses, and vice versa.

Getting Science Faculty Involved

Program directors attending the 1993 meeting vigorously discussed important questions related to developing strategies for long-term change in the way science is taught. How can science faculty who are committed to their laboratory research be persuaded to become more involved in the reform of science education? What strategies can be employed to encourage them to teach undergraduates, welcome undergraduates into their laboratories, or give extra help to students who need it? Can science faculty be drawn in to participate in outreach programs that strengthen science education at elementary and secondary schools?

Dr. Anna Tan-Wilson, State University of New York at Binghamton (*left*), and Dr. James Gavin, Senior Scientific Officer at HHMI, review sessions they have attended.

Institute support in many cases has helped increase faculty involvement at all levels of science education. Science faculties at many institutions are already committed to the Institute-funded programs that are focused on attracting and retaining minority students and women.

Reaching Out to Women and Minorities

Another major issue of the 1993 meeting was how best to reach out to women and underrepresented minority students, who have yet to achieve full participation in all areas of scientific research and education. By inte-

grating their efforts with other institutions, historically black colleges and universities have provided off-campus research experiences to undergraduates. Program directors from institutions with significant enrollments of black, Hispanic, Native American and Pacific Islander students emphasized the value of close, sustained contact with faculty as mentors in helping to retain those students in the sciences. Many of these institutions are also conducting outreach programs to benefit students and teachers in local schools.

Outreach to women and minorities varies widely among different populations, locations, and educational institutions. As noted in meeting presentations, higher education is sometimes viewed as a magnet that attracts much-needed talent away from Native American communities. As these communities achieve greater political stability and more job opportunities become available for individuals with college degrees, these problems are assuming much less significance.

Transferring Science to the Classroom

Teachers in the kindergarten–12 school system are an integral part of the science reform effort. They can spark a burning interest in science among young students or coldly douse their natural desire to explore. But as was repeatedly emphasized at the program directors meeting, outreach efforts to kindergarten–12 are complex, and colleges and universities seeking to develop linkages to precollege science teachers must involve teachers in planning the outreach activities.

Precollege science curriculum units are being developed and summer courses offered to upgrade the training of science teachers in subjects such as molecular genetics, which was not available as an academic discipline when many teachers were completing their bachelor's degrees. Teachers can be offered laboratory research experiences and opportunities for sabbaticals in order to take courses in various scientific fields. Scientists from colleges and universities can help develop science instruction kits and, during the summer, train lead teachers from middle schools, high schools, and two- and four-year colleges to instruct other teachers how to use the new materials.

Just as the world of science is changing rapidly, so is our understanding of how students learn and the role of teachers in the learning process. The Institute is pleased to present information that addresses these important topics, gleaned from the recent meeting of representative program directors of the Institute's Undergraduate Biological Sciences Education Program.

Introduction

Joseph G. Perpich, M.D., J.D. ■ Vice President for Grants and Special Programs

"Our program is directed at strengthening the biological sciences education program at Williams College and expanding outreach programs to community schools. Although the meeting on strategies to enhance science education hasn't yet ended, I have decided to make several changes to our program based on what I have learned here already," observed Dr. Steven Zottoli, Professor and Chairman of the Department of Biology at Williams College. Other participants at the 1993 program directors meeting made similar comments.

Colleges and universities that embark on the reform of science education face three principal challenges, said Dr. Samuel Ward, Professor and Head of Molecular and Cellular Biology at the University of Arizona, during his keynote address to the meeting. First, the goals of teaching need to be changed. Second, educators must learn how to go about changing the ways that science is taught. And, third, colleges and universities need to increase the benefits derived from teaching, which is too often undervalued relative to research. These ideas reflect the major themes that emerged from the 1993 program directors meeting on institutional strategies for enhancing undergraduate science education.

Highlighting Issues in Science Education

The program directors meeting is one of five annual grants program conferences held by the Institute. The others bring together medical student fellows, predoctoral and physician postdoctoral fellows, program directors from science museums, and Washington, D.C., metropolitan area students supported through the Institute's local grants activities.

This year's meeting was the third gathering of directors of programs funded by the Undergraduate Biological Sciences Education Program, which, since it started in 1987, has awarded $204 million to 197 colleges and universities (see *Grants for Science Education 1992–1993*). The first meeting in 1991 focused on student development and outreach, and the 1992 gathering explored curriculum and laboratory development and undergraduate research (see *Attracting Students to Science* and *Enriching the Undergraduate Laboratory Experience*, respectively).

At the 1992 meeting, a number of important issues in science education were highlighted. One was the need to make students more aware of multiple career paths in science. The importance of an interdisciplinary curriculum was also stressed.

Colleges and universities need to increase the benefits derived from teaching, which is too often undervalued relative to research.

Samuel Ward
University of Arizona

Dr. Samuel Ward, University of Arizona (*left*), Dr. Joseph Perpich, Vice President for Grants and Special Programs at HHMI, and Myra Alexander, Oklahoma State University, discuss OSU's grant-supported outreach to Native American students.

Changing the attitude of undergraduate science instructors from a "weed-out" mentality to one of encouraging students ... is as important as new curricula and learning technologies.

Undergraduate mentoring and the value of having a single central facility for laboratory instruction capable of supporting various advanced technologies were other subjects on which attention was focused.

Important questions were also raised by the program directors at this meeting. Should a core curriculum emphasize a broad subject approach or a narrow, in-depth one? What is the most effective method for providing all undergraduates with a valuable laboratory experience? What are the relative strengths of wet laboratories and computer-simulated, or so-called "dry" laboratories?

Changing the Goals of Teaching

Several themes emerged at the 1993 meeting of the program directors. Changing the attitude of undergraduate science instructors from a "weed-out" mentality to one of encouraging students was considered by many meeting participants as important as new curricula and learning technologies. At Washington University, Institute funds support efforts in the biology department to augment student support services with mentoring and problem-solving tutorials. These services create an atmosphere where the students feel that the science departments actually want them to be part of the ongoing enterprise, rather than the old flunk-'em-out attitude of some 10 years ago.

Dr. Sarah Elgin, Professor of Biology and program director at Washington University, emphasized that in addition to nurturing students, faculty must also teach in a way that excites students and encourages them to pursue academic excellence. Thus, the chemistry department at Washington University assigns out-

Stephen Barkanic, Program Officer for Undergraduate Science Education at HHMI (*left*), and Dr. Charles Owens, King College, discuss program activities supported by the Institute grant at King.

standing instructors to teach general and organic chemistry courses. The department believes that these changes will have a profound impact on introductory-level students.

Several Institute-funded programs aim directly at nurturing students, especially underrepresented minority students and women, in the sciences. Fisk University, with a predominantly African American population, has developed a science learning center whose peer tutors take advantage of individual learning styles to help students with mathematics, science, study skills, and academic self-confidence. Participants in the Fisk University panel discussion noted that learning styles seem to vary according to culture and gender and that such variations should be taken into account in the classroom and laboratory.

Dr. Corey Goodman, Howard Hughes Medical Institute Investigator and Professor of Genetics and Neurobiology at the University of California–Berkeley, observed that the Institute-supported program offers a highly diverse population of students opportunities for tutorials, career discussions, time-management workshops, and other activities intended to provide a nurturing academic environment for them among the campus's 22,000 undergraduates. In addition, the program provides student tutors who work with study groups in mathematics, biology, chemistry, and physics.

Does student nurturing lead to a drop in academic standards? Not necessarily, said Dr. Joseph Ackerman, Professor and Chairman of the Department of Chemistry at Washington University. He suggested that most students can make the leap from high school to college-level academic performance if they have some help getting started. More facul-

Maria Koszalka, Program Analyst for Undergraduate Science Education at HHMI, learns about strategies for institutional change in the sciences at Antioch College from Dr. Stephen Pasquale, HHMI program director at the college.

The "freshman-year problem" involves the uneven preparation of incoming students for college-level mathematics and science, particularly chemistry.

ty are frequently needed to provide the additional attention. But eventually, he said, students must make the transition to college-level science if they are to proceed into a major, graduate study, and a career in the sciences.

Changing How Science Is Taught

In her book *Revitalizing Undergraduate Science*,[1] Sheila Tobias recently identified structural change at the departmental level of colleges and universities as a crucial step in reforming science education, a concept that broadly molded the agenda for the 1993 program directors meeting. Two issues that departments must resolve emerged from discussions of curriculum reform. How is the content of interdisciplinary courses to be determined? Or, stated differently, what is included and what is left out? Participants discussed the inclusion of biological examples such as stereochemistry demonstrations and laboratories in organic chemistry courses.

The second issue, referred to as the "freshman-year problem," involves the uneven preparation of incoming students for college-level mathematics and science, particularly chemistry. In the Notre Dame panel discussion, participants described a variety of scheduling approaches to allow students to catch up on chemistry skills before entering biology courses where those skills are needed. The Institute-funded program at California State University–Los Angeles addresses this problem with programs to assess and improve student proficiency in mathematics and other critical areas before and during the first year. Preliminary assessments, according to Dr. Alan Muchlinski, Professor of Biology, and Dr. Margaret Jefferson, Professor of

Genetics at California State University–Los Angeles, indicate the programs are working.

Increasing the Value of Science Teaching

Dr. Timothy Goldsmith of Yale University, keynote speaker at the 1992 program directors meeting, noted that "a central purpose of biological education should be to convey science as a powerful way of understanding the world" (see *Enriching the Undergraduate Laboratory Experience, 1992*). Dr. Goldsmith called on scientists to become more involved with science education at the kindergarten–12 level. "We need to recreate the teacher–scientist partnership along the lines that existed in the post-Sputnik years in the form of summer institutes, but now in the schools themselves," he wrote recently in the *American Journal of Human Genetics*.[2]

Through outreach programs, colleges and universities can be instrumental in enhancing science teaching at the precollege level. To be successful, outreach programs must often provide equipment and laboratory supplies that are unavailable to many kindergarten–12 science teachers. Budget restrictions in schools may prevent the purchase of supplies for precollege science experiments, said a participant in the Spelman College panel discussion. With Institute support, Washington State University has set up a program to loan electrophoresis apparatus, spectrophotometers, video cameras, and other expensive scientific equipment to schools that cannot afford to purchase them. Oklahoma State University supplies and refurbishes science footlocker kits for loan to local science teachers.

At Oklahoma State University the Institute-funded program is designed specifically to help rural Native Americans progress through the educational system and complete a degree in biological sciences. The Institute's grant has been especially crucial in getting faculty involved in a program for reaching rural Native Americans during a time of cutbacks across the campus, said Dr. Alan Harker, Professor of Microbiology and Molecular Genetics. According to Myra Alexander, Manager of Outreach and Counseling, the program is succeeding in overcoming cultural diversity of the disparate communities by seeking input from tribal leaders and the community's "movers and shakers" in education.

A central purpose of biological education should be to convey science as a powerful way of understanding the world.

Timothy Goldsmith
Yale University

Taking Advantage of Technological Advances

Technological advances in education offer another way of enhancing science education. California State University–Los Angeles used Institute support to

The expanded use of computers to analyze data and conduct experiments in chemistry courses is a very important development in the chemistry teaching lab.

William Bartlett and Preston Somers Fort Lewis College

start a videodisc technology laboratory, where students in freshman biology courses can study images of microscope slides from the laboratory courses on their own time. At Fort Lewis College, Dr. William Bartlett, Professor of Chemistry, and Dr. Preston Somers, Professor of Biology, view the expanded use of computers to analyze data and conduct experiments in chemistry courses as "a very important development in the chemistry teaching lab." The computers promote discussions about data and help students with conceptualization. At the California Institute of Technology, Institute funds support the development of computer-based instructional materials for teaching basic chemical and biological concepts. Students help develop video tapes that teach basic chemistry concepts, taking advantage of state-of-the-art animation technology used by Hollywood filmmakers.

A demonstration program held at the program directors meeting featured innovative teaching technologies, ranging from Knox College's electronic textbook for physical chemistry to Villanova University's interactive computer program in Mendelian genetics. Dr. Pamela Bjorkman, Howard Hughes Medical Institute Assistant Investigator and Assistant Professor, Division of Biology, California Institute of Technology, noted during the plenary review session that integration of computers into the science curriculum is not particularly difficult. A greater challenge is dealing with computer maintenance, security, upgrading, and obsolescence, problems that must be dealt with when new computerized learning systems are being planned.

Issues for the Future

Program directors raised several issues that will undoubtedly receive more attention in the future. One important suggestion was to find better ways for the directors to communicate with each other, such as through a computer bulletin board or an electronic mail system. Another issue is how to ensure that programs begun with the five-year Institute grants will continue to thrive after the grant terms have ended. Will internal funding take over when the Institute grant is gone? Will new people continue a program when its innovators leave? "Innovations tend to disappear when either the innovator moves on to another project or the funding cycle ends,"[3] said Ms. Tobias in *Revitalizing Undergraduate Science*. "The model for science education reform is ... a process model that focuses attention continuously on every aspect of the teaching-learning enterprise, locally and in depth."[4]

A third issue is assessment. "Those who would reform sci-

ence teaching at college need to engage in a process of *planning and evaluation*, however unfamiliar (and unpalatable) that process may be," Ms. Tobias wrote.

Participants debated whether trends in increased undergraduate enrollment in the biological sciences are an accurate reflection of Institute-supported program outcomes. Dr. Elgin of Washington University has observed enrollment increases at Washington University but noted that it is difficult to determine how much of the increases could be attributed solely to program outcome. Films such as "Jurassic Park" have made the public more aware of technological developments in biology such as genetic engineering and may stimulate young people to consider a career in biology. The sluggish state of the national economy may cause other students to look more closely at careers in science and medicine. At the same time, says Dr. Elgin, "there is an increase in the quality of what the Biology Department is doing. It is more interesting to be a biology major now that the Hughes grant is operating than it was before, more opportunities to do more things. You put all those together and you have steadily increasing enrollments."

Several programs use assessment methods that include measuring performance on standardized tests and tracking before and after graduation the careers of students who participated in undergraduate research; determining the impact of local outreach programs on elementary students measured through their science scores after taking educational assessment tests; and comparing the grade point averages or Graduate Record Examination scores of undergraduates who participate in Institute-supported undergraduate research relative to those who do not. Dr. Jerry Pine, Professor of Biophysics at the California Institute of Technology, stated that qualitative evaluation is absolutely indispensable in assisting with reform of science curriculum in local K–6 public schools, recalling his own experience. "We did a precourse evaluation," he noted, "and then redesigned the course, once we went through that exercise—before we tried to teach the course."

Qualitative evaluation is absolutely indispensable in assisting with reform of science curriculum in local K–6 public schools.

Jerry Pine
California Institute of Technology

Creating a Scientifically Literate Citizenry

Perhaps the biggest challenge of the future lies in expanding science education beyond the scientific elite to nonscience majors in colleges and universities and to the population in general. Dr. David Goodstein, Vice Provost at the California Institute of Technology, in a recent article in *Engineering & Science* remarked on the state of science education in the United States: "Besides producing scientists, the nation's education system must also cre-

Besides producing scientists, the nation's education system must also create citizens capable of running a democracy and contributing to the population's economic well-being.

David Goodstein
Engineering & Science

ate citizens capable of running a democracy and contributing to the population's economic well-being."[6] In addition, a scientifically literate citizenry is necessary to form the broad political consensus that supports basic scientific research as a common good.

According to Dr. Bjorkman, the value of science education for nonscience majors, like that of a liberal arts education, may lie in helping students learn how to think critically and analyze logically. Others also view science education for nonscience majors as a "seeding" phenomenon to expand science literacy to the general population. "This same group might well be the best source of teachers of science below the college level," Dr. Norman Hackerman, President Emeritus of Rice University, wrote recently.[7]

At the meeting, Dr. Elgin stressed the importance of high school biology for educating the general public. "That first year biology class is really the only place where we can talk to the majority of Americans," she said. "In terms of science education, the first year of high school biology is it for a lot of folks."

If You Build It, They Will Come

The innovative hands-on, minds-on science education programs being constructed with support from the Undergraduate Biological Sciences Education Program are attracting and educating students with general academic interest as well as those with their eyes on a Ph.D. The lesson is clear, said Dr. Frank Vellaccio, Dean of the College of the Holy Cross: "Build it, and they will come."

Providing undergraduates with opportunities for hands-on research experiences is especially important. Dr. Elizabeth Jones, Professor of Biological Sciences at Carnegie Mellon University, noted in a recent statement before the National Research Committee for Biomedical and Behavioral Research Personnel, "The fact remains that a very large fraction of students who participate in undergraduate research programs end up in biomedical research careers. They are able to make the commitment knowing *in advance* that they enjoy doing research and are good at it."[8]

Research programs for undergraduates are one example of how resources in this country are being applied to enhancing science education. Studies of science education in the United States are beginning to take note of the positive impact that such programs are having. A recent report issued by the Organization for Economic Cooperation and Development[9] based in Paris noted that for American students the earlier downward slide of scores for standardized college entrance examinations and math-

That first year biology class is really the only place where we can talk to the majority of Americans. In terms of science education, the first year of high school biology is it for a lot of folks.

Sarah Elgin
Washington University

ematics and science scores has stabilized. American colleges and universities, the report also found, continue to outperform institutions in competing countries, not only in the total number of graduates but in dollars spent for education.

Institutions need to have strategies specifically for enhancing undergraduate science education. In a recent article entitled "Careers 93: A Survival Guide," Dr. James Watson, President, Cold Spring Harbor Laboratory, offered four rules of thumb that might be applied to building effective undergraduate science education programs: Learn from winners; take risks; have a fallback strategy; and have fun.[10] In the pages that follow are example after example of colleges and universities that are building and strengthening their undergraduate science education programs. In the process they are bringing science to life.

References

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3 Tobias, S. op.cit., 21.

4 Ibid., 160.

5 Ibid., 168.

6 Goodstein, D. *Engineering & Science*, Spring 1993.

7 Hackerman, N. *Science* 256:157, 1992.

8 Jones, E. Testimony presented at the National Research Council Committee on National Needs for Biomedical and Behavioral Research Personnel, May 3, 1993.

9 Centre for Educational Research and Innovation, Organization for Economic Cooperation and Development. *Education at a Glance: OECD Indicators*. Paris, France, 1993.

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Undergraduate Program Overview

Grants Competitions and Awards, Phase I, 1988-1992

HHMI has provided a total of $175.4 million in 1988-1992 to 181 institutions for grants to support undergraduate science education in the first phase of the undergraduate program (Figure 1). In providing this support, HHMI has encouraged institutions to develop programs that respond to their particular needs and strengths. Accordingly, the undergraduate program supports a range of activities in numerous scientific disciplines at participating institutions. These activities include programs for student, faculty, and curriculum development, and precollege and outreach programs.

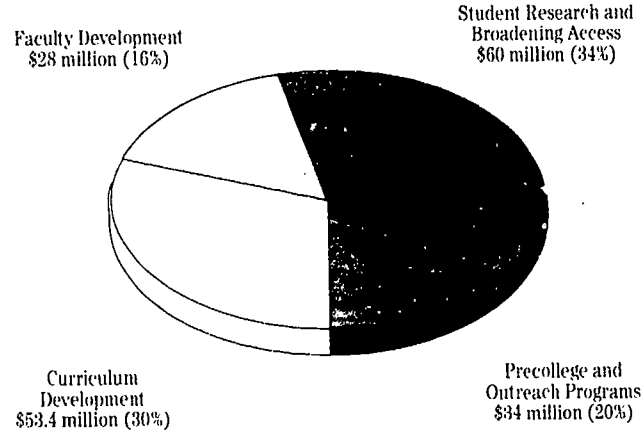
The first phase of the undergraduate program began in 1988 with the initial round of grants competition in which HHMI invited 81 private liberal arts colleges and 18 public and private historically black institutions to apply for five-year grants to bolster their science programs. Following review of the 99 proposals by external and internal panels of scientists and educators, 44 institutions, including 34 private four-year colleges and 10 public and private historically black institutions, were awarded a total of $30.4 million in HHMI grant support. (For further information on the grants awarded, see *Howard Hughes Medical Institute, Grants Program Policies and Awards, 1988-1989.*)

In 1989, 101 research and doctorate-granting universities were invited to submit proposals to enhance undergraduate education in biology and related fields. Following review of the proposals, HHMI provided grants totaling $61 million to 51 universities. These awards were paid by HHMI over a two-year period. (See *Howard Hughes Medical Institute, Grants for Science Education, 1989-1990.*)

In 1991 a total of 98 public and private comprehensive and liberal arts colleges and universities, including institutions with demonstrable records of educating underrepresented minority

Figure 1

Undergraduate Biological Sciences Education Program, Awards to 181 Colleges and Universities ($175.4 million) by Program Component, Phase I, 1988-1992 Competitions



students in the sciences, competed for undergraduate awards. Forty-four of the 98, of which 10 had records of educating underrepresented minority students, received grant support totaling $31.5 million for a range of program activities. (See *Howard Hughes Medical Institute, Grants for Science Education, 1990-1991.*)

The first program phase was completed in 1992, when a fourth competition was held in which 98 research and doctorate-granting universities were invited to submit proposals. HHMI awarded grants totaling $52.5 million to 42 of these institutions. (See *Howard Hughes Medical Institute, Grants for Science Education, 1991-1992* and *Howard Hughes Medical Institute, 1993 Undergraduate Program Directory, A Listing of Program Directors and Grants Awarded at 181 Colleges and Universities, 1988-1992.*)

Figure 2 lists the number of undergraduate grantees by Carnegie Foundation classification (Figure 2).

Figure 2

Grantees by Carnegie Foundation Classification, 1988-1993

Carnegie Classification	1988-1992 Phase I	1993 Phase II
Research Universities I	55	–
Research Universities II	21	–
Doctorate-Granting Universities I	11	–
Doctorate-Granting Universities II	5	–
Comprehensive Universities and Colleges I	20	18
Comprehensive Universities and Colleges II	3	2
Liberal Arts Colleges I	56	22
Liberal Arts Colleges II	8	5
Schools of Engineering and Technology	2	–
Totals	181	47

Assessment Criteria

Institutions have been invited to participate in these competitions on the basis of their recent records of graduating students who go on to medical school or to obtain Ph.D.'s in biology, chemistry, physics, or mathematics. Data for these assessments were provided by the Association of American Medical Colleges, the National Research Council of the National Academy of Sciences, and the U.S. Department of Education and covered the most recent 10-year period for which the data were available (Figure 3).

To identify institutions as eligible to be included in each assessment, HHMI has referred to the 1987 classification of higher education institutions by the Carnegie Foundation for the Advancement of Teaching. These classifications are based on such factors as the level of degree offered, nature of the educational mission, degree of specialization in particular fields, and amount of annual federal support for research and development. HHMI has also taken into account institutions' records of

preparing students from minority groups underrepresented in the sciences for scientific careers.

Proposals are reviewed by an external panel of distinguished scientists and educators. Their evaluations are reviewed by an internal HHMI committee that makes recommendations to HHMI's Trustees, who authorize funding.

Undergraduate Research, Including Opportunities for Women and Minority Students Underrepresented in the Sciences

Of the total funding of $175.4 million provided in the first phase of the undergraduate program, approximately $60 million has been used at 170 institutions for programs to recruit and retain students in the sciences, especially those underrepresented in scientific fields, such as women, blacks, Hispanics, and Native Americans. The principal student activity supported under the program is undergraduate research, providing opportunities for students, many with no prior laboratory experience, to learn scientific concepts, terminology, and techniques while assisting scientists in research projects on or off campus. At a number of institutions, these research experiences have been enhanced when preceded by training activities and followed

Figure 3

Assessment Criteria

In 1988-1992, institutions were assessed for participation in the Undergraduate Biological Sciences Education Program on the basis of the percentage (calculated with data on total baccalaureate degree production collected by the U.S. Department of Education) and absolute number of graduates from each institution who have:

Matriculated in Medical Schools
Data Source: Association of American Medical Colleges.

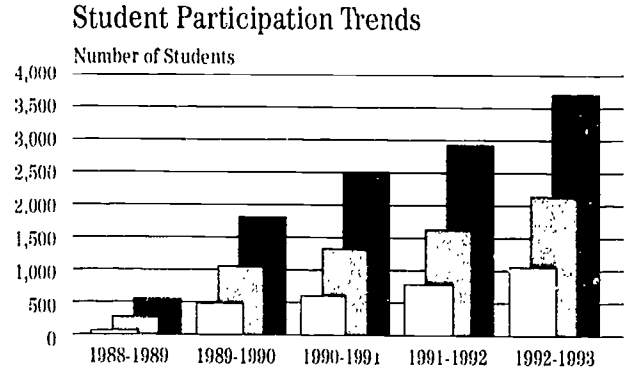
Earned Doctorates in Biology
Data Source: National Research Council of the National Academy of Sciences.

Earned Doctorates in Chemistry, Physics, or Mathematics
Data Source: National Research Council of the National Academy of Sciences.

Note: Assessments for the 1988 and 1989-1990 competitions were based on data for the periods 1976-1986 (for doctorates earned in biology, chemistry, physics, or mathematics). Assessments for the 1991-1992 competitions were based on data for the periods 1979-1988 (for medical school matriculation and doctorates earned in biology, chemistry, physics, and mathematics).

Figure 4

Undergraduate Research, 1988-1993



Student Participation–Total

	Number	Percent
All Students	11,522	100
Women	6,449	56
Minorities	3,158	27

by opportunities for students to present their research and publish significant findings.

Since its inception in 1988, the undergraduate program has supported over 11,500 undergraduates conducting research. Of this total, 56 percent are women and 27 percent are students from minority groups underrepresented in scientific fields (Figure 4). Most of the students conducted research with faculty members at their own institutions, and a limited number worked off campus in government laboratories, at other universities or colleges, or in private corporations (Figure 5). Forty-five percent of these research experiences took place during summer and 36 percent during the academic year, and some spanned both periods (Figure 6).

Grantee institutions have reported the significant impact of undergraduate research opportunities in attracting student interest in the sciences and helping to retain that interest through the college years and beyond. According to a number of participating students, HHMI-supported research experiences have been major factors in acceptance into outstanding graduate and medical programs and receiving national fellowships. For example, several undergraduates receiving research support through this program have gone on to receive fellowships under HHMI's highly competitive predoctoral fellowship program.

Figure 5

Undergraduate Research Sites, 1988-1993

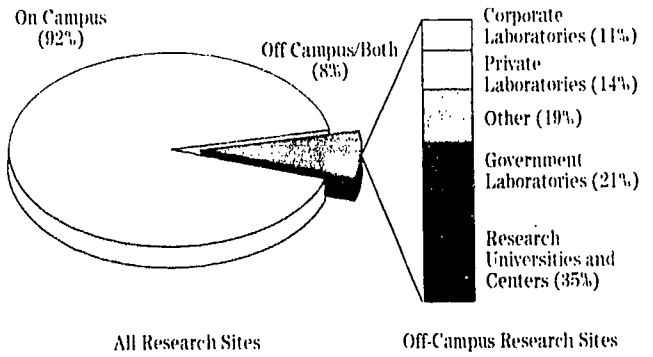
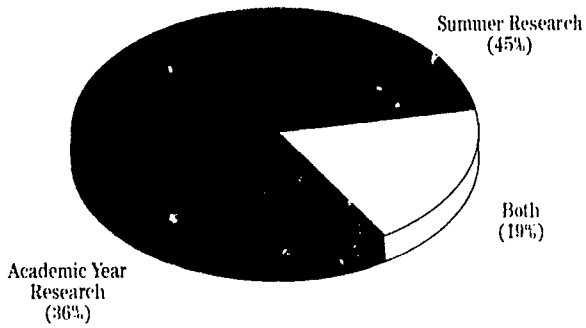


Figure 6

Undergraduate Research by Academic Period, 1988-1993



Faculty Development in the Sciences

In the initial program phase, a total of $28 million has been used by 98 awardee institutions for science faculty development, including the appointment of new faculty members, programs to engage research faculty in undergradu-

ate teaching, and other activities. Since 1988, HHMI funds have enabled 55 colleges and universities to appoint 169 faculty members in a range of scientific disciplines. These HHMI-supported appointments include 82 women (49 percent) and 21 faculty members from minority groups underrepresented in scientific areas (12 percent) (Figure 7).

These appointments are providing departments with opportunities to develop new courses in important areas of modern science, and to update and expand existing curricula.

The scientific disciplines in which HHMI-supported faculty have been appointed include cell and molecular biology, biochemistry/biophysics, and neuroscience (Figure 8). In several cases the new appointments have enabled institutions to bridge science departments, such as biology and chemistry, in the development of interdisciplinary programs. The new faculty members have begun to distinguish themselves at their colleges and universities, which are reporting important contributions in teaching, research, and institutional service.

HHMI provides funds for activities that enrich the current faculty scientists' knowledge of their fields and enhance their ability to convey new knowledge to students. Science faculty members received support to participate in on- and off-campus workshops, seminars, and training programs in the sciences. In addition, a number of faculty received HHMI support to attend professional meetings.

Curriculum and Laboratory Development and Equipment

A total of $53.4 million has been directed to the development of science curricula and laboratories, enabling nearly all 181 grantee institutions participating in the initial program phase to

Figure 7

New Faculty Appointments, 1988-1993*

	Number	Percent
Faculty Appointments	169	100
Underrepresented Minorities	21	12
Women	82	49

Of the 169 Institute-supported appointments, 39 are non-tenure track.

Figure 8

New Faculty Appointments, 1988-1993 Scientific Fields

Field	Number of Appointments
Cell or Molecular Biology	41
Biochemistry/Biophysics	26
Neuroscience	22
General Biology	11
Chemistry	10
Genetics	5
Physics	5
Physiology	4
Other Biological and Scientific Fields	45
Total	**169**

enhance the quality of instruction in the biological sciences and other disciplines as they relate to biology. HHMI grant support in this area is principally directed to the acquisition of modern scientific instrumentation and laboratory renovation. The program also supports the development of new experiments for use in courses, laboratory manuals, and other instructional materials.

Since 1988 HHMI has supported the development of approximately 2,500 courses covering a wide range of scientific disciplines such as genetics, molecular and cell biology, and neuroscience. Approximately 30 fields of biology and other disciplines are represented. Numerous institutions are using their awards to relate biology teaching to chemistry, physics, mathematics, and computer science. In such cases, biological examples are integrated into laboratory courses in the physical sciences and other areas (Figure 9).

Another important objective of HHMI's support of curriculum and laboratory development is the enhancement of opportunities for hands-on laboratory research in undergraduate science courses. Grantee colleges and universities are developing teaching laboratories at the introductory through upper-division levels, providing undergraduates with research experiences that may be continued in faculty laboratories. Institutions report that for many students these research experiences are stimulating interest in science majors and careers.

Figure 9

Curriculum and Laboratory Development, 1988-1993
Selected Course Areas

Area	Number of Courses
General Biology	299
Chemistry	252
Biochemistry	218
Molecular Biology	218
Cell Biology	189
Neuroscience	159
Physiology	134
Laboratory Techniques	120
Genetics	116
Physics	103
Topics in Biological Sciences	102

Precollege and Outreach Programs

In the first program phase, HHMI awarded $34 million to 170 grantee colleges and universities to expand existing linkages or to develop new ones with precollege and other institutions. The objective of these initiatives is to enhance the quality of science programs at these institutions. They are also intended to attract and retain students, particularly women and students from underrepresented minority groups, in the sciences.

Programs include summer and academic-year laboratory experiences for teachers and students, summer science camps,

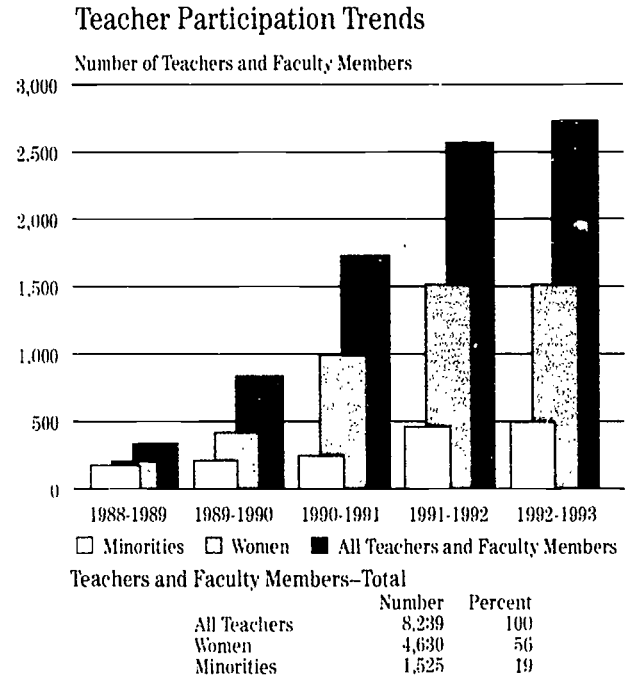
equipment loans, curriculum development, and classroom training for students in biology and chemistry, physics, mathematics, and other areas as they relate to the biological sciences. Approximately 8,200 teachers, of whom 56 percent are women and 19 percent are minority group members, have participated in HHMI-supported outreach programs since 1988. In addition, over 25,000 students, including 59 percent minority students and 54 percent women, have benefited from these outreach initiatives (Figure 10).

Teachers from elementary, middle, and high schools and faculty members from two-year and four-year colleges, and students from these institutions, have been involved in HHMI-supported outreach programs. Among the participating teachers, approximately 66 percent have been from high schools, with elementary school and middle school teachers and two- and four-year faculty also significantly represented. Among the students, 66 percent have also been from high schools. In addition, students from other educational levels have participated (Figure 11).

Colleges and universities have reported on the laboratory activities of precollege students participating in HHMI-supported outreach programs. A number of these students have received recognition for their research through programs such as the

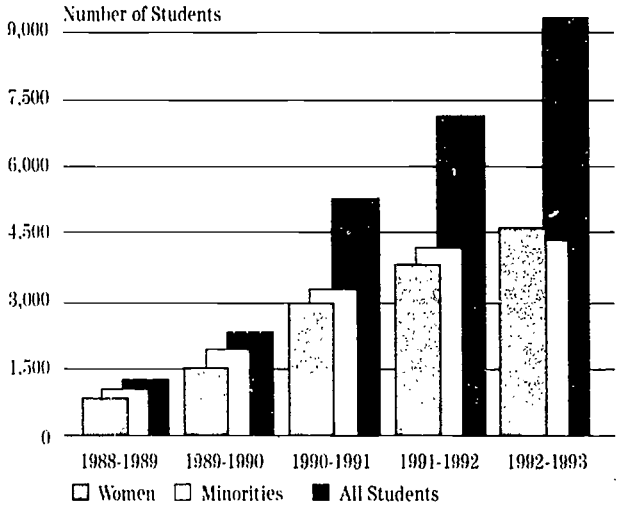
Figure 10

Outreach Program Participants, 1988-1993



Teachers and Faculty Members–Total

	Number	Percent
All Teachers	8,239	100
Women	4,630	56
Minorities	1,525	19

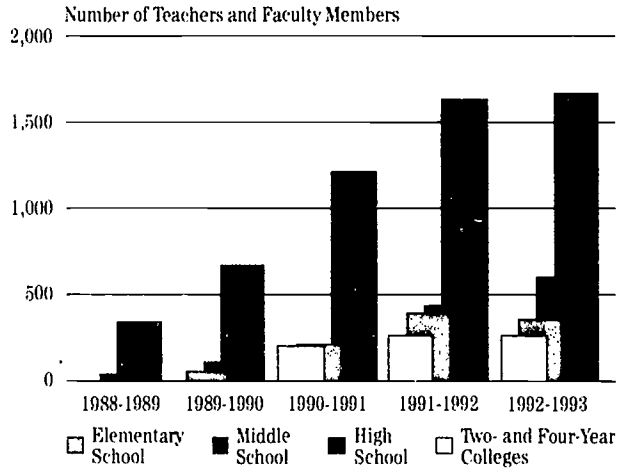


Students–Total

	Number	Percent
All Students	25,371	100
Women	13,718	54
Minorities	14,940	59

Figure 11

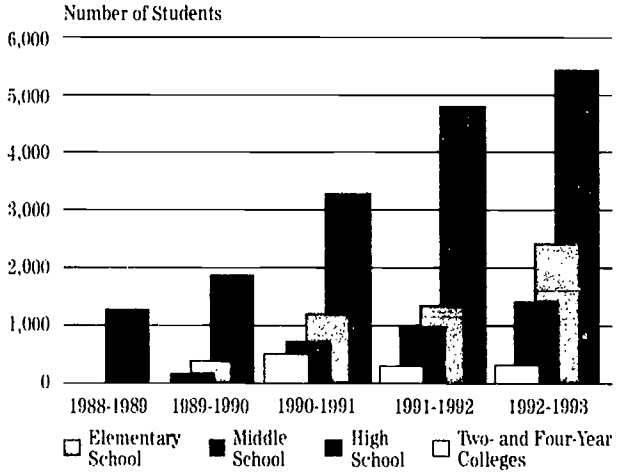
Teacher Participation in Outreach Programs by Teaching Level, 1988-1993



Teachers and Faculty Members–Total

	Number	Percent
Elementary School	887	11
Middle School	1,228	15
High School	5,435	66
Two- and Four-Year Colleges	689	8

Student Participation in Outreach Programs by Education Level, 1988-1993



Students–Total

	Number	Percent
Elementary School	5,245	21
Middle School	3,209	12
High School	16,654	66
Two- and Four-Year Colleges	263	1

Westinghouse Science Talent Search and in local, regional, and national science fairs. Many have also been accepted into leading undergraduate science programs. In addition, a number of teachers from elementary and secondary schools have noted improvements in their science teaching as a result of their participation in HHMI programs.

Grants Competitions and Awards, Phase II, 1993-1994

HHMI's 1993 and 1994 competitions mark a new phase in HHMI's undergraduate program. This second program phase was developed, in part, on the basis of findings from HHMI's ongoing assessments of the undergraduate program (Figure 12). For example, a recurring theme of the 1991 program directors meeting concerned the importance of undergraduate research as a means of attracting and retaining students in the sciences, including women and students from minority groups underrepresented in scientific fields.

The program directors also emphasized at the meeting the key role colleges and universities can play in enriching science education through precollege and outreach programs. A number of presentations focused on activities developed by grantees to provide laboratory and classroom training for students and teachers from elementary and

secondary schools, as well as two- and four-year colleges.

Another important source of background for undergraduate program development is the annual progress reports submitted by grantee colleges and universities. Over the five years of the program, undergraduate science departments have underscored in their reports the impact of equipment acquisitions and laboratory development supported by their grants in enabling them to provide their students with instruction in the contemporary biological sciences and other disciplines as they relate to biology. They also draw attention to a critical need for continued support to modernize the undergraduate science infrastructure.

Based on information collected through these assessment activities, the 1993 and 1994 programs include new guidelines and elements representing changes from previous rounds of competition. Support for undergraduate research, including opportunities for women and underrepresented minority students, remains as a central component in the new undergraduate program. Activities to prepare students for laboratory research and enable them to present their findings will also be supported. In addition, support for precollege and outreach programs in the sciences will continue to be a priority.

Applicant institutions may now request up to the full grant amount for equipment for undergraduate science education. The new program also provides up to 50 percent of the total grant amount for renovation of teaching laboratories. Faculty development and curriculum development in the sciences are no longer included as categories.

Following the fifth competition held in 1993, 47 grants totaling $28.5 million were made to public and private comprehensive and liberal arts institutions (Figures 13 and 14). For the 1994 grants competition, HHMI is extending invitations to 151 institutions clas-

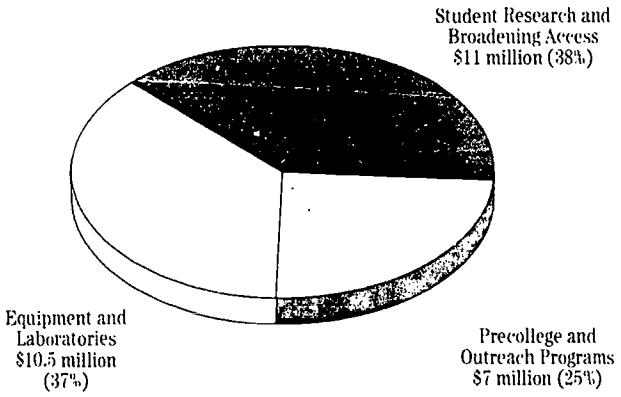
Figure 12

Undergraduate Biological Sciences Education Program

Program Elements and Guidelines, Phase I (1988-1992)	Program Elements and Guidelines, Phase II (1993-1995)
■ Student and faculty development, supporting undergraduate research experiences, opportunities for women and minority students underrepresented in the sciences, and new faculty appointments, included as program elements	■ Student research, including opportunities for women and minority students underrepresented in the sciences, retained as program element
■ Curriculum and laboratory development, supporting new and revised courses, equipment acquisitions, and laboratory renovations, included as program elements	■ Equipment and laboratory development, supporting equipment acquisitions and laboratory renovations for undergraduate laboratory courses, retained as program element
■ Precollege and outreach programs included as program elements	■ Precollege and outreach programs retained as program elements
■ Support for equipment and laboratory renovation limited to 30 percent of total grant amount	■ No limitation on funding for equipment, and funding for renovation limited to 50 percent of total grant amount
■ Five-year grant period	■ Four-year grant period

Figure 13

Undergraduate Biological Sciences Education Program, Awards to 47 Colleges and Universities ($28.5 million) by Program Component, Phase II, 1993 Competition



sified by the Carnegie Foundation for the Advancement of Teaching as public and private Research and Doctorate-Granting Universities. Institutions receiving HHMI awards in 1989-1990 and 1992 and other institutions included in these Carnegie Foundation classifications were invited to compete for four-year awards (Figure 15).

As in the previous competitions, institutions were invited on the basis of their 10-year records of graduating students who go on to medical school or to obtain Ph.D.'s in biology, chemistry, physics, or mathematics. Data for this assessment were provided by the Association of American Medical Colleges, the National Research Council of the National Academy of Sciences, and the U.S. Department of Education.

Proposals will be reviewed by an external panel of scientists and educators. The evaluations of the external panel will then be reviewed by an internal HHMI committee that will make recommendations to HHMI's Trustees, who will authorize funding. Grant awards totaling approximately $72 million over a four-year period will be announced late in the summer of 1994.

Figure 14

Undergraduate Biological Sciences Education Program 1993 Awards

Amherst College Amherst, Massachusetts	$500,000
Bates College Lewiston, Maine	$500,000
Bowdoin College Brunswick, Maine	$550,000
Bryn Mawr College Bryn Mawr, Pennsylvania	$600,000
California State University–Los Angeles Los Angeles, California	$650,000
California State University–Northridge Northridge, California	$700,000
Carleton College Northfield, Minnesota	$850,000
City University of New York City College New York, New York	$650,000
City University of New York Hunter College New York, New York	$650,000
City University of New York Herbert H. Lehman College Bronx, New York	$500,000
Clark Atlanta University Atlanta, Georgia	$550,000
College of the Holy Cross Worcester, Massachusetts	$550,000
Colorado College Colorado Springs, Colorado	$650,000
Concordia College–Moorhead Moorhead, Minnesota	$550,000
Fisk University Nashville, Tennessee	$550,000
Fort Lewis College Durango, Colorado	$500,000
Gettysburg College Gettysburg, Pennsylvania	$500,000
Hampton University Hampton, Virginia	$500,000
Haverford College Haverford, Pennsylvania	$600,000
Hobart and William Smith Colleges Geneva, New York	$550,000
Humboldt State University Arcata, California	$800,000
Knox College Galesburg, Illinois	$500,000
Morehouse College Atlanta, Georgia	$1,000,000
Oberlin College Oberlin, Ohio	$500,000
Ohio Wesleyan University Delaware, Ohio	$500,000
Saint Joseph's University Philadelphia, Pennsylvania	$500,000
St. Mary's University San Antonio, Texas	$650,000
Saint Olaf College Northfield, Minnesota	$500,000
San Diego State University San Diego, California	$500,000
Smith College Northampton, Massachusetts	$600,000
Southern University and A&M College at Baton Rouge Baton Rouge, Louisiana	$700,000
Swarthmore College Swarthmore, Pennsylvania	$650,000
Tougaloo College Tougaloo, Mississippi	$500,000
Tuskegee University Tuskegee, Alabama	$500,000
Union College Schenectady, New York	$500,000
University of Puerto Rico Cayey University College Cayey, Puerto Rico	$600,000
University of Puerto Rico Mayaguez Campus Mayaguez, Puerto Rico	$500,000
University of Puerto Rico Rio Piedras Campus Rio Piedras, Puerto Rico	$500,000
University of Texas at El Paso El Paso, Texas	$850,000
Ursinus College Collegeville, Pennsylvania	$500,000
Wellesley College Wellesley, Massachusetts	$850,000
Wesleyan University Middletown, Connecticut	$500,000
Western Maryland College Westminster, Maryland	$500,000
Wheaton College Wheaton, Illinois	$550,000
Williams College Williamstown, Massachusetts	$500,000
Wofford College Spartanburg, South Carolina	$700,000
Xavier University of Louisiana New Orleans, Louisiana	$1,400,000

Figure 15

Undergraduate Biological Sciences Education Program Invited Institutions, 1994

Andrews University, Michigan
Arizona State University
Auburn University, Alabama
Baylor University, Texas
Boston College, Massachusetts
Boston University, Massachusetts
Brandeis University, Massachusetts
Brigham Young University, Utah
Brown University, Rhode Island
California Institute of Technology
Carnegie Mellon University, Pennsylvania
Case Western Reserve University, Ohio
Catholic University of America, District of Columbia
Clark University, Massachusetts
Clemson University, South Carolina
College of William and Mary, Virginia
Colorado State University
Columbia University, New York
Cornell University, New York
Dartmouth College, New Hampshire
Drexel University, Pennsylvania
Duke University, North Carolina
Emory University, Georgia
Florida Institute of Technology
Florida State University
Fordham University, New York
George Washington University, District of Columbia
Georgetown University, District of Columbia
Georgia Institute of Technology
Harvard University, Massachusetts
Howard University, District of Columbia
Illinois Institute of Technology
Indiana University at Bloomington
Iowa State University
Johns Hopkins University, Maryland
Kansas State University
Kent State University Main Campus, Ohio
La Sierra University, California
Lehigh University, Pennsylvania
Louisiana State University and A&M College
Loyola University of Chicago, Illinois
Marquette University, Wisconsin
Massachusetts Institute of Technology
Miami University, Ohio
Michigan State University
Mississippi College
Montana State University
New York University
North Carolina State University
Northwestern University, Illinois
The Ohio State University Main Campus
Oklahoma State University Main Campus
Oregon State University
Pennsylvania State University Main Campus
Polytechnic University, New York
Princeton University, New Jersey
Purdue University Main Campus, Indiana
Rensselaer Polytechnic Institute, New York
Rice University, Texas
Rutgers the State University of New Jersey Newark Campus
Rutgers the State University of New Jersey New Brunswick Campus
Saint Louis University, Missouri
Southern Illinois University at Carbondale
Southern Methodist University, Texas
Stanford University, California
State University of New York at Albany
State University of New York at Binghamton
State University of New York at Buffalo
State University of New York at Stony Brook
State University of New York College of Environmental Science and Forestry
Stevens Institute of Technology, New Jersey
Syracuse University Main Campus, New York
Temple University, Pennsylvania
Texas A&M University
Texas Tech University
Tufts University, Massachusetts
Tulane University, Louisiana
The University of Akron Main Campus, Ohio
University of Alabama
University of Arizona
University of Arkansas Main Campus
University of California–Berkeley
University of California–Davis
University of California–Irvine
University of California–Los Angeles
University of California–Riverside
University of California–San Diego
University of California–Santa Barbara
University of California–Santa Cruz
University of Chicago, Illinois
University of Cincinnati Main Campus, Ohio
University at Colorado at Boulder
University of Connecticut
University of Delaware
University of Florida
University of Georgia
University of Hawaii at Manoa
University of Houston, Texas
University of Illinois at Chicago
University of Illinois at Urbana-Champaign
University of Iowa
University of Kansas Main Campus
University of Kentucky
University of Louisville, Kentucky
University of Maine
University of Maryland Baltimore County
University of Maryland College Park
University of Massachusetts at Amherst
University of Miami, Florida
University of Michigan–Ann Arbor
University of Minnesota–Twin Cities
University of Mississippi
University of Missouri–Columbia
University of Nebraska–Lincoln
University of Nevada, Reno
University of New Hampshire
University of New Mexico Main Campus
University of New Orleans, Louisiana
University of North Carolina at Chapel Hill
University of North Dakota Main Campus
University of Notre Dame, Indiana
University of Oklahoma Main Campus
University of Oregon
University of Pennsylvania
University of Pittsburgh Main Campus, Pennsylvania
University of Rhode Island
University of Rochester, New York
University of South Carolina–Columbia
University of South Dakota
University of South Florida
University of Southern California
University of Tennessee, Knoxville
University of Texas at Arlington
University of Texas at Austin
University of Toledo, Ohio
University of Utah
University of Vermont
University of Virginia
University of Washington
University of Wisconsin–Madison
University of Wisconsin–Milwaukee
University of Wyoming
Utah State University
Vanderbilt University, Tennessee
Virginia Polytechnic Institute and State University
Washington State University
Washington University
Wayne State University, Michigan
West Virginia University
Yale University, Connecticut
Yeshiva University, New York

Part I: Proceedings

Keynote Address

Why Is Systemic Reform in Science Education So Difficult?

Samuel Ward, Ph.D. ■ University of Arizona

I am pleased and honored to have the opportunity to address you all this evening. I am certainly not an expert on educational issues; I regard myself as a relative newcomer to this arena and am still on a steep learning curve. Reading the preliminary report, I look forward to learning a great deal in the days ahead. I would like to relate some of what we have learned through our National Research Council Committee on Biology Teacher Inservice Programs and from some of the educational initiatives at the University of Arizona.

Since the theme of this meeting is "Institutional Strategies for Enhancing Undergraduate Science Education," I chose to address the question, Why is systemic reform in science education so difficult? Systemic reform requires changes in the institutions involved: schools, school districts, administrations, colleges, and universities. *They must themselves reform.* Systemic reform is also the issue that our NRC committee has found the most problematic in coming to agreement on recommendations.

What is meant by systemic reform? NRC staff members Karen Goldberg and Donna Gerardi compiled 17 definitions from the literature. Here are some examples:

- working with every aspect of the system
- fundamental change that cannot be made within the system
- total transformation of the way business is done from K–12 through higher education

These definitions show why reform is difficult: huge bureaucratic systems are hard to change.

Other definitions have political connotations that refer to specific programs, such as the National Science Foundation's Statewide Systemic Reform Initiative.

Another definition—one that seems easier to achieve—was "a vision, not one particular effort."

It is easy to have a vision. What is difficult is carrying it out. That calls for leadership. The recent NRC report *Fulfilling the Promise, Biology Education in the Nation's Schools* (funded in part by HHMI) argues forcefully that this leadership must come from the scientific community. The report quotes A. Bartlett Giamatti defining leadership[1]:

> Management is the capacity to handle multiple problems, neutralize various constituencies, motivate personnel; in [schools], it means hitting as well the actual budget at breakeven. Leadership, on the other hand, is an essentially moral act, not—as in most management—an essentially protective act. It is the assertion of a vision, not simply the exercise of a style: the moral courage to assert a vision of the institution in the future and the intellectual ener-

Systemic reform requires changes in the institutions involved: schools, school districts, administrations, colleges, and universities. They must themselves reform.

One can take advantage of our pluralistic educational system to change it piecemeal. From individual institutions, reform can spread through the whole system.

gy to persuade the community or the culture of the wisdom and validity of the vision. It is to make the vision practicable, and compelling.

As our NRC committee proceeded, we realized that the "system" doesn't have to be the whole system at first. Systemic reform can start with pieces: single departments, individual schools, a college, or a university. Thus, one can take advantage of our pluralistic educational system to change it piecemeal. From individual institutions, reform can spread through the whole system. Thus, I will use systemic reform to mean changes in institutions. Reform will be recognized when it becomes "self-sustained and independent of the initial program developers."

Is Science Education Reform Really So Difficult?

Yes—based on evidence that the same efforts at reform seem to be repeated over and over again. Here I draw on the writing of Paul Hurd, Professor of Science Education Emeritus at Stanford.[3] When asked what was the most common characteristic of all science reform efforts, Dr. Hurd replied, "Amnesia."

To illustrate the point, I will briefly paraphrase the conclusions from three national studies on science education in this century. Try to decide, if you will, when the reports were written: 1900–1930, 1930–1960, or 1960–1993?

Report 1

- More emphasis on reasoning rather than memorization.
- More attention to developing a "problem-solving attitude" and a "problem-raising attitude."
- More application of the subject to everyday life.
- More emphasis on the incompleteness of the subject and on great questions yet to be solved.
- Less coverage of material.

Report 2

- The prevalent form of laboratory activity must be replaced by genuine investigations.
- Beginning in the formative years of elementary school, substantially more time needs to be devoted to science.
- An orientation to human biology holds great promise both for sustaining students' interest in science and addressing a variety of educational goals important to society.

Report 3

- Facts acquired through a process of memorization have little value in problem-solving situations.
- Science teaching should contribute to the broader purposes of general education.
- The approaches, skills, and attitudes usually associated with scientific methodology are worthy objectives of science education.

At the program directors meeting, the audience's vote on the dates for each report was split almost equally among the

30-year intervals. But most participants thought the first report was the most recent. Actually, that report, by the Central Association of Science and Math Teachers, was published in 1910.[3] The second report, from *Fulfilling the Promise*, is dated 1990.[4] And the third report is from Dr. Hurd's overall summary of 1930s efforts.[5]

This similarity in recommendations over 90 years shows that the problem is not that we don't know what science education reform should be. Could the difficulty in implementing reform reflect a lack of motivation? Again, a look at previous reports suggests that this is unlikely.

In 1983 Terrel H. Bell, Secretary of Education, and the National Commission on Excellence in Education published *A Nation at Risk: the Imperative for Educational Reform*.[6] It opens with these stirring words:

> . . .the educational foundations of our society are presently being eroded by a rising tide of mediocrity that threatens our very future as a Nation and as a people. If an unfriendly foreign power had attempted to impose on America the mediocre educational performance that exists today we might well have viewed it as an act of war. As it stands we have allowed this to happen to ourselves, we have in effect been committing an act of unthinking, unilateral, educational disarmament.

Thomas Toch, in explaining why so little has changed since *A Nation at Risk*, points out that these words were written largely by Harvard physicist Gerald Holton and Nobel laureate Glenn Seaborg.[7] Since *A Nation at Risk*, there have been more than 350 national reports on science education. Nevertheless, in 1990 Glenn Seaborg had to write again,

> The nation is in the middle of an educational crisis; one of the worst crises it has ever faced. . . . scientists and mathematicians need to drop everything as they did 30 years ago and . . . find very different solutions from the ones we used before.[8]

But even this passion for reform and the threat of foreign

Figure 16. In his keynote address, Dr. Samuel Ward reviews ways in which undergraduate research and other programs are spearheading systemic reform in science education at the University of Arizona.

educational superiority are not new. In 1830 the English mathematician Charles Babbage wrote,

> It cannot [have] escaped the attention of those, whose acquirements enable them to judge, and who have opportunities of examining the state of science in England, particularly with respect to the more abstract sciences, we are much below other nations, not merely of equal rank, but below several even of inferior power."

From all this, it is clear that we know what has to be done and are motivated to do it—but nothing happens. As Sheila Tobias puts it,

> What is immediately striking about this "culture of reform" is how ardent and energetic reformers seem to be in inventing the new; yet how difficult reform is to implement, propagate, and sustain. They shake but nothing moves.[10]

How Come?

Let me approach this question by starting with some of the experiences of our NRC Committee on Biology Teacher Inservice Programs. The committee consisted of teachers, scientists, science administrators, and science educators. It was formed in response to recommendations of the NRC report *Fulfilling the Promise*:

> . . . we can't change science teaching fast enough by changing our schools of education, and our colleges who are training pre-service teachers. We need to help the teachers who are already teaching.[11]

This point is reinforced by the recent NSF study reporting the poor preparation in science of many science teachers.[12]

The scientific community, in our committee's view, must take a leadership role, as Seaborg advised and as recommended in *Fulfilling the Promise*. Our goal, then, was to prepare not just another study, but a specific guidebook on how to run programs, on how scientists can be most effectively involved, on what they must know about teachers and schools.

We reviewed more than 185 programs and tried to draw on our own experience to determine what worked best and why. Analyzing educational programs is a frustrating experience for an experimental scientist. Rigorous evaluation was lacking for most, so we relied heavily on questionnaires and participants' assessments. One fact was clear: that the more effective programs shared many common characteristics. For example, the scientists had worked with the teachers to develop a mutual respect and to learn what was really needed. They had followed up initial interactions and established partnerships with the teachers.

I tried to organize a draft as I would for a scientific paper: goals, methods, data, interpretation, conclusions. For a scientist it is natural to first identify the problem, state it clearly; then the approach to a solution is

often obvious. We identified potential sources of problems both for scientists and teachers and suggested ways to solve them. I thought we had prepared an excellent guidebook.

But the teachers and experienced administrators on the committee wouldn't approve the draft. They found the report too negative to be useful, too focused on the problems of teachers and scientists, and not pragmatic enough.

I was puzzled by this response until I realized suddenly that what they had told me was exactly what Sheila Tobias was saying in a section of *Revitalizing Undergraduate Science* entitled "Problem Hunting and Solution Finding":

> Trained in problem definition and problem solving, scientists inevitably bring the habits of doing science to the problem of reform. Thus, those who would reform science education often frame extremely complex issues in terms they are familiar with, namely, "problems" and "solutions." But reform is not a scientific enterprise. What problem hunting and problem solving may lead to instead is an oversimplification of solutions over more modest, incremental change. . . . since their thinking is in terms of solutions rather than strategies, their recommendations are not expressed as options, nor are they rooted in the pragmatic, the real, the here and now.
>
> . . . recommended changes are often out of context, both in terms of institutional limitations and the needs and abilities of the students and faculty they are supposed to serve. This indifference to context may also reflect the habits of doing science, for it appears to rest on an unexamined belief that, once articulated, the "right way" will be self-evident, teacher-proof, and appropriate for a wide variety of institutions.[13]

In contrast to the scientists' approach is the experience of NRC committee member Coleman Genn. Coleman succeeded in *systemic reform* within the New York City school system by taking over the worst school in East Harlem (3 percent graduation) and transforming it to a magnet school for math and science, so that in four years all students went to college. (His approach is described in *Miracle in East Harlem* by Fliegel and Macguire.[14]) Let me quote from a note that Coleman wrote to the NRC committee:

> Our main task in undertaking systemic change was to understand the dominant culture—its formal and informal structures that either facilitate or obstruct progress, and ultimately affect the enterprise. In East Harlem, we adopted a strategy of creative noncompliance, which became creative compliance as we gained control of the system. Our first step was the acquisition of knowledge. We lifted a useful metaphor from the scene in *Patton* where old George observes the advance of a tank column. The Germans approach in the expected order and position. Patton exclaims "Rommel—you bastard—I read your book." Fighting to change bureaucracies may not be as rough as World War II, but increased knowledge will lessen the waiting surprises and frustration.

When I asked Coleman how he changed a school to create

the Manhattan Academy for Science and Math, he said he first hired a large, strong assistant principal and went through the neighborhood to negotiate with the gangs so they wouldn't shoot his kids on the way to school. This is sensitivity to context.

Next, he stood on the steps of his school every day from 7:30 to 9:00 and greeted each student by name. He checked whether they had done their homework and, if not, sent them back home to do it, and then sent a staff member to check up. He also checked to see if they appeared to be on drugs and, if so, sent them home and followed up. This is leadership and vision.

Some Answers

The first answer, then, to why is reform so difficult? is that often scientists don't understand how to make it happen. Their own style of thinking can interfere when strategies are more important than solutions.

I will propose three more answers by focusing on the need for institutional reform in our universities. This will return us more specifically to the theme of today's meeting: "Institutional strategies for enhancing education."

The second answer: Reform in universities is difficult because we must change our goals fundamentally in teaching science, and this is hard for scientists.

This point of view was recently articulated most forcefully by David Goodstein, vice provost at California Institute of Technology. In an article entitled "Scientific Elites and Scientific Illiterates,"[15] he addresses the paradox that by comparison with numerous other countries, we have the worst science education system but the best scientists. To explain this he contends that the pipeline metaphor so popular for science education is flawed in its failure to account for exponential growth. A better metaphor, he says, is a diamond mine, where we crush tons of rock (students) to find a rough diamond (potential scientist) and then polish exquisitely. The more rock crushed, the more diamonds found, accounting for exponential increase in scientists.

Goodstein points out that a fundamental and permanent change must be expected: the demand for scientists cannot keep growing at the present rate. So we cannot just keep training scientists. As one can see clearly from the profiles of the programs described here, there are many ways to avoid crushing so much rock.

While the major objective of undergraduate and precollege programs, such as those of the Howard Hughes Medical Institute, is to increase the output of diamonds to go on to graduate

and medical school, what many of us have observed is that we are producing and polishing a much wider variety of gemstones. We must continue to change our science teaching to reach this larger number of students. How to do that better is one goal of a new NRC standing committee on undergraduate science education: Project on Science Literacy for All Undergraduates.

The third answer is that we often don't know how to go about changing our teaching.

Assuredly this program directors meeting flatly contradicts that statement. All of you are engaged in changing teaching. The ability to do so has been one of the major contributions of HHMI funding. But Donald Kennedy's comment in his oft-quoted 1990 address "Stanford in Its Second Century" is still true on the whole:

> We have not been very systematic about our quest to improve teaching, even though we value it highly and frequently do well at it. I am struck, for example, by the lack of conversation about what pedagogy means, and what makes it successful. It is our profession, yet it is mysteriously absent from our professional discourse. Here we are, engaged in an activity that is vital to ourselves, our students, and our public—yet we speak of how to do it, if at all, as though it had no data base, lacked a history, and offered no innovative challenges.[16]

As a department head I am working hard to change this, and I believe we are doing so; but I often marvel at how scientists, normally rigorous, can approach teaching so casually. I visualize a grant proposal for research written in the way some scientists approach the classroom. In the research plan, the specific aims would be vague and unmeasurable; the background section would be blank; and the experimental design might be justified by the statement "I've been doing this for 17 years, so I know what works."

Paul Hurd, in his summary of the difficulties of implementing reform, notes also that a major problem "has been a consistent failure to directly recognize that the measure of course improvement is to be found more in improved methods of teaching than in the re-assortment and realignment of subject content."[17]

The fourth answer is that our universities value research too much over teaching, so the institutional incentive to reform science education is feeble.

> At present the universities are as uncongenial to teaching as the Mojave Desert to a clutch of Druid Priests. If you want to restore a Druid Priesthood, you cannot do it by offering prizes for Druid-of-the-year. If you want Druids, you must grow forests.[18]

This is where I believe the HHMI grants for biology instruction, and NSF's increased funding for science education, have had the greatest impact. We are all aware of the impres-

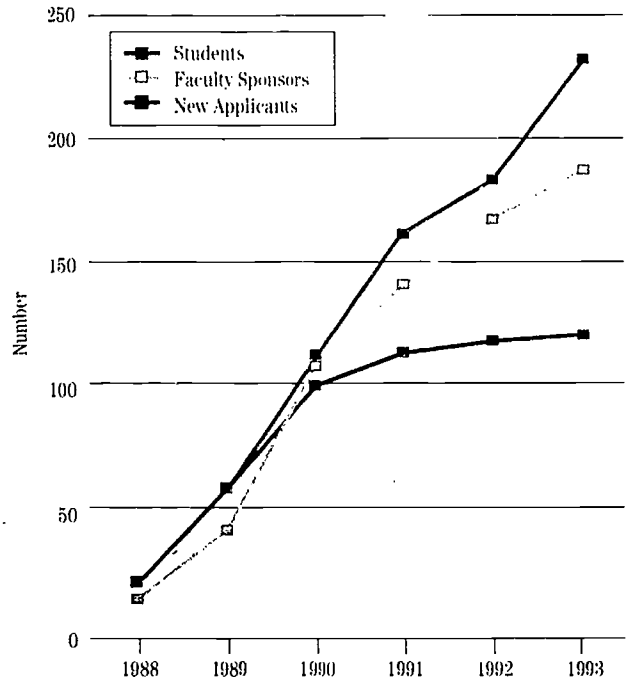


Figure 17. Growth in the Undergraduate Biology Research Program at the University of Arizona.

sive number of students, courses, and faculty that have been reached by the HHMI grants so far. Yet the numbers fail to bring out the most important impact of the Institute programs: the changing values on university campuses in favor of teaching. This, of course, is partly the direct effect of the grant funds themselves. As many of you have discovered, if you get an educational grant for a million dollars, your administration takes notice. But there is a more important indirect impact. When the Howard Hughes Medical Institute, with its prestige as a supporter of science, also supports education, it legitimizes teaching at colleges and universities everywhere. Legitimizing interest in education, as many of you are seeing, leads to major improvements throughout your educational program.

At the University of Arizona, we have a wide range of activities supported by our HHMI grant, but the centerpiece is our Undergraduate Biology Research Program (UBRP). This initiative was developed by Michael Wells, biochemistry department head, and is directed by Carol Bender. Interest in the program has grown explosively, particularly among faculty, so that we now have 185 faculty members from 37 departments participating. The number of accepted students has leveled off because of funding limitations, but applications continue to rise (Figure 17).

We believe there are a number of distinctive features that contribute to UBRP's success:

■ *Participation is restricted largely to UA undergraduates.* We have an excellent student body, including a large pool of Hispanics and some Native Americans. By focusing on our own students, UBRP can extend their research beyond a single summer to complete significant projects. The students have also developed a support network and created a campus-wide esprit de corps for the program.

■ *Students are recruited into the program early with a simple application process and must start in the summer.* This allows freshmen not fully committed to research to see if they like it by

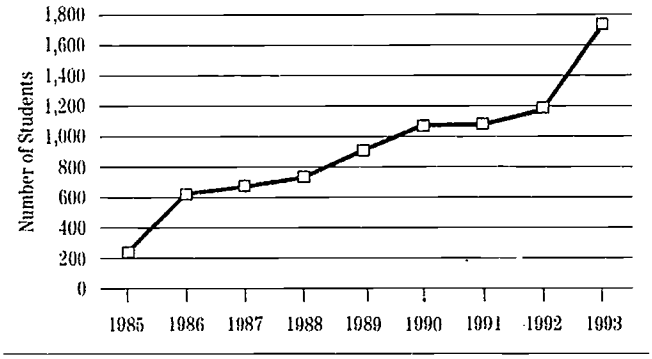


Figure 18. Biology 181 enrollment at the University of Arizona.

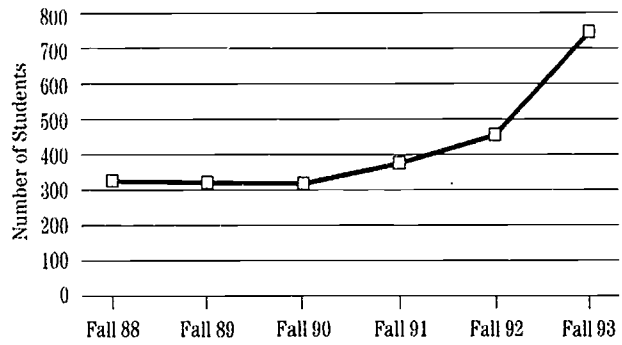


Figure 19. Increase in molecular and cellular biology and biochemistry majors at the University of Arizona.

immersing themselves full time between school years. One faculty member commented that this is an opportunity "for science students to see that knowledge is not just an exercise, but has an application." The summer student can continue research into the school year, which 80 percent do. As one student explained after the summer, "The work is fascinating. We've reached the point where we're beginning to characterize our protein. Stopping now would be like putting down a suspense novel with 50 pages to go!"

■ *Students select their faculty mentors.* After acceptance in the program, students themselves are responsible for finding a mentor to employ them. This empowers the student and fosters a compatible match between student and laboratory.

■ *Biology is broadly defined and includes faculty members from four Colleges—Engineering and Mines, Arts and Sciences, Medicine, and Pharmacy—and the School of Health-Related Professions.* Students can choose to work with any of 185 faculty sponsors from 37 departments. This has engendered several interdisciplinary projects and greater faculty awareness about other work going on.

■ *Faculty sponsors provide half of the students' pay and all of their supplies.* In addition to leveraging program resources to reach more students, this lends quality assurance because faculty members need external funding to afford a student. It also ensures faculty commitment to the student, since the faculty is investing discretionary funds in an undergraduate. Mechanisms have been found for additional departmental and grant support for students doing research in chronically underfunded areas, such as systematics.

■ *UBRP coordinates all undergraduate biology research experiences at UA.* This relieves the faculty of administrative paperwork and enables students to come to one place to see what is available.

The program has catalyzed interest in undergraduate

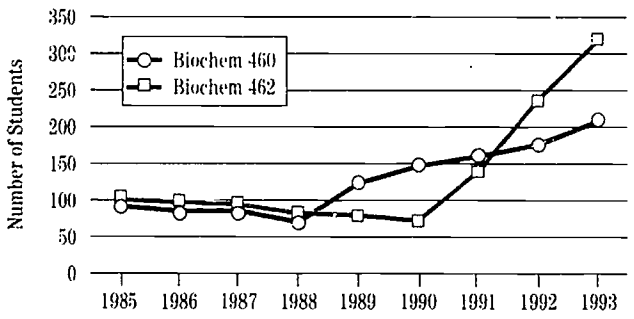


Figure 20. Enrollment in upper division biochemistry courses at the University of Arizona.

teaching throughout the campus, particularly among faculty members in the College of Medicine. These have become enthusiastic supporters, though they have no official responsibility for undergraduate teaching. From interviews with students and advisers, it is clear that interest in undergraduate teaching, reflected by faculty participation in UBRP, extends to the classroom as well. Like many other universities, we are seeing large enrollment increases in introductory biology (Biology 181) as well as in biology as a major and, thus, enrollment in upper-division courses (Figures 18–20). Some of this reflects the mounting interest in undergraduate education among the biology faculty.

The support from HHMI has also catalyzed other changes. For example, the Faculty of Science has developed new guidelines for promotion and tenure of faculty members who take a major role in outreach efforts.

Many of you have experienced similar increases in enrollment and improvements in undergraduate education. The real test for all of our improvements, if they are to be institutionalized and thus reflect systemic change, is whether they are sustained when you the initiators, and the HHMI funding, have moved on.

I have tried this evening to identify obstacles to systemic reform of science education and to describe some of the ways they are being overcome so that educational improvements may be lasting. Other programs described elsewhere in this report point to other ways to overcome such obstacles. In many places trees are indeed growing into forests.

The real test for all of our improvements . . . is whether they are sustained when you the initiators, and the HHMI funding, have moved on.

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Biographical Sketch ■ Samuel Ward

Samuel Ward is Professor and Head of the Department of Molecular and Cellular Biology and Professor of Ecology and Evolutionary Biology at the University of Arizona. He received his B.A. in chemistry from Princeton University and Ph.D. in biochemistry from the California Institute of Technology. After completing his postdoctoral studies at the MRC Laboratory of Molecular Biology in Cambridge, England, he was on the faculty at Harvard University and then the Department of Embryology at the Carnegie Institution of Washington. He was also Professor of Biology at Johns Hopkins University.

In 1988 Dr. Ward became head of the Department of Molecular and Cellular Biology at the University of Arizona, taking a greater role in teaching while continuing his research concerning genetic control of macromolecular assembly and cell morphology, and computer analysis of genomic information. He is the author of numerous papers and reviews appearing in scientific publications.

Throughout his academic and research career, Dr. Ward has been actively involved in education at all levels, from graduate and medical school, through undergraduate, and into the secondary and elementary levels. As a graduate student at the California Institute of Technology, in addition to his responsibilities teaching protein chemistry and neurobiology to undergraduates, he initiated a summer program that exposed 6th-grade students to molecular biology. As a faculty member at The Johns Hopkins University, he taught graduate and medical students in genetics, developmental biology, and other areas; developed and taught undergraduate courses from the introductory through upper-division levels; and taught evolutionary biology to high school science teachers in Baltimore.

More recently, Dr. Ward has played key roles in national ef-

forts aimed at strengthening science education. He is currently chairman of the Committee on Biology Teacher Inservice Programs, sponsored by the National Research Council of the National Academy of Sciences. This committee, made up of scientists, teachers, and administrators, has undertaken a study of programs to provide science teachers at the elementary and secondary levels with training in contemporary scientific principles and techniques. Dr. Ward also serves on the Executive Committee of the Coalition for Education in the Life Sciences (CELS) of the American Society for Microbiology, which is undertaking a major review of the undergraduate biology curriculum.

At the University of Arizona, Dr. Ward teaches introductory biology and cell biology and is director of a program supported by the Howard Hughes Medical Institute's Undergraduate Biological Sciences Education Program. The University's program which provides laboratory experiences for undergraduates primarily in faculty laboratories, has drawn a large number of faculty members from 35 campus departments at the University and Medical School, as well as off-campus sites, as faculty research sponsors. To date, over 400 undergraduates have participated in this program, which has been featured in *Science*. The University's outreach programs have provided a range of laboratory experiences for teachers and students from community colleges, including a Navajo tribal college in northern Arizona, and elementary and secondary schools in the Tucson area. To date, approximately 450 students, particularly females and underrepresented minority students, have benefited from these outreach initiatives.

Politics, Culture, and Tradition: Developing Strategies for Enhancing the Educational Experience of American Indian Students

Oklahoma State University ■ Alan R. Harker, Ph.D. ■ Myra Alexander

Oklahoma State University is developing a model for reaching into rural Native American tribal communities and helping students earn a degree in biological sciences. Dr. Harker described the strategies being used and the problems encountered. Ms. Alexander outlined cultural factors affecting the recruitment and retention of Native American students. Discussion revolved around the development of community support for science education, the influence of sports programs, and the effort to persuade talented underrepresented minority students to return to their communities after college.

Program Description

The HHMI-supported program, developed as a model for use across the state, is strongly integrated into the three tribal communities it now serves. The program seeks and receives much input from the communities through local advisory boards. Consequently, there is an unusually strong outreach component.

"We're trying to enter the community structure of the Native Americans and incorporate their ideas about their educational process into our program," Dr. Harker explained. The program is designed to bring students from the tribal communities to the University and help them complete a program in biological sciences. Those students, in turn, mentor younger students throughout the education system. Thus, the integration of community input and University outreach, particularly through student mentoring, propels the program in a spiraling fashion.

To improve the undergraduate experience of Native American students, the Oklahoma State program has adopted strategies involving instructional technology, problem-based instruction, hands-on experience, and personal attention. In choosing technologies for the classroom and laboratory, the focus is on those that can empower students to take over their own education. These may not necessarily be cutting-edge technologies. An example is the use of video microscopy, which enables groups of students to explore a specimen under a microscope, generates discussion, and allows them to digitally save what they have seen for later study.

The program also fosters the problem-solving approach to science education, exemplified in its 1992 summer camp for 8th and 9th graders. The curriculum was built around solving a real-life problem faced by the city of Cushing over effluent from its waste treatment plant. Students were divided into research groups with graduate-student advisers. "Basically, we turned

"We're trying to enter the community structure of the Native Americans and incorporate their ideas about their educational process into our program."

Figure 21. Dr. Alan Harker describes Institute-supported programs at Oklahoma State University.

the students loose on this problem," Dr. Harker remarked. "We were flexible enough to allow them to go any direction they chose." Groups explored microbiology, investigated water quality, constructed engineering models, interviewed government officials, and sampled public opinion. The students presented their final research results at a symposium.

A stipend-supported scholars program puts Native American students into research settings in their sophomore year or earlier. The most important strategy, however, may be the personal attention given to students, particularly a positive response to needs they express, Dr. Harker said. The program, for example, assumed sponsorship of the University chapter of the American Indian Science and Engineering Society. A tremendous change in the functioning of AISES and the way the students perceive themselves was apparent after the society was provided with an office and a university van for attending regional meetings.

The program still faces a number of problems, Dr. Harker said. The problem-solving approach is energy intensive, so class sizes have been limited. Faculty disagree in their perception of what is needed in laboratories. Faculty involvement has been difficult to achieve at a time of cutbacks across the campus. And the recruitment and retention of rural Native Americans into the sciences has also been difficult.

Ms. Alexander outlined several cultural factors that contribute to this difficulty. Nationally and locally, American Indians do not have a history of staying in school. Across the country, more than a third of the Indian population leaves school. Oklahoma has more Native Americans than any other state. They constitute 8 percent of its total population but comprise 12 percent of the dropout population.

Relations between Oklahoma tribes and the non-Indian population are often strained, owing in part to historical disagreements over federal and state policies, Ms. Alexander said. The resentment and mistrust lead to strained relations between some of the tribes and school districts. Tribal politics can hamper or enhance attempts to improve Indian education. Each of the school districts participating in

the program—Frontier, Ponca City, and Pawnee—has had differing situations.

Enrollment in Frontier is 54.5 percent American Indian, most of whom are of the Otoe-Missouria Tribe. Yet, the first Native American was only elected to the Frontier school board in 1992. "Very thick walls exist between the Indian community and the school," Ms. Alexander said. At times, tribal disagreement has spilled over into school board campaigns.

Inhabitants of metropolitan Ponca City have different concerns than Ponca Indian students bused in from White Eagle 7 miles to the south, a largely rural background. "The relationship between the tribe and Ponca City has been tenuous over the years," Ms. Alexander said. Indian enrollment comprises 11.7 percent at the elementary level but drops in high school to 5.1 percent.

At Pawnee city schools, in contrast, the tribe has a remarkably strong relationship with the school system, where Indians comprise 18 percent of the student population. Native American students participate in many extracurricular activities, such as athletics. In 1992–1993, only three Native American students left high school before graduating.

The program aims to provide experiences in public school classrooms that will inspire students and involve them in science. "The empowered community is the best facilitator toward that inspired experience," Ms. Alexander said. Each community works through its program advisory board. "Our understanding, relationships, and communication still need much work," she explained, "but some of these things are already beginning to come to pass." The Pawnee board has provided strong support for its students in the program; the other boards have showed varied levels of commitment.

Figure 22. Myra Alexander outlines her efforts to strengthen ties between Oklahoma State University and the neighboring Native American tribes.

Discussion

Participants asked several questions about community support for science education. Oklahoma State University is fortunate in having target communities with strong social structures and well-defined leadership. Through its

Figure 23. Dr. Joseph Neale, Georgetown University (*left*), and Dr. William Grant, North Carolina State University, exchange views on program development.

advisory boar s, the program seeks the par icipation of tribal leaders who can pull in the support of the Native American communities. This has been particularly effective with the Pawnee Tribe. In cases where this approach has been less effective, the University, through a variety of sources, has sought the help of knowledgeable individuals in the education community. Another program director supported this approach, noting that key parents in a community may be extremely helpful in getting broader participation in school programs.

Dr. Harker also emphasized the need for listening to the needs and expectations of community leaders. This effort, Ms. Alexander said, has won the trust of many Native Americans who are skeptical of outsiders. Yet other tribal leaders have apparently adopted a wait-and-see attitude before supporting the program. The enthusiastic response of students who attended the summer science camp is already helping change the attitudes of some community leaders. As the program continues to demonstrate its importance, the program will generate more community support, especially when more Native American leaders become involved, Ms. Alexander added.

Participants asked whether sports might help to recruit Native American students to college. It was agreed that sports do help in recruiting and retaining minority students in college, but it was questionable to what extent. At the precollege level, sports may present a conflict, Dr. Harker said, because summer sports camps prevent many students, particularly males, from attending science camps. When coaches teach mathematics and

science, the quality of instruction frequently suffers.

Many participants wondered about the effect of higher education on the well-being of Native Americans and other underrepresented minority groups, noting that in the past many of the brightest students went away to college and never returned to work in their community. Ms. Alexander agreed that obtaining a higher education and a professional job outside the tribal community are often seen as the only hope for Native Americans.

Dr. Harker also noted that the Oklahoma State program seeks to build tribal well-being in two ways. It recruits rural Native Americans who have maintained strong ties with the tribe and are likely to return. And the program seeks Indians within the tribal community who have started, but not yet completed, a higher education. The program hopes to help them finish their education, since they have already demonstrated a strong commitment to the community.

Access to Science Education Opportunities for Students from Traditionally Underrepresented Groups

California State University–Los Angeles ■ Alan Muchlinski, Ph.D. ■ Margaret Jefferson, Ph.D.

The presentations by Dr. Muchlinski and Dr. Jefferson focused on activities in student development and curriculum development funded by the Institute grant. The grant also supports activities in the area of outreach. The discussion centered on means of obtaining faculty support for the program and its relationship to other activities at the University.

Program Description

Background. The University's student population mirrors the diversity of the communities that surround the campus—the Hispanic area of east Los Angeles, the predominantly African-American population of the south-central city, and the Asians who reside in the San Gabriel Valley. At an average age of 25, the students are older than most college students, almost 60 percent are women, and many work to earn money for college or to support a family.

The University's experience in meeting the needs of such a diverse population is reflected in its minority science education initiative, designed to provide access to science education for students from groups that have been traditionally underrepresented in science.

Minority Science Program. Dr. Jefferson gave an overview of the Minority Science Program (MSP) and the Summer Science Bridge Program (SSBP). With Raymond Garcia, Ph.D., Associate Professor of Biochemistry, Dr. Jefferson serves as co-director of both programs. The main objective of the MSP is to improve the retention rates of minority students in freshman science and mathematics courses. The core of the program is the Science Orientation course, where students are divided into small groups according to their enrolled courses. They are guided by a peer mentor, usually another minority student, who focuses on the development of skills, with special emphasis on problem solving, communication, and study skills. Improving proficiency in mathematics is a priority, because advanced mathematics is required to graduate in science. Counseling is important, to ensure that students enroll in the appropriate mathematics courses.

Recruitment strategies include mailings and phone calls to students enrolled in freshman biology, chemistry, physics, and mathematics courses, as well as other students who are identified through faculty referrals or word of mouth. In the two years of Institute funding, the number of student participants has more than doubled, with a slight decrease in minorities and an increase in women.

Summer Science Bridge Program. The Summer Science Bridge Program is a two-week, 80-hour, summer-quarter program for students who will enter the University in the fall quarter. It recruits participants from entering science majors and through outreach program referrals and presentations to local high schools and community colleges.

The bridge program feeds into the Minority Science Program and helps guide students through the transition from high school or community college. The majority of participants are first-time freshmen. The bridge program includes tours and presentations to familiarize students with the science department and the campus, but its primary purposes are to assess student skills in English, mathematics, and computer science and to advise the new students on course selection.

In conducting the assessments, faculty members review academic transcripts and records, administer diagnostic exams, and talk individually with students, who are asked to identify the skills they wish to improve. The students in the bridge program attend freshman-level lectures and workshops, take tests, and learn about financial aid, which is a concern for many. Another important element is contact with previous SSBP students, who give presentations about their experiences with the program and as freshmen.

From the first to the second year of the bridge program, participation rose dramatically, minority participation increased, and the percentage of women decreased. The number of faculty participants more than doubled.

Dr. Jefferson briefly described the Biomedical Professional Development Program (BPDP), a new initiative that will help connect the Minority Science Program to upper division science programs through freshman and sophomore research projects. The BPDP is being funded by a second Institute grant. It is anticipated that 16 students selected from the MSP will be supported for two years, after which they will receive funding from another source, such as Minority Biomedical Research Support of the National Institutes of Health or the National Science Foundation's Research Improvement for Minority Institutions.

While many of these students initially place at the precollege level in algebra, and only 17 percent place in calculus, by the end of their freshman year, nearly all had completed the required mathematics entrance exams as well as the prerequisite and required courses. Moreover, their grade point averages were slightly higher than the average GPA of all the students enrolled in freshman biology, chemistry, and college algebra.

Videodisc Laboratory. Dr. Muchlinski reported on the establishment of a videodisc

Figure 24. Drs. Alan Muchlinski and Margaret Jefferson, of California State University–Los Angeles, respond to questions on their bridge program for prefreshmen.

technology laboratory in January 1993. This facility allows freshman biology students to study laboratory materials in their free time. Animal and plant biology students use the *Biology Encyclopedia Videodisc*, produced by Harper/Collins Publishing Co. and Carolina Biological Supply Co. The laboratory also is available for three upper division courses: embryology students use the *Embryology Videodisc* by Optical Data Corporation at California Lutheran University, and histology and neurology students use the *Slice of Life VI Videodisc* from the University of Utah. Dr. Muchlinski said that one limitation of using videodiscs is that they do not present the exact materials used in the teaching laboratory. He and his colleagues are transferring selected material from their own laboratory collections onto compact discs so that students will see images of the slides and organisms presented in the laboratory class.

According to Dr. Muchlinski, the videodisc laboratory is particularly effective in promoting group study and facilitating access to material. The lab has 10 work stations, is open 30 hours a week, and is staffed by student assistants. The majority of students from the introductory biology courses visited the lab from 2 to 5 times, and a significant number of upper-division embryology students visited 6 to 10 times. Student feedback indicates that the majority of students think the videodisc lab is an important resource. However, Dr. Muchlinski said, it is not intended as a substitute for laboratory experience, particularly in the upper division courses, where students have more access to materials in the teaching laboratory.

Outreach Programs. Dr. Muchlinski briefly described two outreach programs funded by the Institute grant. In the elemen-

tary program, undergraduate science students—many of whom are minority and bilingual—are trained to present physical science "demonstration boxes" in elementary school classrooms. Topics include weather phenomena, oxidation and combustion, and chromatography. Last year, the program visited 26 elementary schools, and over 3,300 students saw the demonstrations.

High school students were brought to the campus for a day to learn about the department of biology and microbiology, and the department of chemistry and biochemistry. During their visit, students heard about careers in these fields, viewed teaching laboratories and science demonstrations, and engaged in "hands-on" experiments. Approximately 900 students participated last year.

Discussion

Commenting that the minority access programs require a large investment of faculty and administrative time, a participant asked what incentives the University offers to ensure faculty involvement. Dr. Jefferson said that the science faculty in general are personally committed to the MSP and SSBP programs, and she described her own enjoyment and satisfaction in advising students and seeing them succeed. Faculty involvement in student assessment and counseling is considered in retention and tenure decisions, she said. This indicates support of the administration and proves to be a strong incentive.

Dr. Jefferson further observed that the time demands are not necessarily as monumental as they might seem at first. For example, the SSBP requires as little as a one-hour commitment from faculty, and participation in the programs is offset by a release from some minor departmental assignments. Having a co-director has been enormously helpful to her, she said.

Participants asked how the SSBP is connected to the general summer orientation program for incoming University students. Dr. Jefferson replied that although there is some overlap between these programs, a separate bridge program is needed for a number of reasons. The fact that the orientation program does not advise science students to begin taking mathematics in their freshman year makes it difficult for many of them to complete the required mathematics courses before graduation.

Another participant said that students who enter his institution with precollege levels of math skills almost never succeed as science majors. He asked Dr. Jefferson whether this was true at the University. She indicated that the program has not been in existence long enough to be able to produce hard data, but she believes their experience will be different. Among other things,

Faculty involvement in student assessment and counseling is considered in retention and tenure decisions . . . This indicates support of the administration and proves to be a strong incentive.

she said, students with precollege placement in mathematics have been helped by the strong network that provided student-to-student contact and support. She added that students who try to take chemistry or advanced biology without adequate math preparation often drop out of science. Correcting the situation means more courses and taking longer to graduate, a real problem for students who already are on a part-time schedule and have a significant workload.

Students also become frustrated if they are not able to enroll in a particular course in the prescribed sequence, a situation which one attendee said is being exacerbated by cutbacks in state funding. Dr. Jefferson repeated that the solution lies in advising students as to which courses to take in the early years so they will not find that they should have taken other courses to graduate. Dr. Muchlinski added that students who preregister experience less frustration.

In response to another inquiry, Dr. Jefferson said that the University has approximately 400 majors in biology, 500 in computer science, 50 in chemistry, and 10 each in physics and geology.

Constructing an Interdisciplinary Major in Biochemistry and Molecular Biology

Gettysburg College ■ Ralph A. Sorensen, Ph.D.

In his presentation, Dr. Sorensen described the development of an interdisciplinary program in biochemistry and molecular biology at Gettysburg College. Students are benefiting from this new and challenging curriculum as well as from the teaching skills of two faculty members recruited with HHMI support. Moreover, the program has engendered additional cooperation between the chemistry and biology departments.

Program Description

The HHMI grant played a catalytic role in bringing the chemistry and biology departments at Gettysburg College into a closer, more cooperative alignment, said Dr. Sorensen. These two departments hired two new faculty members, one in each department, equipped laboratories, started a summer program, and quickly designed the essential features of a new major in biochemistry and molecular biology.

Dr. Sorensen described the development of the biochemistry program linking the two departments. Some of the activity quickly centered on devising the course requirements for a rigorous new program, one that would not only satisfy faculty members from the two departments but also would be in keeping with the liberal arts tradition at the College.

The new major specifies 17 required courses in biology, chemistry, mathematics, and physics, including an independent research project with a supervisor from either the biology or chemistry department during a student's senior year. Several faculty groups at first expressed concern because the proposed major appeared to absorb too much of a student's time. They soon were convinced, however, that the program actually leaves more room for electives than did earlier ad hoc versions of a dual biology and chemistry major. Moreover, the breadth of education for anyone enrolling in this major proves far greater than that for most students majoring in the humanities and social sciences, who are required to take only two science courses during their four years at Gettysburg, Dr. Sorensen pointed out.

Approved late in 1992, the new biochemistry and molecular biology major already is attracting a number of high-quality students, according to Dr. Sorensen. In addition, it has brought a new emphasis on cooperative activity between members of the science faculty, such as sharing equipment and facilities, and exchanging ideas about research and the training of undergraduates.

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Figure 25. Dr. Ralph Sorensen describes Gettysburg's new interdisciplinary course in biology and chemistry.

Discussion

During the discussion Dr. Sorensen emphasized that the two new faculty members appointed under the HHMI grant have done much to establish the new sense of cooperation between the chemistry and biology departments. He noted that the appointees—Dr. Koren Holland, Assistant Professor of Chemistry, and Dr. Steven James, Assistant Professor of Biology—have brought fresh perspectives to enhancing the science curriculum and new opportunities for student research.

One program director asked whether the new interdisciplinary program means that students who elect such a major may have no departmental "home." Dr. Sorensen replied that he hoped students would develop a kinship for both the biology and chemistry departments. These departments are housed in separate buildings, however, making it difficult for biochemistry students to establish a base in both.

Another participant noted that, at her college, students do not declare a major until they reach the junior year, allowing them to think more in terms of a concentration in biology or chemistry. Another participant said that, at his liberal arts college, students who are interested in pursuing an interdisciplinary science degree are often erroneously advised to commit early to either a biology or chemistry major. He suggested that improved advising, particularly for incoming students, could significantly increase the numbers of students in biochemistry.

Dr. Sorensen agreed, adding that the science faculty at Gettysburg currently recommends that entering students take both chemistry and biology in their first year if they feel confident of their commitment as well as their ability to cope with the course

load. He said that the departments are seeing a marked increase in the number of students who enroll in both biology and chemistry courses at the introductory level. Dr. Sorenson thought that this was largely due to an increase in student interest in biology nationally, and partly due to the attractiveness of this new major.

Program directors discussed the potential for a crowded curriculum for students pursuing a biochemistry or joint biology-chemistry degree. One concern centered on the breadth of a liberal arts education for undergraduate science majors and ensuring that students can maintain an appropriate balance of science and humanities courses. Discussants noted that widely held perceptions of science majors taking a narrow range of science courses, to the exclusion of other areas, are usually incorrect. One program director cited data showing that the range of courses in which science majors enroll is at least as broad as, and often broader than, that of humanities students.

The misperception of science majors as too narrowly focused in the sciences often discourages talented students from pursuing the sciences, program directors noted. In addition, negative stereotypes of scientists can result in peer pressure that may dissuade students from pursuing science studies. Because of this pressure, many students who show potential for science do not even attempt science courses, and others who have begun a science major may drop out.

At Gettysburg College, Dr. Sorensen noted, efforts are under way to counteract this negative peer pressure. Central to this effort is developing camaraderie and social interaction in the laboratories, where students can establish an identity and personal relationships as well as strengthen research skills. The primary source of this interaction is the requirement of a senior research project for the B.S. degree.

Program directors discussed barriers to cooperation between the biology and chemistry departments at their institutions. A participant described the particular difficulties of establishing effective collaboration at his institution, where the chemistry department and biochemistry departments at the undergraduate college, the medical school, and the college of agriculture have been unable to resolve differences in course content and curriculum. The recruitment of new faculty members and ongoing discussions suggest that needed changes will be made. In all but formal terms, the program director said, these departmental walls have disappeared and the students will be able to pursue a modern curriculum that reflects the developments in the field.

Economic pressures can force departments to resolve such differences, a program director sug-

gested. He noted that at his institution, the faculty agreed to make the science curriculum uniform when they recognized that they would be teaching twice as much because of budget cutbacks if they did not. Accordingly, most of the barriers to collaboration among the fields of biochemistry, molecular biology, and microbiology have now disappeared on his campus.

Although these distinctions among scientific fields may be fading, the barriers between traditional chemists and modern biologists sometimes remain intact, usually to the disadvantage of students. One potential problem noted by a program director from a liberal arts college is that students from one discipline may receive negative messages about that field from faculty members in the other field.

Other participants noted that courses in organic and physical chemistry have frequently proven to be insurmountable obstacles to biology majors continuing in their studies. Progress is being made, however, against this once intractable problem. A program director from a major public research university described efforts at his institution on the part of organic chemists to overcome these obstacles. An important first step, another faculty member said, is recognition of the problem on the part of all faculty members concerned and awareness that science faculty must work together to ensure that bright, talented students are encouraged to advance in the sciences.

Enhancement of Biology Curricula Through Course and Faculty Development and High School Enrichment

Spelman College ■ Pamela J. Gunter-Smith, Ph.D. ■ Jann Primus, Ph.D.

Dr. Gunter-Smith began with an overview of activities designed to increase scientific competence and literacy of all students, including minority students underrepresented in the sciences. Dr. Primus addressed how Spelman College integrates its efforts with those of other research institutions to provide off-campus research opportunities for its undergraduate students while conducting outreach programs to benefit students and teachers in local schools. Following the description of programs, participants exchanged information about successful outreach programs and off-site research opportunities for students.

Program Description

Dr. Pamela J. Gunter-Smith, Professor of Biology and Chair of the Biology Department, presented an overview of activities supported by the Institute's grant to Spelman College. Two broad goals of the program are to provide undergraduates with opportunities leading to careers in biomedical science and to increase the science competency of all students in general. Program components include the development and integration of science curricula, summer research opportunities for undergraduates, faculty development including linkages to major research institutions and cooperative research projects, and outreach to local high schools.

About one-third of all students at the College major in science, and one-quarter of the science students are included in the biology major. Students often enter with a strong interest in medicine; they are less familiar with biomedical research as a career. Currently, the introductory biology course for science majors is undergoing extensive revision. The revised science curriculum will stress concepts, emphasize problem-solving with the help of peer tutors, and involve the use of undergraduate teaching assistants. Assistants are now being trained so that they can better aid their peers. Additional sites for summer research are being added to enable students to become involved as early as possible with research.

Five existing courses have been evaluated by visiting professors during the 1992–1993 academic year. Dr. David Nelson, Professor of Biochemistry at the University of Wisconsin at Madison, evaluated genetics, cell and molecular biology, and biomolecules. He suggested that in planning the curriculum for the next 5 to 10 years, consideration be given to the evolving overlap between them in order to avoid duplication. Dr. Lafayette Frederick, Professor of Botany at Howard University, reviewed the

Figure 26. Drs. Jann Primus (*left*) and Pamela Gunter-Smith tell about their experiences in developing programs to attract and retain minority women in science at Spelman College.

College's general botany course. The fifth course, microbiology, was reviewed by Dr. Linda Fisher of the University of Michigan at Dearborn.

Program successes include the enhancement of laboratory resources, the recruitment of new faculty, including a neurobiologist, increased numbers of undergraduates participating in research, and the development of linkages to local high schools. Workshops for middle and high school teachers and their students have also enhanced outreach efforts.

Dr. Primus noted that a plan to provide high school teachers with summer research experience did not generate enough local interest to be carried out. Lack of time, a common issue for high school teachers, may have been the problem. The College is considering whether to offer the program again.

In addition, she said, the College is seeking closer interactions with other institutions where its undergraduates are sent for summer research experiences. Examples of institutions to which Spelman College students were sent included Georgia State University, Meharry Medical College, Naval Research Laboratory, the National Institutes of Health, Morehouse School of Medicine, Merck and Company, Baylor College of Medicine, Brown University, Case Western Reserve University, Chicago Board of Health, Emory University, Massachusetts Institute of Technology, Princeton University, Roswell Park Cancer Institute, United States Surgical Corporation, University of Maryland School of Medicine, University of Michigan School of Medicine, University of Pennsylvania, University of Rochester, Upjohn Laboratories, and Vanderbilt University.

In the summer of 1992, the College placed 29 biology majors in a total of 21 educational, governmental, and corporate sites. Students' entry into research programs was facilitated by the Director of the Spelman College–Howard Hughes Program and the Director of the Office of Science, Engineering and Technical Careers. When students return to the College for the fall semester, they are expected to furnish either abstracts or full reports of their research projects.

Current efforts are to provide more opportunities for student research on campus by focusing on faculty development and building a research infrastructure that would allow faculty and students to work jointly on research projects for up to three months. For example, Dr. Victor Ibeanusi, an environmental biologist, received support from the Institute's grant to conduct summer research. Eight students assisted with his investigations on the appropriate environmental conditions and mechanisms for remedying environmental hazards with biological systems.

Although the College works with science coordinators in the local schools, close grass-root interactions between faculty and teachers appear to be particularly useful. Faculty involvement is also important for the footlocker and other outreach programs.

A video of students from Spelman College discussing their recent research experiences highlighted some of the impacts of the program. In the videotape, 11 students from Spelman College participating in a Research Roundtable speak of their successes in gathering cutting-edge data through use of modern techniques and state-of-the-art equipment. Each praised her preceptor for encouragement, display of sensitivity, and creation of a pleasant environment conducive to the project.

Discussion

One participant asked whether programs such as Upward Bound could be used to recruit students. While such programs may prove useful, the key factor appears to be the development of strong personal relationships with teachers and others in the schools to help identify students who might benefit most from interaction with Spelman College.

One program director noted that rapport with science teachers can be developed through state science associations, by having a faculty member participate on a board that certifies science teachers, and by loaning science equipment to schools. Another participant observed that inviting science coordinators to visit the campus and meet faculty can also aid in recruiting students underrepresented in the sciences.

Science workshops for teachers in the community appear to

be particularly valuable. Spelman College offers a workshop for 7th- to 12th-grade teachers twice a year. Successful workshops require close attention to the stated needs of the teachers in the community and active faculty participation. Younger teachers may prefer receiving academic credit, whereas more experienced teachers may prefer a stipend.

The need to involve teachers in planning activities early on was emphasized by some program directors. Several suggested the appointment of teachers to planning or local advisory boards. Having faculty spend time in public school classrooms was also mentioned as a valuable aid to promoting greater interaction between the two groups of educators. One participant noted that the best advertising for outreach programs was word of mouth from students who had participated and found them to be a good experience.

Outreach programs that lend equipment to schools in the community can be particularly valuable. One attendee noted that a committee of teachers can decide on the focus of the program for elementary and middle school students and set priorities for equipment to be purchased. A shortage of funds in the schools may limit the purchase of even the simplest items such as batteries and cooking oil. Supplies and equipment can often be distributed through normal channels. Once the materials are in the schools, teachers need to be shown how to use equipment. If teachers are afraid they will break the equipment, it may not be fully utilized.

One participant suggested that teachers describe their experiences at teacher workshops. About 80 percent of the participants in these workshops use the ideas presented by their fellow teachers in their own classrooms. Another participant recommended compensating schools for released time for teachers and identifying national corporations to donate equipment that can be lent to the schools. The National Science Teachers Association mailing lists are helpful in identifying science teachers in a particular area.

One participant asked what criteria should be used for placing students in off-site research programs, and whether institutions can ensure that students will return to the campus once the off-site research is completed.

Another participant said she did not fear the loss of these students because her institution nurtured women and provided them with significantly valuable intangibles. She also found that Institute funds were particularly useful in helping overcome the difficulties of placing inexperienced freshmen and sophomores in student research programs.

How students respond to an experience in science research depends, in part, on the creation of a close, working relationship

with a faculty mentor. Many students, especially those from underrepresented minority groups, may have had limited opportunities with scientists and may be less willing to consider a research career. Interactions with faculty role models can often help dispel misunderstandings and promote interest in a career in science among students from underrepresented minority groups. Researchers from other institutions are brought to Spelman College as guest lecturers and potential contacts from off-campus sites where students could be placed for summer research.

The undergraduate teaching assistant program in the Biology Department at Spelman has become highly competitive, and a training program has been instituted for participants. Teaching assistants gain experience through mandatory training sessions the week before the laboratory exercise. They run through the experiment again even though they have previously taken the course. Instructors develop rapport with the teaching assistants in the laboratory. The instructor also helps the teaching assistants learn how to teach students. Teaching assistants are paid for the training sessions and for time in the laboratory.

Some minority high school students apply to historically black colleges and universities, which present an academic environment that students may feel is more supportive. Precollege programs at Spelman College, particularly for high school seniors, seek to make students underrepresented in the sciences more confident of their own skills. The outreach programs are not used to recruit students but to provide them with a valuable enrichment experience in the sciences. Through the program, students learn to think critically and logically. Through the summer programs they often form close bonds with other student participants.

Interactions with faculty role models can often help dispel misunderstandings and promote interest in a career in science among students from underrepresented minority groups.

The Integration of Chemistry, Cell Biology, Genetics, and Physiology in the Undergraduate Biology Curriculum

University of Notre Dame ■ John G. Duman, Ph.D. ■ Morton S. Fuchs, Ph.D.

The major component of the HHMI-funded program at the University of Notre Dame is four new courses—bio-organic chemistry, cell biology, genetics, and physiology—that integrate chemistry and biology. Drs. Duman and Fuchs described the courses, the problems that led to their development, and other components of the program. During the discussion, the participants explored the difficulty of deciding what to include in integrated biology courses. They also discussed the uneven high school preparation of freshman students and strategies to cope with it.

Program Description

The idea to develop separate courses for biology and biochemistry majors grew out of differences between the course sequence followed by these students and that followed by premedical and other preprofessional students. Previously, they all took many of the same biology and chemistry courses, according to Dr. Fuchs. In addition, the two-semester organic chemistry course presented so few biological examples that biology majors found little relevance in it. "Any resemblance between organic chemistry and biology was purely coincidental," he said. Consequently, the University's program developed a two-semester bio-organic chemistry course for the sophomore year as well as integrated genetics and cell biology courses, and an integrated comparative physiology course for the junior year. Biology and biochemistry majors will take these courses.

The bio-organic chemistry course includes a four-credit lecture and a one-credit laboratory. "The point is to teach organic principles and, where you can, use biological examples," said Dr. Duman. For example, in teaching stereochemistry, the instructor includes amino acids, carbohydrates, and enzyme and substrate relationships. The laboratories consist of biological types of processes. The course uses an organic chemistry text and a biochemistry text because no unified textbook was available.

The new genetics and cell biology courses have been integrated to eliminate much of the duplication found in the conventional courses. Thus there is time for more thorough topic coverage, and the research and problem-solving orientation of these disciplines is enhanced. In addition, molecular biology has been integrated into the courses where possible.

The genetics and cell biology laboratories emphasize problem-solving and the use of modern techniques and equipment, addressing a long-standing problem of laboratories that merely demonstrate phenomena with outdated equipment. "It's important to turn out students who ... are

The new genetics and cell biology courses have been integrated to eliminate much of the duplication found in the conventional courses. Thus there is time for more thorough topic coverage, and the research and problem-solving orientation of these disciplines is enhanced.

knowledgeable when they go into a research setting," Dr. Duman explained. The genetics laboratory is taught by an instructor who works on the *retinal degeneration-B* gene of *Drosophila*. This system will be used as a teaching tool to illustrate approaches to problem-solving and simultaneously teach students the basic techniques used in a genetics laboratory.

The new comparative physiology course being developed involves a four-credit lecture in the fall and a two-credit laboratory in the spring. Much more molecular biology and biochemistry is integrated into the new course than is found in traditional physiology courses.

In its student development component, the HHMI-funded program provided summer research opportunities for students from Notre Dame and from four other institutions with special relationships to the University: Xavier University of Louisiana in New Orleans and Clark Atlanta University (Georgia), which are historically black, and St. Mary's of San Antonio and St. Edward's in Austin, which have large Hispanic populations. The summer research program was launched in 1992. "We're not getting many underrepresented minority students into the summer program," Dr. Duman remarked. "We'll have to work on that." But, he added, "the quality of the students who have participated has been excellen. "

The outreach component of the Notre Dame program brings high school science teachers to the campus during the summer. The program stresses the integration of chemistry and biology and provides the teachers, most of whom have never done research, with a research experience. The point is to give them a sense of how research is done, which they can take back and impart to their high school students.

Discussion

Participants devoted considerable time to discussing what should be taught in biology courses. How should information, topics, and concepts be selected for integrated courses? What is the minimal amount of information that should be included? What should be the balance between the teaching of concepts and processes?

One way to handle the burgeoning quantity of information in biology would be to add another lecture to the course, Dr. Duman said. Another way might be to extend the time for a bachelor's degree in biology from four years to five. He also proposed establishing a core curriculum in biology, a step that would reduce repetition of some topics and allow more time for others. Another program director proposed a dual approach—information and concepts can be taught rather effectively to large groups, but problem solving and critical thinking are best taught in small groups. Dr. Duman suggested this might be

Figure 27. Drs. Morton Fuchs (*left*) and John Duman respond to questions about new undergraduate courses at Notre Dame that integrate areas of chemistry with modern biology.

accomplished through lectures combined with discussion sessions that focus on research or problem solving.

Dr. Duman also stressed the need to ensure that students be given a certain baseline of information in each course. Another participant added that having an orderly progression of courses with established content, even if it changes each semester, is important for reducing repetition.

Participants did agree that a certain amount of information should be imparted in a biology course. But no consensus was reached on the volume of that information or how to select it.

The participants were also concerned about the freshman year problem: uneven high school preparation and differing expectations of students entering their first year of college. Students may not have the background in chemistry needed for some of the introductory biology courses. Participants proposed a variety of solutions, usually structuring course progressions to allow time for students to complete college-level chemistry.

At Notre Dame, the Department of Biological Sciences is considering a first-year course in evolution and classical population genetics, which do not require much chemistry, Dr. Fuchs said. Biology courses requiring more chemistry (i.e., cell biology) would begin in the sophomore year, after students have completed their freshman year of chemistry.

One participant noted that his department offers the first biology course in the second freshman semester, after the students have completed one semester of chemistry. Another participant said his department offers a course on genetics and evolution in the second freshman semester. The course deals with Mendelian genetics, basics of cell biology, and

Figure 28. Dr. Donald Mitchell, Professor of Chemistry at Juniata College (left), and David Howe, a teacher at Lewistown High School, demonstrate modern biological equipment used by high school teachers in Juniata's outreach program.

fundamental principles of evolution and does not require a tremendous amount of chemistry.

Another program director suggested reversing the order of the freshman biology course so that evolution and ecology, which require little chemistry, are offered in the first semester. Still another director said his department starts the freshman year with a biological-organic chemistry course and with specialized organismic-level biology courses, which require little chemistry, develop observational skills, and familiarize students with plants and animals.

A problem with resequencing freshman-year courses is that some students prefer not to take ecology or organismic biology until their junior year, commented a participant. Another added that some students consider switching from biology to biochemistry because they are not getting the type of biology they want during the first year. Dr. Fuchs noted that many students are excited about genetics by reports in the newspaper, and a number of them entering biology avoid organismic courses, preferring to focus early on genetics. He suggested that such students be provided a broad exposure to biology in their introductory years rather than specializing early in topics related to genetic engineering.

One participant said his department hopes to solve the first-year problem by offering freshmen in the life sciences an introductory seminar taught by faculty members as well as a course in genetics and evolution. For the seminars, students meet in groups of 20 to 25, study fundamental principles of biology, are shown how biology relates to other disciplines, and tour laboratories where they might do undergraduate research. The major drawback is that with 500 to 700 students, the freshman seminars can take a great deal of faculty time.

DEMONSTRATIONS OF EDUCATIONAL TECHNOLOGY IN THE LIFE SCIENCES

In recognition of the increasingly important role of educational technology in undergraduate life sciences education, the Howard Hughes Medical Institute invited program directors to demonstrate at the meeting computer simulations, interactive learning modules, and other such materials developed as part of their Institute programs. The demonstrations listed below represent a portion of the instructional technology developed through the undergraduate program. Additional such materials are presented in the Profiles section of this report and in the 1992 program directors meeting report entitled *Enriching the Undergraduate Laboratory Experience*. Program directors may be contacted directly for further information.

Demonstration	**Presenter**
Science Van Outreach Program: Teacher Training, Experiments, and Equipment for High School Biology Classrooms	Donald J. Mitchell, Ph.D. Professor of Chemistry Director of Outreach Program Department of Chemistry Juniata College Huntington, PA 16652-2119 (814) 643-4310 (814) 643-3620 (fax)
"Cells: Islands of Order in a Sea of Chaos." An Animated Software Program in Biochemistry and Cell Biology	Robert W. Mead, Ph.D. Associate Dean College of Arts and Sciences University of Nevada, Reno Reno, NV 89557-0008 (702) 784-6155 (702) 784-1478 (fax)
A Medical Genetics Software Program for Promoting a Research Approach to Undergraduate Science Education	John R. Jungck, Ph.D Professor and Chairman Department of Biology Beloit College 700 College Street Beloit, WI 53511-5595 (608) 363-2267 (608) 363-2718 (fax)
From Segregation to Mapping: An Interactive Software Program in Mendelian Genetics	R. William Marks, Ph.D. Associate Professor Department of Biology Villanova University Villanova, PA 19805-1699 (215) 519-4863 (215) 519-7863 (fax)
An Interactive Computer Program for Training Undergraduates for Peer Tutoring in Science and Mathematics	Mary E. McKelvey, Ph.D. Professor and Chair Department of Biology Fisk University 1000 17th Avenue North Nashville, TN 37208-3051 (615) 329-8796 (615) 329-8758 (fax)

Computer Animation of Central Processes in the Study of Molecular Biology and Genetics	Steven R. Heidemann, Ph.D. Professor Department of Physiology Michigan State University 111 Giltner Hall East Lansing, MI 48824-1101 (517) 355-6475, ext. 1236 (517) 355-5125 (fax) Heidemann@pslvax.psl.msu.edu (Bitnet)
Approaches to Problem-Solving in Oklahoma State University's Summer Science Camps for American Indian Students	Alan R. Harker, Ph.D. Associate Professor Department of Microbiology and Molecular Genetics Oklahoma State University 307 LSE Stillwater, OK 74078 (405) 744-5929 (405) 744-6790 (fax)
Simulation Software in Population and Evolutionary Biology	Daniel Udovic, Ph.D. Associate Professor and Department Head Department of Biology University of Oregon Eugene, OR 97403 (503) 346-6051 (503) 346-6056 (fax)
Electronic Textbook for Physical Chemistry	Robert G. Kooser, Ph.D. Philip Sidney Post Professor of Chemistry and Chair Department of Chemistry Knox College Campus Box K-46 Galesburg, IL 61401-4999 (309) 343-0112, ext. 286 (309) 343-9816 (fax)
Computer Tools for Visualization of Concepts in Structural Biology*	Pamela J. Bjorkman, Ph.D. Assistant Professor Division of Biology Assistant Investigator Howard Hughes Medical Institute California Institute of Technology Pasadena, CA 91125 (818) 395-8350 (818) 792-3686 (fax) bjorkman@citray.caltech.edu (Bitnet)

*See pages 52–56.

Increased Research Opportunities for Minority and Caltech Students; Computer Tools for Visualization of Concepts in Structural Biology; and the Caltech Initiative in Precollege Science Education

California Institute of Technology ■ Pamela J. Bjorkman, Ph.D. ■ Jerry Pine, Ph.D.

Undergraduates are working with the faculty to develop sophisticated computer programs for visualizing complex chemical and higher level molecular and biological structures.

Dr. Bjorkman discussed the use of the Institute grant in the development of computer graphics for the study of atomic, macromolecular, and organismic structure by undergraduates. She also described undergraduate laboratory research programs to enhance the participation of students, particularly women and underrepresented minority students, in biological research. Dr. Pine described outreach activities supported by the grant to enhance the science curriculum in the Pasadena public schools, especially at the elementary school level.

Program Description

Dr. Bjorkman provided an overview of the California Institute of Technology, noting the size of the faculty (approximately 275) and the undergraduate enrollment (about 850). She commented on the high quality of Caltech's students as evidenced by their strong SAT scores, high school class rankings, and other factors. More than 70 percent of Caltech undergraduates go on to graduate school after completing their bachelor's degree.

With a grant from HHMI, Caltech is building three programs—the first to develop new educational tools for the computerized representation of biological structures, the second to enhance opportunities for student research and broaden access to the sciences for students traditionally underrepresented in these areas, and the third to enhance precollege science and mathematics education in the surrounding community and elsewhere.

Dr. Bjorkman described in detail several efforts involving computer usage at Caltech. For example, undergraduates are working with the faculty to develop sophisticated computer programs for visualizing complex chemical and higher level molecular and biological structures. She discussed the importance of allowing students opportunities to view these structures in a three-dimensional format, noting the difficulty of understanding them in a two-dimensional one. Her colleague, Dr. Nathan Lewis, Professor of Chemistry, is working with undergraduate students to develop broadcast quality videotapes to aid in teaching basic chemical concepts such as atomic orbital theory. HHMI funds were used to purchase four Silicon Graphics Personal Iris workstations, and special effects software has been installed on them as part of this effort. The first package of

four videos was scheduled for release by the end of 1993. Plans call for distributing this material to universities and high schools as an adjunct to teaching basic concepts in chemistry. During her remarks, Dr. Bjorkman presented a video of the animated simulations.

Dr. Bjorkman is applying similar computer-based principles to help students understand macromolecular structures. "We have written a manual that enables someone with no computer experience to display protein and DNA structures using a Silicon Graphics Personal Iris Computer," she said. Last year, after learning how to use the system, each student chose for a course project a structural problem to be addressed using computer graphics. The students are encouraged to use the computers as often as they want to, and they are made available on a 24-hour basis. "A number of students have continued to use the computer for their research even after the course is done," she noted.

Meanwhile Caltech faculty members are making a concerted effort to increase the research opportunities of minority students and women, Dr. Bjorkman continued. Undergraduates submit research proposals that are reviewed by faculty members much as they themselves submit proposals to federal and private funding organizations for peer review. Students are provided travel funds to present their research at national meetings.

Figure 29. Dr. Pamela J. Bjorkman demonstrates computer graphics used by Caltech structural biology students to visualize complex biological molecules in a three-dimensional format.

This program has been expanding and, since 1988, the number of women participants has doubled, rising to 30 percent, Dr. Bjorkman said. Overall, the number of Caltech biology students is rising, with equal numbers of men and women. Caltech also provides summer research opportunities to undergraduates from underrepresented minority groups who are enrolled at other institutions. Dr. Bjorkman said that an objective of this program is to encourage participating students to consider research careers, and that several "graduates" of the program have enrolled in graduate school.

Figure 30. Dr. Jerry Pine describes Caltech's efforts to involve Pasadena-area students in active inquiry and discovery.

Dr. Bjorkman described a program supported by the grant in which introductory biology students are teamed with junior and senior biology majors as peer mentors. The student groups meet weekly to cover problems and materials presented in classes and laboratories.

In 1991, Caltech also expanded its outreach program that brings underrepresented minority students to the campus during summers. The summer course provides opportunities for such students to do research projects with Caltech faculty and to see on a firsthand basis what scientific careers are like, Dr. Bjorkman said. The summer students participate in weekly seminars and roundtable discussions and, at the end of the summer, they present their research findings. She noted the importance of the summer laboratory experiences in opening up opportunities in research for students who may never have considered a research career. For students going into other fields, including medicine, the program can broaden their perspective, strengthen their problem-solving skills, and give them a taste of fundamental research.

Another important element of Caltech's outreach program focuses on activities of the Caltech Precollege Science Initiative that are supported by the HHMI grant. One is the development of inquiry-based hands-on high school science courses. As an initial step in the process a very successful residential summer program for 11th graders, primarily from underrepresented minorities, has been established and taught for the past two summers.

A second activity has been the development of a new science content course for preservice elementary teachers. From Caltech's work in K–6 science education in Pasadena, they see the urgent need for elementary teachers to learn science through inquiry and cooperative hands-on learning, as it should be taught in their classrooms. A one-semester course developed with biology and physics components was very successfully trial-taught during the summer of 1993. The students, most of

whom were fifth-year interns with bachelor's degrees, came with insecurity or hostility to science and no experience with scientific inquiry, and the course was very successful in generating enthusiasm for science as well as skill in scientific inquiry.

Discussion

Dr. Pine also discussed the role of teacher training in developing this approach. Teachers need support and encouragement to incorporate the new approach to science into their own classrooms, he said. Instructional kits that can be readily used in the classroom setting are most useful to teachers. Once teachers familiarize themselves with the contents of such kits, they tend to adapt and modify them to suit their own needs, which is an important stage in the acceptance and deployment of the revamped approach. To make all this happen, it also is important to find financial support for released time for the teachers, particularly during the preliminary stage when they are learning to use new inquiry-driven approaches, Dr. Pine said.

Dr. Pine discussed ways in which college and university faculty members can be helpful to elementary-level teachers. He said that faculty members generally lack the experience or training to work in elementary school classrooms. Many Caltech faculty members volunteer their services to work collaboratively with the teachers in exploring the kit-based materials. They have developed a deeper understanding and appreciation of the roles and responsibilities of precollege teachers, particularly those at the primary levels. Dr. Pine noted that the program he and his colleagues have developed could be applicable in other settings, and he said that some federal support is available to begin implementing these programs in other regions across the country.

Figure 31. Dr. David Gapp, Hamilton College, examines an exhibit on approaches to problem-solving used in Oklahoma State University's summer science camps for Native American students.

Several program directors discussed the role of computer graphics in the undergraduate curriculum and asked Dr. Bjorkman to describe the development of the educational software at Caltech. Dr. Bjorkman noted that Caltech undergraduates had an integral role in designing, implementing, and testing

the software. She also discussed the involvement of other Caltech departments and laboratories in developing the graphics, including the Jet Propulsion Laboratory supported by the National Air and Space Administration. In closing, Dr. Bjorkman described plans to make the computer graphics software widely available to other universities and colleges, as well as to high schools.

New Ways of Teaching Chemistry and Biology at Liberal Arts Colleges: The Fort Lewis Experience

Fort Lewis College ■ William R. Bartlett, Ph.D. ■ Preston Somers, Ph.D.

The "Fort Lewis experience" includes recent changes in the College's science education programs as well as the institution's ventures into outreach activities in the local community. Fort Lewis has a unique mission to serve Native American students, which the biology and chemistry departments are helping to fulfill with the assistance of a grant from the Howard Hughes Medical Institute. HHMI support also has allowed Fort Lewis to revise its introductory biology programs and other courses to meet the challenges of attracting students to science. In their discussion, Dr. Bartlett and Dr. Somers described some of the strategies being used to implement the College's new approaches to science education.

Program Description

Dr. Bartlett began by describing the environments that influence the mission of the College, chiefly its remote setting in western Colorado and its cultural environment, which is unusually diverse. There are more than two dozen Native American reservations within 150 miles of the campus. Because of this proximity and the availability of free tuition, there is a substantial Native American student population at Fort Lewis. A number of Hispanic students also attend the College.

The "new ways of teaching" range from new courses to outreach programs to shared perspectives between biology and chemistry. There are new activities and new faculty members in biochemistry, and additional equipment has been purchased for the molecular biology program.

Stronger ties have been created between the biology and chemistry departments through joint research seminars, interdepartmental exchange of students and laboratories, and team-teaching of new courses in bio-organic chemistry, pharmacology, and biophysical measurement. Outside speakers participated in a biomedical lecture series during the 1992–1993 academic year. These activities have lowered departmental barriers and increased faculty communication, according to Dr. Bartlett. He added that these new approaches appear to have resulted in greater student interest in graduate school and medical school.

Undergraduate research is another prominent feature of the Fort Lewis experience. HHMI support has contributed to a summer research program that has grown from 10 to 37 participants and contributes significantly to student interest in science and preparation for graduate school. Faculty involved in undergraduate research are motivated to keep current with

Stronger ties have been created between the biology and chemistry departments through joint research seminars, interdepartmental exchange of students and laboratories, and team-teaching of new courses in bio-organic chemistry, pharmacology, and biophysical measurement.

Figure 32. Drs. Preston Somers (*left*) and William Bartlett explain how Institute support at Fort Lewis College increased undergraduate research opportunities in biology and chemistry for women and minority groups underrepresented in the sciences.

the latest developments in their field, according to Dr. Bartlett.

Outreach Activities. Dr. Somers described the outreach components of the HHMI-funded program, which are designed to attract minorities, women, and first-generation college students. The Summer Science Enrichment Program recruits public school teachers, taking advantage of the fact that a significant number of local teachers are Fort Lewis graduates. The teachers gain intellectual stimulation and access to curricular materials and scientific equipment. They receive graduate credit for the program as well as a stipend.

The selected teachers help recruit high school students. The program accepts a maximum of five students per teacher, and the goal is to have 60 percent of the participants from minority groups. Dr. Somers acknowledged that students participate not only for the intellectual opportunities but also because they are excited about the week-long trip to Colorado State University in Fort Collins, 400 miles away. A small stipend makes the program more competitive with summer jobs and places a value on scientific work.

The summer program participants learn standard collection methods, quantitative analysis, replication, testing of hypotheses, and other principles of science. Among other things, they study the resistance of bacteria to antibiotics, collect and identify aquatic invertebrates, measure their own heart rates and other data to learn about exercise physiology, and conduct water quality analysis in order to understand acid mine draining, an important environmental issue in the region.

In the summer of 1993, over 20 students and 4 teachers par-

Figure 33. Drs. Caroline Kane, University of California–Berkeley (*left*), Sarah Elgin, Washington University, and Pamela J. Bjorkman, California Institute of Technology, discuss the importance of student research in attracting women and minority students to the sciences.

ticipated in the three-week program, which is on a daily schedule (as opposed to a residential program) and is operated in conjunction with a similar program in engineering. Field trips have included a visit to a state-of-the-art industrial farm on the Navajo reservation.

During the third week, the group goes to Colorado State University, where students visit the University's "Little Shop of Physics" for hands-on science projects designed especially for young students. Besides learning more about science, students can become comfortable in a campus setting and learn to interact informally with professors, gaining confidence in their ability to go on to college and study science. This approach seems to have been successful, according to Dr. Somers; seven of the eight high school seniors who took part in the 1992 summer program have gone on to college, and all but one are majoring in some aspect of science.

Fort Lewis has initiated a different kind of outreach with its Mentor Program, which brings College faculty to high school science classes. Dr. Somers said the greatest challenge is getting the faculty to participate, because they have so little free time. He added that the program has been most successful where the professor has some connection to the public schools, such as a spouse who teaches or a child who is a student.

Dr. Somers briefly described some changes in Fort Lewis science courses. The introductory biology program has shifted from descriptive teaching to a more investigation-based approach, with one three-hour laboratory per week. There is new emphasis on laboratory write-ups, teaching methods of

protocol, and hypothesis development. The desired result is that in addition to learning the biological subject matter, students will develop good laboratory techniques and become comfortable with open-ended problems. The college also offers a course in human anatomy and physiology, primarily for non-science majors, that is designed to "add some spark" to the subject matter. The use of videomicroscopy has been very helpful in achieving this goal.

An important part of the Fort Lewis experience in chemistry is the expanded use of computers. In setting up the computer laboratory, the chemistry department consulted faculty at Montana State University, who pioneered in this area. Six computers are available for every 20 students. The computers are used in the second semester for data entry and analysis, and eventually the students use them in about half of the experiments. Dr. Somers called the use of computers the "greatest development in the chemistry teaching lab," in part because they promote discussion about data results and lead to better conceptualization on the part of the students.

Discussion

During the discussion the audience expressed interest in various aspects of the outreach programs and introductory courses. One participant asked whether recruiting minorities was made easier by the "day camp" format of the summer science program. Dr. Somers replied that the days-only format was probably less expensive than a residential program, particularly since transportation was provided by the public school district and some of the high schools were 60 miles away. In response to another question, he indicated that fewer than one-third of the science faculty have served as mentors.

Another participant asked whether there was much instruction in theory when freshmen were introduced to sophisticated scientific equipment or whether the instruction was primarily technical. Dr. Somers said it was a combination of both; the freshman biology course stresses theory, but students also are taught how the equipment operates.

If You Build It, They Will Come: The Holy Cross Program

College of the Holy Cross ■ Frank Vellaccio, Ph.D. ■ Mary E. Morton, Ph.D.

Dr. Vellaccio's presentation focused on two Hughes-supported initiatives at the College of the Holy Cross: curriculum development and K–16 partnerships. He proposed several discussion topics related to undergraduate science education, including the differing environments for undergraduate research at universities and liberal arts colleges; the question of whether the concept of education as a K–16 continuum is a fad or the future; the need for better forums for exchanging ideas about science education; and the challenge of minority education in a predominantly white institution.

Program Description

Like many institutions, the College of the Holy Cross is expanding its science education programs beyond the training of scientists. One program is designed to attract more students to biology and chemistry by using a hands-on discovery approach that encourages greater interest in science among students, including women, minorities, and non-science majors.

Dr. Vellaccio described the cornerstone of the Holy Cross plan to enhance science education as "quality personalized instruction" by a committed faculty using a stimulating curriculum. As a small liberal arts institution, the College is already geared for personalized instruction, with low student-teacher ratios and laboratories that offer hands-on experience, but it is moving into newer territory with some of its science education programs.

Discovery Curriculum. One of the challenges in science education is designing courses that can serve the sometimes conflicting objectives of training science majors and providing science education for non-science majors. In the mid-1980s, chemistry faculty developed an innovative introductory curriculum that helped bridge these objectives by bringing non-science majors into the laboratory. This approach evolved from the observation that laboratory experiences had a positive effect on students with little prior interest in science.

The curriculum, now part of the chemistry and biology departments at Holy Cross, is based on the principle that students should be involved in the process of discovery, not passive recipients of "revealed truth" through the traditional lecture-based curriculum. The Discovery Curriculum emphasizes development of such skills as critical analysis, scientific communication, and creative thinking, and it draws on the immersion model of teaching, in which a student is surrounded by the culture and language of a subject.

According to Dr. Vellaccio, "Surrounding our undergraduates with a comprehensive research

Figure 34. Drs. Frank Vellaccio and Mary E. Morton describe components of the neuroscience curriculum at the College of the Holy Cross.

and teaching environment stimulates intellectual discourse, innovation and enthusiasm," and these are the qualities that will attract students to science.

With the HHMI grant, Holy Cross has been able to extend the Discovery Curriculum model to its newer, more advanced concentration in neuroscience, which involves biology and disciplines from other departments. Dr. Vellaccio said that one of the most important components of the neuroscience curriculum is the laboratory course taught by Dr. Morton.

Among the unique features of the course are (1) a combined cellular and molecular emphasis; (2) integration of a student's previous science training; (3) exposure to sophisticated laboratory techniques such as receptor binding assays, localization of receptors and ion channels by immunofluorescence, Northern blot analysis, solution hybridization analysis, *in situ* hybridization analysis, primary cell culture, established cell line cultures, and riboprobe synthesis; and (4) preparation of laboratory reports with a professional format, using original literature. HHMI funds were used for laboratory equipment and instrumentation, and for library holdings and student summer research stipends.

K–16 Partnerships. The Institute grant is also supporting two projects in what Dr. Vellaccio termed a K–16 partnership with local schools in Worcester, Massachusetts: a sabbatical program for high school science teachers, and Youth Exploring Science (YES), a science program for 6th–8th graders. The goal of the sabbatical program is to improve

precollege preparation in science by giving senior teachers the opportunity to "retake" introductory courses and learn about changes in various fields, some of which have seen dramatic developments in relatively short periods. During their leave, the teachers are replaced by Holy Cross science graduates.

In the two years of the program's operation, the teachers have found that it is particularly helpful to take courses in the science fields complementary to what they teach. A typical schedule for a biology teacher would include Introduction to Biology, Atoms and Molecules, Astronomy, and the Biology of Birds in the first semester and Introductory Biology, Organic Chemistry, Nutrition, and Medical Detectives in the second semester. Teacher feedback indicates that the program has been extremely successful. In addition to enhancing their knowledge of science, Dr. Vellaccio said, the program reminds the teachers what it is like to be a student and restores their pride.

The YES initiative involves African-American students in a weeklong program at the College. Each day the students learn about a different field of science through hands-on activities anchored in familiar concepts. Topics include energy from garbage; exploring light through lasers; eyewitness testimony; probability of winning the state lottery; and using chemicals to solve crimes. Students also receive guidance on college preparatory courses, and they experience the college environment. Other partners in the program include Holy Cross African American students, teachers and parents, and the New England Science Center.

Dr. Vellaccio indicated that the YES program was rewarding and will be continued, but it was more difficult to operate than the sabbatical program, and an assessment of the ultimate impact on student interest in science education will not be possible for a number of years.

Discussion

The ensuing discussion touched on the purposes of science education, and differences in approach that result from institutional mission. One participant expressed concern about training more people in science, based on his perception of a shortage of professional opportunities. Some cited opportunities outside of research, such as those created by the growth in health-related professions.

Others said that job training is not necessarily the primary function of the liberal arts curriculum. For example, Dr. Morton said that her courses encourage students to look at other aspects of science, such as the economics of a science-based issue, ethics issues involved in science,

. . . a common thread throughout the presentations at the meeting was the need to make science meaningful for students. Increased contact with teachers is important in creating student interest in science.

and learning the latest laboratory techniques. Overall, it appeared that one's view of science education depended on one's institutional affiliation, and that science education at the undergraduate level is more broadly oriented because of the added goal of an educated citizenry, while graduate schools tend to focus more narrowly on professional training.

Asked to describe Holy Cross minority recruitment, Dr. Vellaccio said there is intense competition among institutions, and efforts to attract and retain minorities in science encounter a number of obstacles. While achieving greater diversity in the student population is a college-wide goal, providing the appropriate level of academic and cultural supports for minority students is especially difficult unless one has a diverse population in the faculty, administration, and community.

The importance of role models in science was echoed by several members of the audience, including one who suggested that recruitment efforts are more appropriately undertaken at the overall college level rather than by individual science departments, and that science courses for nonscientists offer a way of generating greater interest among minorities once they come to the college.

A participant expressed concern that some new approaches in science education may be fads that educators are pressured to embrace because of demands to serve broader objectives. Dr. Vellaccio disagreed, saying that change does not happen overnight in academe, and that people do not change their teaching methods precipitously. He said that many institutions are trying different things because there is no single solution to the problems, and reasoned experimentation is appropriate.

Various concepts of "personalizing" science also were discussed. A participant observed that a common thread throughout the presentations at the meeting was the need to make science meaningful for students. Dr. Vellaccio said that increased contact with teachers is important in creating student interest in science. He added that the Discovery Curriculum is in one sense a return to a previous era when teachers spent more time in the laboratory. As teaching assistants were hired for laboratory classes, teachers spent less time with students. Now that teachers are back in the lab, student interest seems to be increasing.

There was some discussion about whether there are aspects of science that students can't "discover." A participant said that skills and paradigms have to be conveyed through passive learning. Dr. Vellaccio cautioned against taking too extreme a view of the Discovery Curriculum, pointing out that it is a specially designed

Figure 35. Dr. Jeanne S. Poindexter, Barnard College (*right*), raises an issue for discussion. Drs. Ruth E. Reed, Juniata College, and Steven Stegink, Calvin College, are seated beside her.

science curriculum, but it is not the only way to teach science. Dr. Morton added that skills are routinely taught in her laboratory courses; students do not just learn experimental techniques. They also gain skills in critical thinking because the experiments are open-ended and students must apply original analysis in presenting their results.

Developing Innovative Teaching and Learning Strategies for Success in Science and Mathematics Through Modern Technology

Fisk University ■ Mary E. McKelvey, Ph.D. ■ Karen Martin

Dr. McKelvey and Mrs. Martin discussed the development of a multi-segmented program, with special emphasis on a new learning center for students in the sciences and mathematics. Other activities supported by the Institute have enabled Fisk University to provide students with faculty-sponsored laboratory opportunities, acquire supplies and small equipment items for laboratory use, and develop an outreach program for precollege students.

Program Description

Fisk University, founded in 1866 just after the Civil War, has a predominantly African American student body, noted Dr. McKelvey. She and Mrs. Martin described the new Science Learning Center supported by the HHMI grant as a place where students are learning to overcome some of their anxieties about mathematics and science and to replace them with efficient study skills and a new sense of confidence. At the same time, the Center provides a place for students to gather informally with colleagues.

Mrs. Martin became director in the fall of 1992. Interest in the Center surged following a special publicity campaign geared to attract Fisk students, she said. About 50 to 60 students participated in a total of 300 tutoring sessions. Early this school year, Mrs. Martin spoke about the Center during a call-in show concerning women and learning on the Fisk campus radio station.

According to Mrs. Martin, the Center provides computer workstations where students can learn at their own pace and be assisted by tutors if necessary. Programs are available to students to undertake problem sets in algebra, calculus, and trigonometry. It was noted that most of the students who have requested tutorial services have sought assistance in mathematics. In addition, students can take tests on the computer in such areas as anatomy, cell and molecular biology, chemistry, and genetics, and perform exercises in logic, problem solving, and spatial reasoning. Software is also available for students preparing for the Medical College Admission Test (MCAT) and the Graduate Record Examination (GRE).

Emphasis is also placed on peer tutoring, and tutors are taught to pay attention to individual students' learning styles and active learning methods, and to evaluate students who continue to have difficulties with their classes. Freshmen who are tutored at the Center are showing improvement in their courses, Mrs. Martin said, with nearly 90 percent retained at the University. Mrs. Martin noted the

Figure 36. Karen Martin (*left*) and Dr. Mary E. McKelvey respond to questions about student participation in the science learning center at Fisk University.

important role of the tutors in the initial success of the program. The Science Learning Center is developing an instructional software program for tutors and began offering supplemental instruction in mathematics courses for the first time during the fall of 1993.

Another part of the overall HHMI-supported program at Fisk is offered during the summer before students begin their first year of college. For the 1992 summer program, Fisk had 21 precollege students enrolled in its "academic survival" program, Dr. McKelvey said. Most of the students who participate are from Tennessee, but some have been recruited from other states. Students are instructed in the courses they will take as freshmen, including algebra, biology, and chemistry. They also are trained in computers and their general study skills are enriched. In addition, the precollege students meet for question-and-answer sessions with students from the upper classes at Fisk—another measure that is helping to build precollege students' confidence.

The biology course focuses on such topics as cell structure and function, DNA replication, ecology, and protein synthesis. In the chemistry segment of the program, students learn about chemical bonds and solutions, measurement techniques, atomic structure, and other areas.

According to Dr. McKelvey, these efforts are already having a positive effect. Pre- and post-program assessments have shown significant improvement in students' performance in the course work covered during the summer. Nearly all the students participating in the summer programs during 1992 and 1993 have gone on to college, and a significant number have enrolled at Fisk.

. . . once students come to feel "connected" with their classes, teachers, and subject matter, they are more willing to take risks and to participate more fully in science activities.

The science and mathematics enhancement efforts also showed signs of working well, as evidenced by the increased numbers of students who are graduating from Fisk with science degrees, particularly in biology, Dr. McKelvey said. More are going on to medical school or graduate school in science. "We anticipate that the HHMI support will help us to continue increasing the number of students who follow careers in mathematics and science," she said.

Discussion

One of the issues addressed during the discussion period concerned differences in learning styles that appear to reflect cultural and gender differences. Mrs. Martin referred to studies indicating that men often rely primarily on visual experience, and so they are more likely to stand back, observe, and do well by keeping their distance from a subject. In contrast, young women may feel more comfortable connecting with others, and responding to information presented orally. Mrs. Martin emphasized the need to provide for a variety of learning styles that encourage students with different strengths to succeed in science.

Program directors discussed ways of involving students from multiple cultural backgrounds in the sciences. A participant from a historically black liberal arts college discussed the potential for isolation that underrepresented minority students may experience, particularly those enrolled at majority institutions. She emphasized the need to actively encourage such students to participate in discussions, classroom and laboratory exercises, and other activities.

Program directors discussed another potential barrier students, including those from underrepresented minority groups, may face in the sciences: reluctance to engage in discussion out of concern for giving incorrect answers. Mrs. Martin observed that once students come to feel "connected" with their classes, teachers, and subject matter, they are more willing to take risks and to participate more fully in science activities.

Participants also discussed precollege and outreach programs developed by grantee institutions that have shown early success in attracting and retaining students in the sciences. While the HHMI-supported programs emphasize science and mathematics, some of these programs, such as that at Fisk, include enrichment of writing and general study skills. A participant from a private urban university noted the benefits of including some nonscience material in the outreach program, such as helping the students develop skills that can be valuable for success in college and avoiding science "burnout."

Other participants endorsed this approach because it can provide students with a picture of a liberal arts environment.

Program directors asked about students' perceptions of the Science Learning Center, and whether students were reluctant to take advantage of its services out of concern for being stigmatized. Mrs. Martin said that the learning center is located in the honors center, a site that has helped to alleviate students' concerns. Dr. McKelvey added that the program serves two functions—enhancement and educational development—but students generally regard the learning center as an opportunity to enhance their knowledge and skills.

Taking Advantage of Student Diversity in Improving the Biological Sciences

University of California–Berkeley ■ Corey S. Goodman, Ph.D. ■ Caroline M. Kane, Ph.D.

The University of California–Berkeley is a large public institution with a highly diverse student population. Dr. Goodman provided an analysis of assessment studies to understand how more minority students underrepresented in the sciences can be attracted to participate in on-campus science activities. Dr. Kane focused on how the Institute-supported program builds on what has been learned through these assessment activities.

Program Description

Background. Dr. Goodman began by observing that about 22,000 students attend the University of California–Berkeley. About 12 percent of the 6,200 graduating seniors are biology majors, including 440 students in molecular and cell biology and 293 in integrative biology. Approximately 95 percent ranked in the top 10 percent of their high school graduation class, and 100 percent ranked in the top 15 percent of their high school class. Although the University has been considered one of the foremost public academic institutions, it seeks to constantly improve the academic experiences offered to its undergraduate students.

The student population at the University is highly diversified and includes about 16 percent Hispanics, 7.9 percent African Americans, and 1.3 percent Native Americans. Studies conducted by the University over a five-year period revealed that enrollment of African Americans, Hispanics, and Native Americans as science majors was significantly below their proportions in the total undergraduate population. Demographic projections indicate that blacks and Hispanics will constitute 30 percent of the population of California by the year 2020; yet, if present trends continue, less than 5 percent of those entering science professions will come from these groups.

Over the past decade, in addition to making major improvements in physical facilities for research and teaching in the biological sciences, the University has united life-science instruction and academic departments. Ten departments ranging from biochemistry to zoology have been reorganized into three new departments: Molecular and Cell Biology, Integrative Biology, and Plant Biology. In addition to replacing and reorganizing undergraduate majors, previous lecture courses, and laboratory courses, the University has revised and updated an emerging new curriculum. However, alterations to the science curricula alone have not increased the recruitment and retention of underrepresented minority students in academic science majors.

Preventing students, particularly underrepresented minority

students, from "getting lost" among the 22,000 undergraduates at the University is an important factor in providing a supportive academic environment. Enrichment programs can make a significant difference, although the University's experience has been that some programs work better than others. Because students tend to be self-selecting, not all who could benefit from enrichment programs such as summer research experiences will apply.

Biology Fellows Program. Three major components make up the University's program. One component, the Biology Fellows Program, offers students, particularly women and underrepresented minorities, opportunities to conduct research in laboratories on campus, in the Lawrence Berkeley Laboratories, and at Children's Hospital Oakland Research Institute. Stipends are available to support student research during the semester and the summer.

One difficulty in establishing this program was developing effective advertising. Fewer applications than expected were received by the designated deadlines for the semester and summer stipends. With extension of the deadlines, and announcements to students as well as to faculty and department offices, about 120 applications were eventually received and 25 summer stipends were awarded. Twenty applications for the fall stipend awards were reviewed.

Biology Scholars Program. A second program, the Biology Scholars Program, targets a highly diverse population of students and provides curriculum and career counseling, professional workshops, and panel discussions with faculty and graduate students as well as professionals from outside the University. In addition, the program provides student tutors who work with study groups in mathematics, biology, chemistry, and physics. Internships and employment and research opportunities have also been sought for the students from the substantial number of local biotechnology firms in the San Francisco area. A center has been established with a resource library containing career information and announcements about jobs, internships, summer programs, and research positions. The initial group of participants included 38 women and 16 men, of whom 13 were Hispanic, 18 African American, 1 Native American, and 1 Filipino.

Dr. Kane continued the presentation, noting that the Institute-supported biology project focuses on two of the four major components of the undergraduate biological sciences education program. In the Biology Fellows Program, approximately 10 students are chosen each semester to receive stipends for support as they perform independent research. Undergraduates in the summer Biology

Figure 37. Drs. Corey S. Goodman and Caroline M. Kane outline the reorganization of ten biology departments into three new departments at the University of California–Berkeley.

Fellows Program work for 8–10 weeks and participate in faculty seminars and research symposia. Each summer, about 25 students are involved, and each receives a stipend and money for supplies.

Undergraduates who have participated remain an integral part of the program and are invited to continue attending the science seminars and symposia. Students who participated once may reapply during a new round of competition but must compete against the incoming students. Successful applicants are judged on the basis of enthusiasm, curiosity, and interest displayed in a required essay; letters of recommendation; and their grade point average. Students who are not awarded one of the fellowships are still invited to attend some of the events.

The new programs supported by the Institute are modeled after and integrated with other programs on campus, including the Minority Engineering Program, the Professional Development Program, and the Chemistry Scholars Program. The latter program recruits minority students in the freshman year, supports them in chemistry courses, and continues working with those who select chemistry as a major.

At the end of each semester, interviews are conducted with students in the Biology Scholars Program component to discuss the impact of the program and to obtain their evaluations of the program and suggestions for changes. One problem has been diminished attendance by students at programs and workshops as the semester progresses, due to an increasingly heavy workload. The students themselves suggested regularly scheduled meetings, which have led to greater group cohesion and participation.

This HHMI-supported program offers 100 students the opportunity to discuss careers in science or medicine, participate in workshops on time management, attend a center for program participants, enjoy informal activities, and utilize resources for networking, tutorials, and participation in curriculum development. A significant number of African American and Hispanic students participate in the program. About 34 percent are men, which is important because men may be less willing to ask for help and therefore it may require greater effort to get them involved in these programs.

In addition, the Biology Scholars Program students are required to take a special course that orients them to academic life, introduces them into the "culture" of the biological sciences, and provides them with experience in making presentations. One concern is that students, even entering freshmen, may not be receiving the information provided in this course early enough to enhance recruitment and retention of underrepresented minority students in science careers. Even after a biology major is declared, attrition of certain underrepresented groups may continue.

With the award of the Institute grant, a new course for freshmen, Current Topics in the Biological Sciences, taught experimentally in the year before the award was received, could be continued and enrollment expanded. Reader materials were developed and instructors were selected who could also serve as role models in science. One of the course goals was to encourage the type of questioning done by practicing scientists in developing hypotheses. This approach enabled students to learn that many questions in science remain unanswered and that opportunities to do research could help clarify these questions. In addition, guest speakers were chosen who were directly interested in recruiting and retaining freshmen in biology.

Five upper-division undergraduate major laboratories in Molecular and Cell Biology have been modified as a direct result of the Institute's support: General Biochemistry and Molecular Biology Laboratory, Cell and Developmental Biology Laboratory, Genetics Laboratory, Immunology Laboratory, and Neurobiology Laboratory.

The University is exploring how to use quantitative and qualitative data, together with anecdotal evaluations, to define and evaluate program success. Program assessments are particularly important because the University must convince faculty and legislators that the programs merit continued support. Another issue is how to deal with established science programs whose quality has diminished. A third is whether student advisers

Program assessments are particularly important because the University must convince faculty and legislators that the programs merit continued support.

A major impact of the Institute-supported program on campus was to highlight the importance of research for biology and other majors.

should intervene directly or merely provide advice, guidance, and support to students.

Discussion

One participant noted that students often fail to understand the challenge of being a science major until they take their first examination. Often undeveloped study skills increase the difficulty of dealing with the demands of a curriculum. Older students can serve as mentors to help younger students through this difficult transition.

Institute-supported programs are intended to focus student attention on careers in science. About 90 percent of the participants in the Institute-supported biology program are premedical students, probably because they have no role models in science research careers, but they know someone who is a doctor. This program exposes students to many alternative careers including basic research. The Biology Scholars Program is effective because students form a support network across the underrepresented minority groups. Participants are also encouraged to work with incoming students and with their communities to increase interest and participation in science. The University is using the Institute's support to incrementally increase program participation rather than as a substitute for current support. However, variations in such factors as institution size can affect the tendency of students to form a cohesive group and the success of the program.

Another program director noted that a major impact of the Institute-supported program on campus was to highlight the importance of research for biology and other majors. Students should also be permitted to participate in various program components such as seminars and workshops even when they do not win an award in general campus competition. If the program is handled effectively, students who participate in it can become magnets who draw in other students. The final result may be an increase in biology majors at an institution where overall student enrollment has not increased. Participants agreed that issues and approaches for resolving those issues would vary from institution to institution.

Genetics as a Springboard to Research: Broadening the Community of Learners

Washington University ■ Sarah C. R. Elgin, Ph.D. ■ Joseph J. H. Ackerman, Ph.D.

A major theme of the HHMI-supported program at Washington University is broadening the community of learners in the biological sciences. Dr. Elgin described new support services and the summer research program. Dr. Ackerman outlined efforts to make introductory chemistry more appealing to prospective science majors in general, and to biology majors in particular. Dr. Elgin also described how genetics and molecular biology has been a focus of outreach to high school science teachers, both in training and curriculum development. During the discussion, participants sought further detail about the support services, focus groups, and other program activities conducted at the University.

Program Description

The program at Washington University is largely directed toward helping biology students in their first two years of college develop experimental skills and an interest in participating in the undergraduate research program. The biology major is heavily predicated on chemistry, with students taking general chemistry the first year and organic the second. In the first freshman semester, students usually take a research seminar. In the second freshman semester, students begin two serial courses in fundamental biology, followed in the second sophomore semester by a genetics course with an intensive laboratory.

The program reinforces the student support system by offering mentoring and problem-solving tutorials, particularly during the first sophomore semester, which has proved to be a critical transition point for many biology majors. An advising system has been developed to help undergraduates find research opportunities with one of the 281 faculty available. The HHMI grant has provided visibility to summer research opportunities for undergraduates, with whole or partial support for 32 students.

The introduction of tutorials and a new laboratory for the genetics course may have contributed to the increased enrollment in biology courses, according to Dr. Elgin. In 1993, of the 720 first-year students, 390 enrolled in freshman biology. Retention has increased also. Previously, about 65 percent or fewer of the freshmen in biology progressed to sophomore courses. Now the figure is around 75 percent, and increasing. The support services have contributed to an atmosphere where the students feel that the science departments actually want them to be part of the ongoing enterprise.

The number of women participating in the biological sciences at Washington University is rising. Women account for a majori-

Faculty must pass on the excitement of the chemical sciences to the students and let them know why chemistry is important in the biological arena.

ty of students in the Fundamentals of Biology II tutorials and the summer research program and comprise 46 percent of Ph.D. students in the Division of Biology and Biomedical Sciences. Participation by minority students has been increasing at the undergraduate level but is still very low (3.5 percent) among Ph.D. students.

About 600 students take a chemistry course in the first freshman semester. A minority of this course enrollment is composed of those who are, or will be, chemistry majors. The large majority are majoring in other disciplines (biology, chemical engineering, psychology, etc.) Thus as a whole, this audience is captive, potentially indifferent, or even hostile, Dr. Ackerman said. In addition, despite their strong academic records, the quality of the students' high school preparation varies widely, and many have not yet developed self-discipline and intellectual toughness. "The main challenge is to get students to engage in the pursuit of scholarship," he said. Faculty must pass on the excitement of the chemical sciences to the students and let them know why chemistry is important in the biological arena.

To those ends, the Chemistry Department has assigned some of its best instructors, who are also excellent researchers, to the general and organic chemistry courses. With the HHMI grant, the department is also bringing more advanced biology technologies into lower level laboratories by introducing scanning UV spectrophotometers and developing investigative laboratories to cover enzyme catalysis and inhibition, antibody/antigen interactions with ELISA (enzyme-linked immunospecific assay), drug/DNA interactions, and other topics. "Our hope is to bring in laboratories that really excite the student and let the student know that chemistry, per se, is biology," Dr. Ackerman said, "and it's very relevant."

The HHMI grant expanded an outreach program that Washington University has been operating for about three years. The goal is to build a system that addresses all the barriers science teachers face. The program upgrades the training of science teachers through summer courses, develops modern biology curriculum for use in their schools, and maintains a loaner-equipment and supply system to support the teaching of the new curriculum.

The program offers a three-week summer course in molecular biology to 18 high school teachers at a time. An evolution/ecology course is also planned. Parallel courses in genetics/life cycles and ecology/evolution are being developed for elementary school teachers.

Many of the high school teachers taking the summer molecular genetics course received their bachelor's degree prior to the discovery of new advances in molecular genetics. The lectures are designed to

Figure 38. Drs. Sarah Elgin and Joseph Ackerman describe a program designed to develop students' experimental skills and interest in graduate research.

familiarize them with the most pertinent topics. The laboratories, although time-consuming, take the teachers through the basic steps needed to do bacterial transformations, DNA analysis by gel electrophoresis, and other manipulations. Teachers perform these processes at least twice to become comfortable while doing them.

The course also includes field trips to the Human Genome Center of the Washington University Medical School and to Monsanto Company to learn about crop transformation. At the end of each day, the teachers meet with faculty to discuss how to integrate what they are learning into their high school courses. High school science teachers now want to introduce recombinant DNA and biotechnology to their first-year biology classes.

The teachers encountered three major problems in teaching genetics. First, experiments with even the best-suited plants or animals take several weeks, and the timing can be difficult. In the future, the teachers will probably switch to using yeast, because students can do a cross and see results the next day. The second problem is getting students to understand the complexity of many genetic traits. A third problem is convincing students of the limitations of genetic engineering.

The outreach effort is complex, Dr. Elgin said. "We're really trying to ... change the culture of the school," she said. "We're trying to convince teachers both to use material that is up to date and to invest in a science curriculum that is inquiry-driven and hands-on."

Two essential elements were identified. Teachers need time for planning and preparing science activities and discussing their work with University faculty. In addition, a central system is needed to supply the teachers

with equipment and materials. The program has arranged for the teachers to use an existing central supply system operated by the St. Louis Mathematics and Science Education Center, an arm of the Cooperating School Districts of St. Louis County. Every teacher who takes the summer course can call the Center to reserve equipment kits and supplies for their students to carry out the experiments discussed and developed during the summer.

Discussion

One participant asked whether students viewed introductory science courses as "weed-out" courses for premed students. Dr. Elgin said that with the expanded array of support services, students are beginning to view faculty as wanting students to succeed.

Another participant asked if it was realistic to expect freshmen to successfully complete a rigorous chemistry course. Dr. Ackerman pointed out that sooner or later, all students are going to have to make the jump to university-level scholarship. Also, said Dr. Elgin, the University has only four years to prepare them for graduate or medical school. "They have to start working quickly," she said. "A lot of it's (poor) study habits."

Dr. Ackerman said that student indifference is a problem, recounting that the Chemistry Department once invited 80 at-risk students to special tutorials, but that a disappointingly small fraction responded. One participant suggested talking with faculty in other departments to find relevant examples that could be integrated into chemistry courses.

Responding to a question about a biology support group just established, Dr. Elgin said the program at Washington simply tries to respond to requests from students in the group. Requests have chiefly concerned biology-related careers, so the program is working to provide that information.

Another participant asked about the student focus groups conducted by the Chemistry Department. The University, in concert with the Department, contacted a marketing expert, very familiar with the University, who donated his time to gather and evaluate student perceptions of introductory chemistry courses through a series of small focus groups. "What we found out was that the students ... have incredible respect for the intellectual ability of the faculty; they're in awe," Dr. Ackerman said. But "many felt we were trying to weed them out and that there was undue antagonism between faculty and students." The findings regarding student perceptions were shared with the entire faculty.

Summary of Key Issues

Alan R. Harker, Ph.D. ■ Pamela J. Bjorkman, Ph.D. ■ William R. Bartlett, Ph.D. ■ Joseph G. Perpich, M.D., J.D.

Dr. Harker opened by noting that recruitment of underrepresented minority students presents problems, whether the students are Native American or African American. It often depends, he said, on understanding how the cultural background of the students affects their perception of institutions in general and science careers specifically. Recruiters need to be very sensitive to cultural and other issues, he added. One important approach is to brainstorm with target groups, such as teachers and tribal leaders, to listen carefully, and to learn about potential problems before initiating a new program. An institution needs not only to be sensitive to community concerns but to build relationships continuously with the community.

Another important area of concern is faculty involvement. Faculty are often reluctant to get involved in public school programs unless they have a child in school or a spouse who teaches there. Finding ways to keep faculty enthusiastically involved in programs is also important, as are ways to more effectively communicate information between faculty and groups they are seeking to serve.

Dr. Bjorkman summarized issues pertaining to science careers and the use of computers in undergraduate programs. She noted that the California Institute of Technology planned to make its computer videos and curriculum materials available to other institutions by the end of this year. Integration of computers in the curriculum either through interactive student programs or video presentations is important.

More challenging to an institution are problems of computer maintenance, security, and obsolescence. The service agreements necessary to maintain computers are expensive. A systems manager may also be important as system networks grow more complicated. Caltech has used fiberoptic cable for a security system, but the cables are expensive and monitoring the cable for an alarm signal continues to add to the cost. Once purchased, a computer can become obsolete within six months because of the ongoing, rapid development of computer technology.

Dr. Bjorkman also addressed the larger issue of the future of careers in biomedical research. Can the increased number of students be sustained by the number of available opportunities, she asked. Perhaps students should also consider science careers in alternate areas such as industry or the government. The value of an education in science, like a liberal arts education, may lie in learning to think critically and to conduct logical analyses. Students with some exposure to science may not necessarily plan a career in science but will be

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more science literate when they graduate. In addition, Dr. Bjorkman discussed how the enrollment of underrepresented minority students may be one factor in determining which institutions are awarded a training grant by the National Institutes of Health.

Dr. Bartlett focused on issues involving science curricula. He noted that the HHMI grant at Fort Lewis College encouraged the participation of underrepresented minority students in research within the academic community. A diverse student population, he felt, was desirable, and faculty should be committed to involving minority students in their laboratory research. Opportunities to utilize science in multiple career paths are needed to draw in more women and underrepresented minorities.

Discussion

Discussion centered on several key issues. It was acknowledged that one institution's outreach programs in the elementary schools, for example, might have to be modified for another institution. Faculty participants need effective strategies for coping with their other academic responsibilities as well. The discussants questioned how the responsibilities of an institution could be distributed more equitably among faculty while maintaining the quality of the programs.

Several suggestions were put forth, including one to allow faculty to take sabbaticals on-site, rather than at a distant institution, while continuing some measure of program participation. Another idea was based on rotating cycles of faculty activities. Research, one participant noted, often provides a welcome respite from teaching duties. The stress of research activities can likewise be diminished by classroom teaching.

Effective methods for communicating between program directors and institutions also generated considerable discussion. Several participants noted that the exchange of ideas at the present meeting had prompted them to consider revising program strategies, thereby enhancing the potential impacts from the program. Others thought that regional meetings of program directors would be useful. Dr. Perpich mentioned that the Institute has been considering the use of E-mail and the development of an electronic bulletin board to enhance communication among programs. Another participant noted that the National Research Council was engaged in programs to enhance science literacy, particularly for non-science majors. These efforts were expected to lead to the development of cross-referenced databases and in-house software that could be shared by means of an on-line Internet system. Over 600 items had already been collected, and the addition

of other materials would further enhance the program.

Participants also queried how they should define an undergraduate for purposes of eligibility in the Institute-supported undergraduate programs. Would students who take additional course work after receiving their bachelor's degree still be eligible? Such students could use the Institute program as a "bridge" between their undergraduate experience and the need to make more concrete career choices. Some participants saw value in allowing students to conduct research in the summer following their graduation. Others seemed to favor the broad-based definition of an undergraduate as any student who was not a graduate student. One participant noted, however, that NIH defines an undergraduate as someone who has not yet received a bachelor's degree. Dr. Perpich observed that while institutions needed to remain flexible, it is not always desirable to have students prolong their undergraduate education.

Dr. Harker also pointed out that institutional flexibility was limited. Oklahoma State University, for example, offers two introductory biology courses, one for biology majors and one for nonmajors. Each course requires a separate professor, which raises the institution's operating costs. Furthermore, students who take the non-major course are required to take the other introductory biology course if they subsequently decide to major in biology.

Community colleges must also be considered in designing programs to aid in the recruitment and retention of underrepresented minorities in science. Many students enter four-year programs after one or two years of study at a community college. These students also need support and can benefit from participation in undergraduate research while still at the community college. One program director mentioned that his program offers faculty mentors and opportunities for summer research to students from community colleges. Through the Institute's undergraduate program, several colleges or universities have programs involving undergraduates from community colleges. In addition, an NIH program, "Bridges to the Future," helps groom community college students for science through summer workshops.

One participant noted that the recruitment of minority students must take into account the general environment from which these students come, and their possibly greater familiarity with medicine as a career choice than science. At least one institution has used African American advisers and role models in the dormitories in an effort to correct this imbalance. Dr. Harker mentioned that when four-year institutions recruit outstanding minority students from community colleges

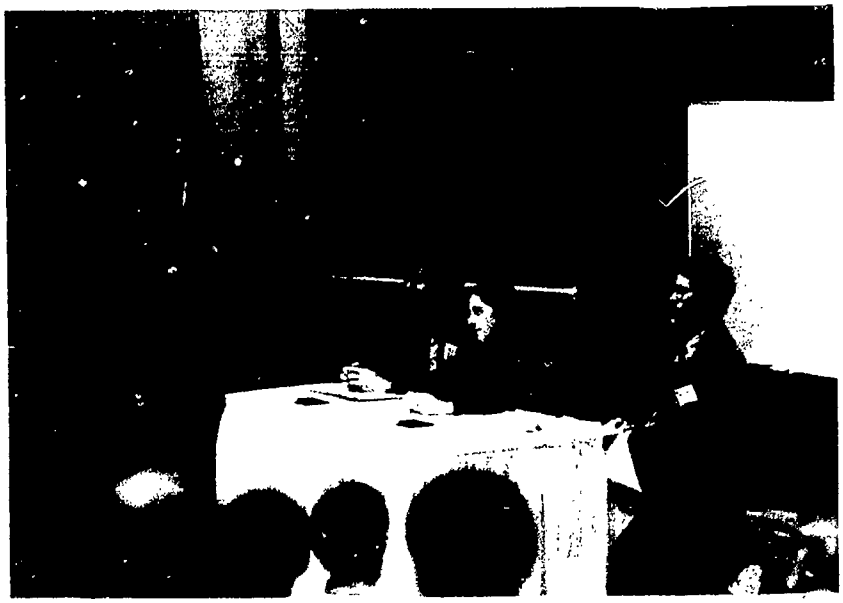

Figure 39. Dr. Perpich leads the final review session with Drs. Alan R. Harker, Oklahoma State University (*left*), Pamela J. Bjorkman, California Institute of Technology, and William R. Bartlett, Fort Lewis College.

in a sensitive manner, good relationships between the institutions can be maintained.

Several program directors had suggestions for effective recruitment. One is to have both institutions cooperate by planning the course of study for each student. A second is to have a full exchange of students in both directions. For example, students from a four-year institution can visit a historically black institution; and students from the historically black institution can visit the four-year institution. A third approach involves building collaborations with faculty from other institutions and including representatives of both in joint committees and boards within the program context. Linkages, particularly to institutions with a large minority student population, represent a fourth solution. Students may leave an institution for a variety of reasons; loss of a student does not necessarily reflect weakness.

In his closing remarks, Dr. Perpich stressed that other than one's family, teachers play a crucial role in developing a student's intellectual interests and pursuits. Although elementary students may struggle with science, they have a natural curiosity upon which an interest in science can be built. A new competition for 1993 under the Precollege Science Education Initiative for Science Museums involved selected aquaria, botanical gardens and arboreta, children's museums, general science museums, natural history museums, science technology centers, and zoos in fostering the interests of students, particularly those in elementary school, in science.

The Institute's support of precollege programs reflects the importance attached to bolstering education in science, starting

with the earliest years of school. Attracting students to science can best be achieved by recognizing the inherent curiosity and creativity of young students and by transcending the traditional boundaries and limitations of science education. An array of public and private organizations must contribute to revitalizing science education at all levels.

Dr. Perpich noted that Sheila Tobias in her book *Revitalizing Undergraduate Science* had observed that the goals of the HHMI undergraduate program are to increase the number and quality of biological science programs at undergraduate institutions and to increase the proportion of undergraduates, including women and minorities underrepresented in the sciences, who select research as a career. Through the Institute's support for undergraduate programs institutions are changing and opportunities are increasing.

Commenting on the Institute's approach to undergraduate education, said Dr. Perpich, Ms. Tobias concluded that "what is interesting about the Howard Hughes program is how very well it meshes with the lesson of the case studies, such as that of Fort Lewis College....The Institute's purpose was institutional change and enlargement of opportunities. It targeted colleges and universities which had already demonstrated a capacity to produce minority graduates in the biomedical sciences, providing 'postperformance' rewards. Its grants were not to individuals for experimentation, but to departments for improvement. The specific line items were general enough for each institution to tailor its spending to its own needs, and the time frame, in every instance, was five years—time enough to plan, implement, and assess."

Today we are at a crossroads in science education, Dr. Perpich noted. Educators from grade school to graduate school are fundamentally re-examining and re-evaluating methods for teaching science. Lines between different scientific disciplines are becoming blurred as educational and scientific advances force a new appreciation for interdisciplinary activities. The Institute's annual meeting of the undergraduate directors provides a broad canvas on which institutional approaches to exposing undergraduates as well as teachers and students from local schools to science can be evaluated. At these meetings, a wide-ranging exchange of information and ideas on what works and what doesn't work in science education takes place. The many changes occurring in science education today should help make science more interesting and accessible to all students tomorrow.

Lines between different scientific disciplines are becoming blurred as educational and scientific advances force a new appreciation for interdisciplinary activities.

Part II: Program Profiles

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Arizona State University

Program Director
James P. Collins, Ph.D.
Professor and Chair
Department of Zoology
Arizona State University
Tempe, AZ 85287-1501
(602) 965-3571
(602) 965-2519 (fax)
ICJYC@ASUACAD
(Bitnet)

Arizona State University is a public research institution in Tempe, Arizona. In 1992 the Howard Hughes Medical Institute awarded the University $1,500,000 to support (1) a program to attract and retain students in the sciences, including women and underrepresented minorities, through revision and integration of the core biology curriculum to emphasize student experimentation and discovery, to include the development of new instructional materials and scientific equipment; (2) development of faculty to implement the new curriculum, and opportunities for community college faculty and high school teachers to participate in the curriculum development; and (3) enhanced undergraduate research during the summer and academic year, to include introductory seminars on research concepts and techniques, travel to scientific meetings, and colloquia to present research.

Student Research and Broadening Access

An overarching goal of Arizona State University's HHMI grant is to establish the Biology Research Experience for Undergraduates Program. This program enables undergraduates to participate in independent research in the laboratories of faculty members. Students enter the program in the summer, and each has the opportunity to continue throughout the academic year. They receive a stipend and a supply budget funded by the HHMI grant.

Before the program began in the summer of 1993, a special steering committee designed the application process to ensure that applications reached the widest possible audience. Twenty-seven students, 37 percent of whom are minorities, and 63 percent female, were selected from among 110 applicants. Most were majors in zoology, botany, or microbiology. Sixty faculty members in 14 academic units agreed to act as faculty sponsors.

One of the students taking part in the program is Bradley Segura, a Hispanic senior majoring in zoology, who plans to attend medical school. He is investigating the microorganisms that are associated with the sweet potato white fly, *Bemesia tabaci*, which ranks with the gypsy moth as being one of the most deleterious insects for U.S. agriculture. The white fly is detrimental to marketability because infestation produces honeydew, a sweet, sticky fluid that adheres to harvesting equipment. Under the sponsorship of Dr. Elizabeth Davidson, Associate Research Professor of Zoology, Mr. Segura is attempting to determine whether microorganisms associated with the white fly are responsible for synthesizing the honeydew polysaccharide from smaller sugars found in plant sap. "Once we know what types of microorganisms

are involved, we can target them for elimination and minimize the impact for crops," said Mr. Segura.

Another student is Renee Seidler, a senior majoring in microbiology, who plans to enter a graduate program in molecular biology. Her project, in the laboratory of Dr. Bertram Jacobs, Professor of Microbiology, is on the importance of viral double-stranded RNA-binding proteins in interferon resistance. She is studying the *E3L* gene in vaccinia virus, a gene that confers interferon resistance. The gene codes for a protein that binds to the virus's double-stranded RNA, thus masking its presence in an effort to evade detection by the human interferon system. Ms. Seidler's efforts are aimed at identifying mutant *E3L* genes that are sensitive to interferon. "An interferon-sensitive vaccinia virus would be a better vehicle for a vaccine, such as one for HIV infection," said Dr. Jacobs.

Curriculum and Laboratories

A completely revised biology curriculum envisioned at Arizona State University is expected to foster the critical inquiry approach stressed in the faculty workshops described below. When the first group of faculty members completed the workshop in the summer of 1993, they were encouraged to translate what they had learned into novel course material, and they could apply for HHMI support for equipment and laboratory renovation. Following the summer faculty workshops, which set the stage for curriculum development, the committee provided support to faculty to implement the knowledge gained in the workshops. According to Dr. Steven Rissing, Professor of Zoology, "We want to offer faculty 'graduating' from the workshop, as well as others active in bringing teaching innovation to courses in the life sciences at ASU, the opportunity to request funds for equipment and laboratory renovation."

Faculty Development

The HHMI grant is supporting intensive summer workshops for Life Science faculty members. These workshops are designed to emphasize ways to redesign courses to introduce critical inquiry, rather than rote memorization, into the biology curriculum. While future workshops will be geared for faculty who teach introductory courses, the first was designed for faculty who teach upper-division core curriculum biology courses. This month-long Teaching Strategies Workshop was held in June 1993. The course was taken by 13 faculty, mostly from the Zoology and Botany Departments, under the instruction of

Dr. Anton Lawson, Professor of Zoology.

According to Dr. Lawson, the philosophy behind the workshop is "that we are teaching science consistent with the way science is done." The approach to instruction mirrors the learning cycle by beginning with exploration and raising questions, then proceeding to invention and hypothesis testing, and ending with the application of the new ideas in different settings. During the final two weeks of the course, participants proposed at least two new experiments or ideas for their courses, benefiting from feedback when they actually taught the new material to the other faculty members in the workshop.

Precollege and Outreach

One significant component of Arizona State University's outreach efforts is to work with community college faculty members in the Maricopa County Community College District to encourage participation in the University's teaching strategies workshops. Outreach efforts are focused on teachers of introductory biology courses because many of their community college students transfer to the University in the sophomore and junior years and constitute 40 percent of the life sciences graduates.

In 1993, American Indian students at Estrella Mountain High School on the Gila River Indian Reservation in Laveen, Arizona, took part in a presentation on comparative anatomy and physiology at Arizona State and were given tours of teaching laboratories, the campus science library, and its American Indian Institute, a special campus office devoted to easing the transition from reservation life to campus life. High school students may eventually be able to take part in a summer Biology Camp supported by the Institute.

Institutional Profile

Total Enrollment	39,903
Undergraduate Enrollment	29,646
Number of Faculty Members	1,389
Endowment (in millions)	$36
Annual Budget (in millions)	$462

Brandeis University

Program Director
John E. Lisman, Ph.D.
Professor of Biology
Brandeis University
Waltham, MA 02254
(617) 736-3145
(617) 736-3107 (fax)
lisman@brandeis
(Bitnet)

Brandeis University is a private research institution in Waltham, Massachusetts. In 1992 the Howard Hughes Medical Institute awarded the University $1,400,000 to support the following: (1) development of a new introductory curriculum in the life sciences, integrating biology with chemistry, physics, and mathematics and emphasizing the relationships among the physical and life sciences and quantitative and computational approaches to biology; (2) programs to strengthen the statistical skills of life sciences undergraduates through the appointment of a molecular geneticist with expertise in biostatistics, creation of a computer laboratory, and development of a new course in biostatistics; and (3) increased opportunities for faculty-student research collaboration, including laboratory experiences for students from minority institutions.

Student Research and Broadening Access

Brandeis students, as well as minority students from other campuses, were able to take advantage of two summer programs made possible by the HHMI grant. One of these programs provided summer research support to 11 Brandeis students, 8 of whom are female and 2 black. After an orientation period, students work in faculty laboratories for up to 12 weeks and participate in weekly seminars and luncheons. At the end of the program, students take part in a mini-symposium in which they give 10-minute slide presentations about their research. The mini-symposium is expected to attract the entire Brandeis scientific community.

Minority students from Howard University and the University of Puerto Rico Rio Piedras campus, also can take advantage of summer research opportunities at Brandeis. The summer of 1993 marked the culmination of a year-long effort to cultivate the institutional relationships essential to initiate the program. Three students from Howard University and two from the University of Puerto Rico had their travel, stipend, and room and board funded by the HHMI grant. Many of their organized activities were coordinated with those of the program offered to Brandeis students.

One visiting undergraduate from the University of Puerto Rico Rio Piedras Campus was Joannella Hernandez Morales, who undertook her research project in the laboratory of Dr. Lawrence Wangh, Associate Professor of Biology. Dr. Wangh's laboratory is investigating the basic mechanisms of DNA replication in eukaryotic cells. The goal of Ms. Morales's project was to study how a plasmid derived from bovine papilloma virus replicates in *Xenopus* egg

extracts. She attempted to distinguish the underlying DNA structure that accounts for variations in supercoiling that take place when the plasmid DNA assembles into a chromatin complex *in vitro*. "I had never done techniques like two-dimensional gel electrophoresis before, and now after two weeks I can see some results," observed Ms. Morales, who would like to enter graduate school in the United States.

Curriculum and Laboratories

With its Institute grant, Brandeis University has embarked on a program that strives to enhance the quantitative and computer skills of biology majors. Biology majors can enroll in an experimental one-year freshman course that integrates physics and calculus. Most biology majors take introductory physics and calculus as separate courses two years apart, even though the material is strongly interrelated. Drs. Daniel Ruberman and Robert Meyer were supported by the Institute's grant during the summer of 1993 to redesign their courses into a single course, entitled Calculus and Physics for the Life Sciences, taught by both of them.

Many of the lectures and laboratories reinforce the relationships between the two fields and weave in applications to the life sciences. In one lecture, physical principles governing work and energy are illustrated by calculating the number of calories the heart uses to pump blood during a day. Students learn about centrifugal force and circular motion by determining how fast macromolecules of a given size must spin to be concentrated in an ultracentrifuge. "The integration will strongly promote the use of math as a tool to solve problems.... Bringing together faculty from different science departments has also been the most valuable part of the year," said Dr. John Lisman, Professor of Biology and program director.

Another example of the new emphasis on quantitative and computer skills can be found in Introduction to Neuroscience, a course for 40 juniors and seniors. With Institute support, Dr. Lawrence Abbott, Professor of Physics, developed new computer software and problem sets to teach basic principles of neurophysiology. His software programs are designed to simulate classic experiments in neuroscience that demonstrate the electrical properties of nerve cells. The programs illustrate patch clamp recordings of single channels, voltage and current clamp recordings, and the propagation of action potentials.

After a lecture demonstration, students have an opportunity in their computer "laboratory" assignments to manipulate (on the computer) screen variables

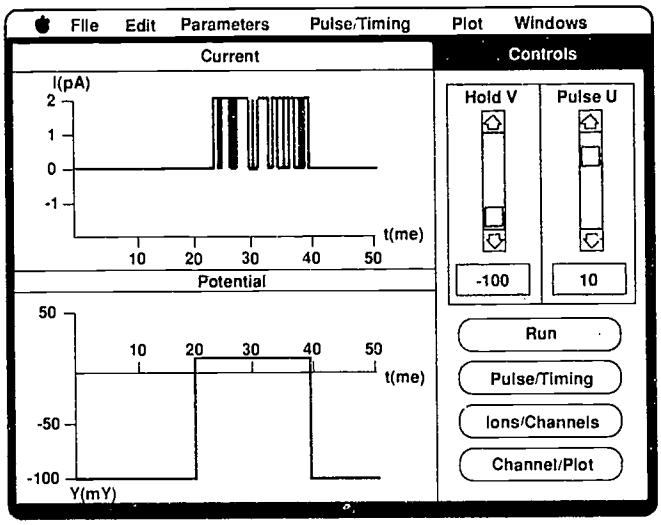

Figure 40. Program simulating patch clamp recording. The "Current" window shows current passing through the ion channel in response to the clamping voltage shown in the "Potential" window.

such as ion concentrations across a nerve cell membrane, just as if they were conducting a real experiment. For example, using the software program on patch-clamp simulation, students can measure how much current flows through an ion channel in the cell membrane at different voltages across the channel (Figure 40).

This program and related software developed by Dr. Abbott allow students to model not only the physiological impact of opening one ion channel but also the impact of opening up to 100 ion channels simultaneously. Using these programs, students concentrate on the quantitative aspects of neurophysiology without the difficulty of simultaneous exposure to new wet lab techniques, which can be acquired in separate laboratory courses. In a computer program currently under development, an artificial neural network is represented by a grid of 150 neurons in which black denotes a firing neuron and white a silent neuron. Initially the grid is white. Students can draw a black pattern on the grid with the mouse and ask the network to "learn" this pattern. Learning can be verified by entering an approximate but inaccurate version of the pattern. When the network is run the inaccurate version is transformed into the learned pattern (Figure 41).

Computer training and its application to biology are ordinarily limited to small classes in order to provide students with hands-on instruction. But with new equipment funded by the Institute, this training can now be introduced in a lecture setting. Through the purchase of an active liquid crystal display panel that is mounted on an overhead projector and driven by a Macintosh computer, Brandeis students in several chemistry and biology lecture courses can see a color image of the computer display projected onto a large screen.

Brandeis faculty have devised multiple uses for this new system. One faculty member, Dr. Fran Lewitter, uses it to demonstrate the role of databases in human genetics, such as the Genome Data Base and GenBank. Dr. Neil Simister, Assistant Professor of Biology, uses the system in his course on Cell Structure and Function. Structures of DNA, proteins, and sugars are displayed and rotated with a software program to give students an understanding of these basic cellular building blocks. Cell function is

then graphically illustrated using HyperCard, which creates an animated effect akin to moving quickly through a stack of cards. After drawing each step of protein synthesis onto a "card" in a "stack" on the HyperCard program, Dr. Simister projects the stack onto a lecture screen to show the complex sequence of events governing protein synthesis.

"Students are easily overwhelmed by the number of events and the nomenclature of protein synthesis," said Dr. Simister. "Using HyperCard, I was able to break down the events by running through the cards fast and then slowly, giving an animated effect. The students could visualize the growing chain of amino acids as the ribosome moves along the mRNA. They grasped it much better, having seen it," said Dr. Simister.

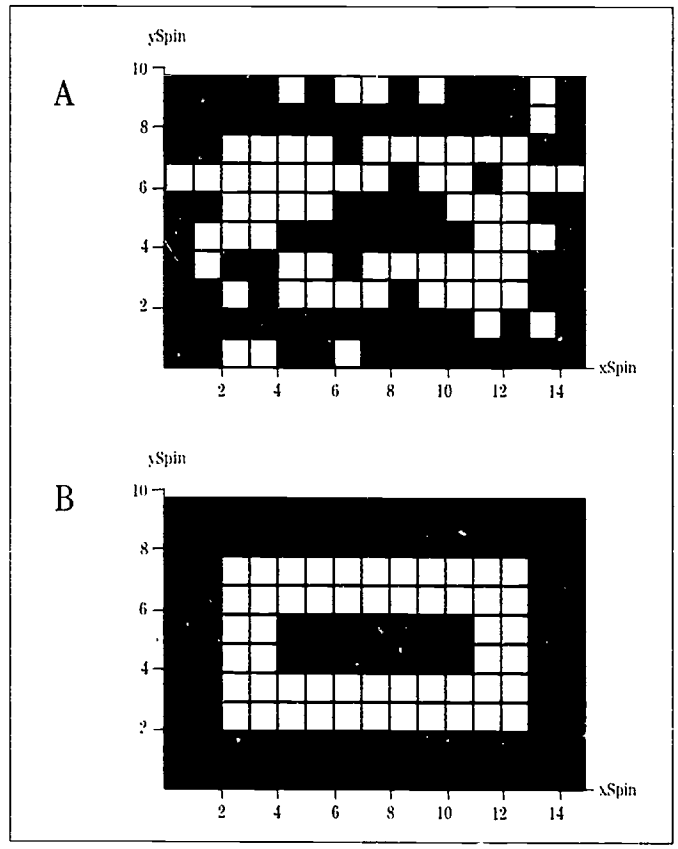

Figure 41. Computer screen simulation of a model neuron network participating in associative memory. A black square indicates a firing neuron and a white square a silent neuron. Students use the program to test how many patterns can be stored by the network and how precise the input pattern must be to assure recovery of a pattern. "A" represents an inaccurate version of the learned pattern; "B" represents transformation of the inaccurate version into the initial learned pattern.

Faculty Development

The HHMI grant enabled Brandeis to hire Kent Reuber, a computational specialist whose responsibility is to improve the computational proficiency of biology undergraduates. With the assistance of faculty members, he is establishing a Biological Sciences Computer Cluster, which is expected to operate with up to 10 Macintosh workstations funded by the grant. Mr. Reuber is also helping to fill the computer hardware and support needs of several introductory biology courses.

A major goal for Brandeis in 1993–1994 is the appointment of a molecular biologist who can emphasize in courses the quantitative methods used in molecular biology.

Institutional Profile	
Total Enrollment	3,693
Undergraduate Enrollment	2,856
Number of Faculty Members	467
Endowment (in millions)	$161
Annual Budget (in millions)	$130

California Institute of Technology

Program Director
Pamela J. Bjorkman, Ph.D.
Assistant Professor
Division of Biology
Assistant Investigator
Howard Hughes Medical Institute
California Institute of Technology
Pasadena CA 91125
(818) 395-8350
(818) 792-3686 (fax)
bjorkman@citray.caltech.edu (Bitnet)

California Institute of Technology is a private research institution in Pasadena, California. In 1992 the Howard Hughes Medical Institute awarded it $2,000,000 to support (1) enhancement of a summer research program for undergraduates, particularly women students, and provision of laboratory experiences for minority students and their faculty research advisers from other institutions; (2) development of computer-based instructional materials (to be made available to other institutions) for undergraduates studying such topics as atomic, macromolecular, and organismic structure, three-dimensional modeling of biological phenomena, and imaging of living tissue; (3) acquisition of new equipment to expand the use of computers for undergraduate instruction in cell biology, neurobiology, and other areas; and (4) expansion of a program that imparts new approaches to teaching biology to teachers in Pasadena-area high schools.

Student Research and Broadening Access

The HHMI grant is supporting undergraduate research projects at Caltech under the aegis of the Summer Undergraduate Research Fellowships program. Undergraduate candidates submit research proposals modeled on the grant system used by senior investigators when they apply to federal agencies or private foundations for research support, and assignments and awards are made on the basis of reviewer recommendations. More than 70 percent of participants go on to graduate programs, once they have earned their Caltech B.S.

Moeen Abedin, who did research in cell biology as part of the program in the summer of 1992 and then continued the project during the academic year, working with Dr. William Dunphy of the Biology Department, said the experience may lead to a career in research. According to another student participant, Tara Chapman, the program provided "a unique opportunity to work with one of the foremost researchers in the study of mitochondrial DNA. More important, I have been able to experience research as a full-time occupation, and I no longer have any reservations about pursing a research career." Ms. Chapman worked with Dr. Anne Chomyn, Senior Research Associate in Biology. Ms. Chapman presented her research findings at the seventh National Conference on Undergraduate Research at the University of Utah in March 1993 (Figure 42).

Another participant in the program, Jed Pitera, tried to improve expression of a class I major histocompatibility complex allele in a mammalian system, working in the laboratory of Dr. Pamela Bjorkman, Assistant Investigator

in the HHMI medical research program at the California Institute of Technology. Although the project took "longer than expected," Mr. Pitera said, "the experience served me well. In addition to providing me with valuable research skills...in DNA manipulation and tissue culture, it has given me perspective on what it means to be actively involved in research.... I have both stabilized my resolve to go to graduate school and acquired a good idea of my prospective field, protein biochemistry."

The Biology Undergraduate Mentor Program was developed by Dr. David Anderson, Associate Professor of Biology and HHMI Assistant Investigator. As part of this program, junior and senior biology majors met weekly with introductory biology students, helping them to solve problems and to go over difficult materials taught in the classroom. The program was "overwhelmingly successful," according to Dr. Anderson. Not only did students enrolled in the course benefit, but the participating mentors found the review of materials useful as they prepared for GREs and MCATs.

Another Institute-supported program enables undergraduates from underrepresented minority groups to do research in biology and chemistry during the summer. It is managed by Dr. David Van Essen, Professor of Biology, and Dr. Kai Zinn, Assistant Professor of Biology. "We found that at the end of the summer about half of the 1992 students in this program expressed an interest in doing research as a career," Dr. Van Essen said. One of the students who showed exceptional aptitude for research, Keith Brown, was admitted to do graduate work at the institution in the fall of 1992. Another student, John Entsuah, conducted research in 1992 under the direction of Professor Paul Patterson on a project entitled "Isolation and Partial Characterization of a Chick DNA Fragment Homologous to a Highly Conserved Sequence in Mammalian CNTF (code for a neurotrophic factor) Genes" (Figure 43).

Curriculum and Laboratories

With HHMI support, faculty from several departments at the California Institute of Technology are making use of sophisticated, but readily accessible, computer graphics terminals for teaching fundamental chemical and biological concepts to undergraduate students. The approach begins with a course in introductory chemistry and extends to biological macromolecules, cell structures, and a primate database that has led to the discovery that the size of particular brain structures is closely related to life span, according to Dr. Bjorkman.

Figure 42. Tara Chapman (*right*), an undergraduate, with her research sponsor, Dr. Anne Chomyn (*left*), at work on their project involved with characterization of two cDNA clones for the NADH dehydrogenase complex.

The opportunity to purchase computer graphics equipment and rapidly put it to use in teaching an array of atomic, molecular, and biological concepts was a key benefit of HHMI support, according to faculty and staff at the California Institute of Technology. In addition, a newly created undergraduate mentor program benefited the juniors and seniors who served as mentors as well as the first- and second-year biology students who received special attention and tutoring from them.

The computer graphics systems take advantage of cutting-edge animation technology now being used by filmmakers. Silicon Graphics, Inc., workstations, like those used in such films as "Jurassic Park," are used to generate the animated teaching sequences; and broadcast quality animation and rendering software, provided by TDI, Inc. (Thompson Digital Image, Inc.), is used to build the models and to translate two-dimensional representations of chemical objects into lifelike three-dimensional images. Advanced chemistry computational software, furnished by Biosym, Inc., is then used to provide accurate chemical representations of the desired animated chemical reactions. The rendered three-dimensional images are then recorded onto broadcast master 1/2-inch betacam-SP tape, which exceeds the industry standard for TV broadcast master video tape. The sequences are then edited on 1-inch video tape submasters in a broadcast studio at the Jet Propulsion Laboratory, and 24-track sound (music and voice narration) is added and dubbed onto the sub-master video tape. The finished product is a 1/2-inch betacam-SP master video tape, from which copies in the VHS and super-VHS format can

Figure 43. John Entsuah records data as part of his undergraduate research project concerning isolation and partial characterization of a chick DNA fragment homologous to a highly conserved sequence in mammalian CNTF genes.

be readily made for facile distribution and viewing.

Dr. Nathan Lewis, a professor in the Chemistry Department, uses these resources to demonstrate key features of atomic orbital theory, which is essential for understanding how chemical elements form molecules. Two undergraduate students, Chris Bryant and Corinna Garcia, who helped develop the system for conveying some of these chemical concepts in outreach programs, made presentations at several meetings, including the seventh National Conference on Undergraduate Research held at the University of Utah in March 1993.

At another level of complexity, computer graphics are used to teach biology students how protein and DNA molecules interact in three-dimensional space. According to Dr. Bjorkman, "The students learn how to use the terminals themselves and can see a lot more this way. DNA structures are pretty meaningless on the flat page of a textbook. On the graphics terminal, a student can measure distances in angstroms and try to dock molecules in clefts. Students don't have much of an idea of what molecular structures are until they examine them in 3-D."

The program being used is very versatile. It enables users to add or subtract structural details, such as van der Waals distances and hydrogen bonds, to give either a relatively cluttered or a spare image of the macromolecule being examined, Dr. Bjorkman pointed out. With these skills in hand, students are poised to appreciate what occurs in a protein when the gene encoding it is slightly altered. "Right now there's a gap in molecular biolo-

gy, and many researchers don't have the ability, say, to recognize the importance of conserved amino acids," she said. However, students who learn these skills with the help of new computer graphics tools "will have a better feel for the structure of proteins they work on."

Dr. Scott Fraser, Anna L. Rosen Professor of Biology, is developing a similar computer graphics approach to teaching students about cellular and organismic structures. A software package he developed offers a convenient means to process confocal microscopic images of biological specimens. He is using a disc player, mass storage devices, and a Macintosh Quadra purchased with HHMI grant support to develop an affordable virtual image-based approach for training purposes.

Precollege and Outreach

Institute funds helped support a diverse group, Young Engineering and Science Scholars, during an intensive six-week summer program for high school students who have completed the 11th grade. This program, designed to evaluate changes in the high school curriculum for biology and other sciences, is proving a valuable way to reach students who are capable of doing well in science courses but have not had the opportunity. Many of them come from small towns or from inner cities where equipment for teaching laboratories is scarce and modern concepts in molecular biology have not been introduced into standard courses. Thirty percent of the 1992 summer class at Caltech were black and 40 percent Hispanic.

High school teachers and Caltech graduate and undergraduate students act as faculty for this program, which involves lectures, seminars, laboratory exercises, and other informal gatherings. "In my high school chemistry class, we had only three labs the entire year," said 1992 high school participant Angie Gonzales from Porterville in central California. "At Caltech, we're constantly in the lab, doing stuff we couldn't even imagine at home."

"The summer program for high school students was a fantastic success," said Dr. Jerry Pine, Professor of Biophysics, who has been involved in the design and development of the program. "The students were turned on like crazy to science, and they learned a lot."

In a survey of students following the 1992 course, 80 percent indicated that the program "confirmed or strongly encouraged" their desire to pursue a career in science. Nearly 90 percent said the program "increased their confidence in their ability to engage in scientific study and pursuits."

Another element of Caltech's outreach program involves

improving the science curriculum and elevating enthusiasm among kindergarten–6th-grade teachers. It, too, is proving a success, Dr. Pine said. "We are working with a pilot group of 16 teacher-interns, and they are enormously enthusiastic. They are learning about science—and will be teaching it—by doing it. Based on our first three all-day sessions, this approach clearly has a bright future."

Institutional Profile	
Total Enrollment	1,957
Undergraduate Enrollment	862
Number of Faculty Members	275
Endowment (in millions)	$420
Annual Budget (in millions)	$194

California State University–Los Angeles

Program Director
Alan Muchlinski, Ph.D.
Professor
Department of Biology
California State University–Los Angeles
5151 State University Drive
Los Angeles, CA 90032-8201
(213) 343-2065
(213) 343-2670 (fax)

California State University–Los Angeles is a public comprehensive university. In 1991 the Howard Hughes Medical Institute awarded it $800,000 for support of a program to include the following components: (1) a research training program for female undergraduates, to include introductory seminars and laboratory rotations, faculty mentoring, and support for individual research projects; (2) a prefreshman summer program in the sciences for students, including women and students from underrepresented minority groups; (3) development of the entry-level biology curriculum to include new courses and the establishment of a computer laboratory as well as improvements in the laboratory components of upper-division courses in cell biology, biochemistry, and other areas; (4) faculty development, including opportunities for faculty scientists to upgrade skills in teaching and research, and start-up support for new faculty members; and (5) precollege outreach to schools in the Los Angeles area.

Student Research and Broadening Access

Prefreshman Bridge Program. California State University is using its Institute grant to provide incoming freshmen a head start on the academic year through the Summer Science Bridge Program. This program provides students about to enter college-level science programs with activities and experience to help them to make the transition to college and to continue in their science studies. In 1992, the initial year of the program, a total of 46 students participated, 80 percent of whom are black, Hispanic, or Pacific Islanders and 57 percent are women.

Following the application and review process, selected students become part of a program that includes presentations on science by faculty members, such as "Hemoglobin: Structure and Function" by Dr. Donald Paulson of the Department of Chemistry, background on research areas and campus laboratory facilities, orientation to the library system, and other topics. Faculty presentations are complemented by talks by undergraduates who are in various stages of their college careers.

An important component of the Summer Science Bridge Program is the development of study groups that the prefreshmen would continue into their college years. These workshops emphasize effective study skills, time management, and the importance of group study, particularly when taking calculus courses. An objective of the program is to identify students and their proficiencies before they enroll in introductory science and mathematics courses in their freshman year. Through diagnostic tests, the program's

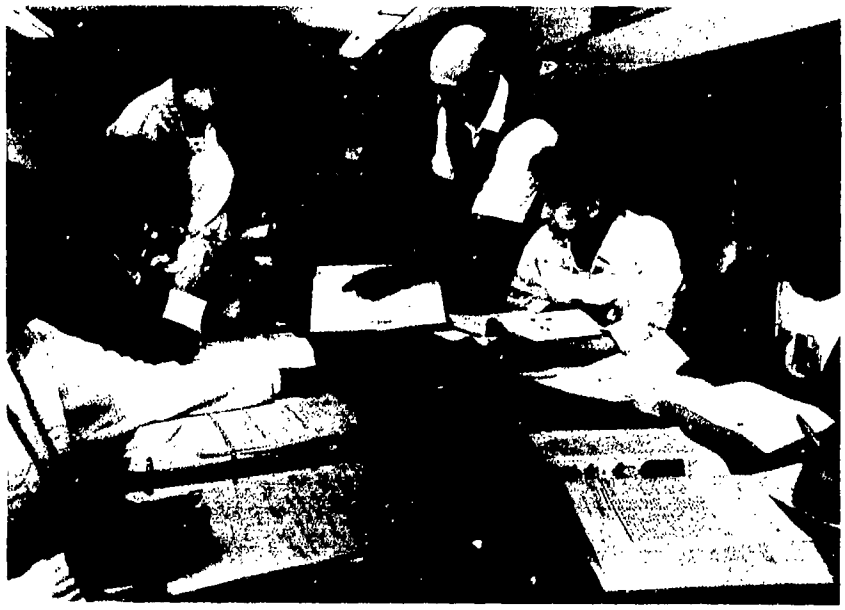

Figure 44. Dr. Margaret Jefferson and Dr. Raymond Garcia (*standing*), working with (*from left to right*) Denita Redd, Jovenal Mendoza, Francisco Villeda, Max Fernandez, and Robert Green, students participating in a program to encourage group study in the sciences.

organizers can track students into appropriate course levels and avoid the high attrition that students, particularly those from underrepresented minority groups, experience in introductory courses (Figure 44).

"Unfortunately many of our students who come to Cal State are at the precollege level of math. They have to start with that and they have to keep taking math until they get into calculus," said Dr. Margaret Jefferson, genetics professor and co-director of the study program. Science majors are required to take a minimum of two quarters of calculus, and some take as many as five quarters. "We can't turn these kids away," she said. "They're determined they want to be science majors."

Dr. Jefferson says that the summer program supported by the HHMI grant is "turning out to be absolutely essential in terms of getting students into their freshman math and science courses—placing them in the right course and then seeing that they stick with it until they complete all their math requirements. Without the necessary math prerequisites they can't start their science courses," she explained (Figure 45).

Dr. Jefferson uses a computer to track every participating science major's grades during the academic year and sees that they complete their required math courses.

Lissette Sisco, a freshman biology major, said the summer bridge gave her the opportunity to overcome her anxieties about pursuing a science degree. She noted that the exposure to faculty members and the University in general helped to allay her concerns. She also met other biology majors and the mentors who would lead her study pro-

Figure 45. Summer Science Bridge students Lissette Sisco and Humberto Gallardo review the results of their Entry Level Mathematics test.

grams in mathematics and chemistry during the academic year.

The faculty "told us we had to start our math as early as possible because science majors really need it," Ms. Sisco said. She followed their advice and took trigonometry, calculus, and calculus for biology in her freshman year. Next year she will take biology and organic chemistry.

Once the academic year begins, a special study program provides mentors to help students, including underrepresented minority students, realize their dreams of graduating as science or mathematics majors.

The HHMI grant also supports student mentors who each supervise a study group of 10 to 20 freshmen. The mentors attend classes of the biology, chemistry, calculus, and college or precollege algebra courses they supervise, consult with the professors teaching the courses, and take turns solving problems with the students and explaining terms and concepts at the blackboard. The mentors give quizzes covering the weekly assignments.

The University also uses HHMI funds to increase the number of mentors covering math courses in the program, and increases the number of students taking the math courses and having tutors. Over an approximate one-year period, 119 students from freshmen through seniors participated in the program. Fifty-five percent were Hispanic, black, or Native American. Slightly over half were females.

In the program, the mentors advised the incoming freshmen to study chemistry and math every day, instead of trying to cram at the last minute before an exam. Ms. Sisco participated in the math and chemistry group study programs and found them "very helpful.... Being able to study with other people and knowing that other people were having difficulty with the class, too, helped," she said.

Ms. Sisco plans to pursue a doctorate and a career in biology. When sne entered the campus a year ago, she had some doubts about her ability to reach her goal. But with the freshman year behind her she says, "I feel stronger about doing what I want to do. I think that it is possible. I know that I can do it and I'm going to work toward that."

Humberto Gallardo, a freshman biology major, also praised the study program. "A tutor

helped me out in Biology 101 and 102," he said. "He answered all my questions. Without him I probably wouldn't have gotten a good grade."

Student Research Program

With HHMI support, five female undergraduates began work in a research laboratory during the academic year.

■ Darlene Holden, a junior biology major, is working in the laboratory of Dr. Roger R. Bowers, who investigates two pigmentation mutants of chickens as possible models for the human skin depigmentation disease vitiligo. She has learned electron microscopy.

■ Regina Leoni, a junior biology major, worked under the direction of Dr. Alan Muchlinski, Professor of Biology and program director. Ms. Leoni and several other undergraduate students investigated whether lizards get a fever when infected with bacteria. Previous studies in Dr. Muchlinski's laboratory had shown that the common agama developed a fever when infected with wide-ranging doses of bacteria. In contrast, Ms. Leoni and other students found that the savannah monitor lizard exhibited a fever response to only a very narrow dose range of bacteria. Similar studies that had used only one dose of bacteria had reported no evidence of a fever in that lizard. When challenged with a broad dosage range of bacteria, the Sudan plated lizard, also tested by the students, showed no evidence of a fever. Ms. Leoni co-presented her results at the Experimental Biology '93 meetings in New Orleans.

■ Peggy Momjian is working with Dr. Sandra Sharp, who conducts studies of the regulation of actin genes. Ms. Momjian has been adapting BC3H1 cells to a less costly growth medium. She is monitoring the rate of cell division, plating efficiency, and morphology. When a suitable growth protocol has been established, she will monitor actin expression.

■ Pham Van and Vy Nguyet, sophomore microbiology majors, are working in the laboratory of Dr. Joseph Seto, studying the structure/function relationships in proteins responsible for host specificity and infectivity of Sendai virus. The laboratory has isolated a variety of strains with mutants in one of several proteins known to play a role in infectivity and host specificity. Ms. Van and Ms. Nguyet have been sequencing mutants in the *M* gene and constructing plasmids containing the mutant genes. The M protein may be involved in maturation and assembly of virions at the cell surface.

Two other students appointed during 1992 continued their work into the next year.

■ Shadi Shayegan, working with Dr. Alan Goldstein, completed a study on how genes for human antibodies can be fused to a virus

vector, which then carries the gene into the tobacco cell. The human antibodies produced in transgenic tobacco plants were characterized, using immunoblotting and enzyme-linked immunosorbent assay (ELISA) techniques.

■ Shiva Avari, working in Dr. Sharp's laboratory, tested the hypothesis that the level of mRNA for vascular smooth-muscle actin is lowered by the expression of the regulatory genes *MyoD-1* and *herculine*, which lead to muscle formation.

Curriculum and Laboratories

A videodisc technology laboratory that students may use at their convenience is helping change the University's approach to teaching science.

The HHMI grant was used to establish, supply, and staff the lab, which has 10 videodisc work stations. Each work station is equipped with a Macintosh IIsi computer, a laserdisc player, and a color monitor. Twenty students at a time can use the laboratory. In addition, three portable work stations are available for use in the classroom.

The videodisc technology allows students in introductory biology courses to see images of the microscope slides from their laboratory classes. They see live and animated video motion sequences of processes and biological events, and images of organisms. For instance, they see slides on cells and tissues; mitosis and meiosis; protozoans, bacteria, and algae; and blood and circulation.

Two upper-division courses also made use of the videodisc technology. In histology, students saw images that show detailed histological features from various sections of the human body. Embryology students looked at images of developmental stages of starfish, sea urchins, frogs, chickens, pigs, and humans.

"Before we established the videodisc laboratory, most students were not able to review the material that was presented in the teaching labs," said Dr. Muchlinski. Now students can view video images of cellular organelles and various types of animal tissues. "I think it's introduced a new excitement among the students for studying biology," Dr. Muchlinski said.

A major need in the biochemistry teaching laboratories had been for recording spectrophotometers capable of measuring in the ultraviolet region. The HHMI grant helped pay for four new UV-visible scanning spectrophotometers. The new equipment will allow faculty to introduce undergraduates to experiments involving absorption spectra, difference spectra, and kinetic measurements, and perform new experiments in DNA and protein structure, ligand binding, and the kinetics and regulation of

enzymes. The new instruments will be used in an upper-division biochemistry course.

Faculty Development

Under the HHMI grant, Dr. Mark Cook joined the faculty last September as Assistant Professor of Biology to conduct research in neuroanatomy. Dr. Cook, who has a Ph.D. in anatomy from Michigan State University, seeks to understand how efferent nerves in the rat brain send messages along the central nervous system. His goal is to determine the pathway of neuronal excitation and to learn what certain cells do with the sensory signals conveyed to them.

Dr. Cook is designing a human neuroanatomy course that will be open to undergraduate and graduate students. One undergraduate worked in his laboratory during the winter quarter, processing brain tissues for electron microscopy. Dr. Cook teaches courses in electron microscopy, human anatomy, and comparative anatomy.

In addition to supporting Dr. Cook, the HHMI grant allowed six faculty members to attend conferences and workshops to help them keep current in their research.

Dr. Sharp attended a Gordon Conference on Myogenesis at the Tilton School in New Hampshire, June 15–19, 1992, where she presented some of her work on the regulation of actin genes and met with other researchers. As a result, Dr. Sharp acquired additional clones and probes that she says will be of great benefit to her research, and she brought back new information to use in her Principles of Gene Manipulation course.

Institutional Profile	
Total Enrollment	20,804
Undergraduate Enrollment	15,383
Number of Faculty Members	671
Endowment (in millions)	$4
Annual Budget (in millions)	$120

Centre College

Program Director
John Preston Miles, Ph.D.
Chair, Division of Science and Mathematics
Associate Professor of Chemistry
Centre College
Danville, KY 40422-1094
(606) 238-5414
(606) 236-9610 (fax)

Centre College is a private liberal arts institution in Danville, Kentucky. In 1991 the Howard Hughes Medical Institute awarded the College $500,000 to support (1) initiatives in the sciences for teachers and "at-risk" students at the elementary, middle, and high school levels; (2) enrichment and expansion of an established program in biochemistry and molecular biology and appointment of a new faculty member with expertise in these areas; and (3) laboratory research during the summers for students and faculty scientists.

Student Research and Broadening Access

The HHMI-funded program at Centre College provides summer research opportunities for undergraduates, filling a gap between others that are available during the academic year. In summer 1992, its first year, the program funded nine students. Six continued their research with other support during 1992–1993. Five of these, with partial support from the grant, presented their work at a meeting of the Kentucky Academy of Sciences.

"We foresaw the good, positive things that would happen," said Dr. Preston Miles, Chair of the Division of Science and Mathematics and HHMI program director. "What's happened isn't as surprising as the fact that it's really gotten going here in just about the second year."

The summer research program offers a stipend, room and board, and an allowance for laboratory supplies. In summer 1993 Manoj Warrier investigated phytoalexins in the laboratory of Dr. Margaret Richey.

"We're testing a hypothesis on the mechanism of how certain pathogenic fungi attack the soybean and how [the fungi] overcome the soybean's defenses, such as the plant cell wall and certain chemicals that plants have as a defense mechanism," said Mr. Warrier, a double major in chemistry and in biochemistry and molecular biology.

Initially, the researchers investigated pathogen mechanisms against the phytoalexin glyceollin produced by soybean. "We're assuming that pathogens have a defense mechanism against this particular phytoalexin and are unhindered by it, while nonpathogens are [hindered]," Mr. Warrier said. He was involved with producing glyceollin from soybeans and purifying it, using column or thin-layer chromatography, and testing the compound's purity with ultraviolet spectrophotometry.

Mr. Warrier, entering his senior year, is considering enrolling in an M.D./Ph.D. program after graduation. 'I have an interest in doing some medical research," he said. "I don't want just my M.D. if I plan to do that.

I'd rather also have the laboratory background, which I think is really essential."

In summer 1992 biology major Carrie Sinex constructed a Y-maze, flow-through aquarium needed to extend her research. "The year before, I had done some study on predation cues in fish," Ms. Sinex explained. Others had reported that chemicals from predator fish triggered antipredator behavior in prey fish; however, her own work indicated that visual cues were important.

To investigate chemical cues, Ms. Sinex built the flow-through aquarium, including a 350-gallon holding tank at each end. The idea was to isolate a predator fish behind a perforated barrier in one arm of the Y-shaped aquarium, allowing its chemicals to flow down to a prey fish in the stem. If the prey fish reacted to the predator chemicals, it would flee to the chemical-free water in the other arm. She did the research during her senior year.

"What my research indicated," Ms. Sinex said, "was that, at least in the two species I studied, there was not a lot of detection of the chemical cues." She presented her work, entitled Behavioral Responses of Northern Studfish to Visual and Chemical Cues from a Bass, at the Kentucky Academy of Sciences meeting.

In summer 1993 the program enrolled 11 more students, who became involved with structural studies of membranes, computer modeling of biological processes, an immunofluorescence study of cell differentiation, and other research topics. The number of students involved was nearly double that envisioned at the outset of the program.

The new summer research program has generated enthusiasm and interest among the students, Dr. Miles said, and may be contributing to a rise in majors in the biological sciences. The number of biology majors has increased to 40, from a level around 25 to 28, and the number of biochemistry majors has risen to 12, from about 3 to 6.

Dr. Miles said that the specific impact of the Institute's grant is difficult to assess at this early stage of the program's development, but he pointed out that "the increase in number of majors is coincident with the visibility of these programs due to [support from] the HHMI grant."

Curriculum and Laboratories

Introduction to Cellular and Molecular Biology, a sophomore-level lecture course, is required for students majoring in biochemistry and molecular biology or in biology and is taken by most premeds and many chemistry and psychobiology majors.

With support from the HHMI grant, Dr. Linda Roberts, Assistant Professor of Biology, and others have developed a

new laboratory course that will be offered in 1993–1994 as an accompaniment to the new lecture course. It involves experiments with electron microscopy, protein electrophoresis, and enzyme reaction bioseparations. HHMI funding provided microscopes, shaking incubators, a high-purity water system, centrifuges, and other items to equip the laboratory. The HHMI grant is also helping to equip a research laboratory for Dr. Roberts.

Faculty Development

The addition of a permanent tenure-track faculty member funded by the HHMI grant played a key role in improvements to the biology program. Dr. Linda Roberts, an expert in biochemistry and structural biology, began her duties in fall 1992. She has a Ph.D. in molecular genetics from Washington State University and recently served as a research associate with the Southern Research Institute in Birmingham, Alabama. During the 1992–1993 academic year, she taught advanced courses in molecular biology and biochemistry as well as the introductory biology course. She also mentored a 1993 participant in the HHMI-funded summer research, in collaborative work on the reconstruction of human apolipoprotein A-1 with synthetic lipid and cholesterol.

Four faculty members received support for professional development and were also involved in collaborative research in 1992–1993 with undergraduates who had participated in HHMI-funded summer research in 1992.

Precollege and Outreach

Centre College is located at the edge of Appalachia, where many students are educationally disadvantaged. The HHMI-funded outreach program enhances science education for precollege students in the area, as well as for women and underrepresented minority students from the entire region, through a summer science camp for elementary and middle school students and a summer workshop for science teachers.

According to Dr. Miles, the summer science camp in 1993 was immediately popular. A local newspaper announced it on an April afternoon, Dr. Miles recalled. "That night ... the phone was already ringing with calls from parents."

The camp eventually enrolled 150 4th- through 8th-graders, who attended morning or afternoon sessions for one week. Children worked in groups of no more than 15 to investigate aquatic ecology, household chemicals, or the biology of ground water. The HHMI grant provided for teacher stipends

Figure 46. Participants in the HHMI-Centre College High School Teacher Workshop in Molecular Biology (*from left*) Rob Hartgrove, Daviess County High School; Veronica Wheeler, Lawrence County High School; and Glen Zwanzig, Manual High School, discuss the results of a plasmid transformation experiment.

and supplies, and Centre College provided the facility.

The camp enrolled 77 girls and 73 boys. Of these, 28 were from Appalachia or were economically disadvantaged, and 8 were from underrepresented minority groups. The number of minority students was somewhat lower than expected. "Making contacts in the minority communities is difficult," Dr. Miles said. "As we get more involved with the public schools, that's where we'll have our success."

The HHMI-funded summer workshop for science teachers provides precollege science instructors with an opportunity to enhance their scientific knowledge. "This is science that has happened since they graduated," Dr. Miles said. The workshop "is an opportunity for them to get new science." A secondary goal is to show teachers experiments that could be incorporated into a high school science curriculum.

The first workshop was held in 1993 and focused on molecular biology (Figure 46). The two-week camp attracted 14 high school teachers, who received a stipend, travel allowance, and accommodations on campus. Materials for the course were developed during summer 1992 by Dr. Margaret Richy, Assistant Professor of Biology, with the collaboration of an HHMI-funded summer student researcher, Jenny Day-Ellis.

Interaction among Centre College faculty and area science teachers over the first two years of the Institute grant has led to outreach through an informal network. "It just means maintaining contact and [having] them feeling comfortable calling us," Dr. Miles said. For instance, teachers will now call the college to obtain chemicals, get advice

on new equipment, or troubleshoot an experiment.

The HHMI-funded program has also taken advantage of ad hoc opportunities for outreach. In spring 1992, for example, the project joined another on-campus program, Learning Is Fun Together, aimed at 4th and 5th graders at risk of low academic achievement. Dr. Michael Barton, Associate Professor of Biology, designed a program of eight weekly meetings in which 120 students used Wisconsin Fast Plants, which develop from seed to seed production in a month, to study the effects of fertilization on growth rate and flower and seed production.

Institutional Profile	
Total Enrollment	900
Undergraduate Enrollment	900
Number of Faculty Members	89
Endowment (in millions)	$61
Annual Budget (in millions)	$19

City University of New York Brooklyn College

Program Director
Ray H. Gavin, Ph.D.
Professor and Chairman
Department of Biology
City University of New
York Brooklyn College
Brooklyn, NY 11210
(718) 951-5396 or
(718) 951-5715
(718) 951-4615 (fax)

City University of New York Brooklyn College is a public comprehensive university. In 1991 the Howard Hughes Medical Institute awarded the College $1,200,000 to support (1) student development through academic counseling and preparation in the sciences for first-year and transfer students, expanded research opportunities for undergraduates, and activities to encourage students to consider careers in scientific areas; (2) faculty development to include science activities for current faculty and support for the appointment of a new faculty member in either molecular biology or immunology; (3) curriculum development that will provide modern laboratory equipment for new courses in molecular and cellular biology, immunology, and other areas, as well as for the establishment of an interdisciplinary honors program; and (4) partnership with a local high school that will include an honors program for students, an initiative that brings college science faculty to the school, and workshops to develop skills of high school science teachers.

Student Research and Broadening Access

Dr. Ray H. Gavin, Professor and Chairman of the Department of Biology and HHMI program director, identified revival of a research program at Brooklyn College of CUNY as a principal contribution of the Institute program during the 1992–1993 academic year. Although undergraduate research is part of a long-standing tradition at the College, it all but disappeared from view because of funding shortages during the last decade, he said. In 1991, however, HHMI support revitalized the program, enabling 10 undergraduates to participate. By 1992 participation more than doubled, so there are now close to 30 students engaged in research in biology at the College, and the program is running near capacity.

An important feature of the program is its bi-weekly meetings during which both faculty members and students engage in "spirited discussions," Dr. Gavin noted. The atmosphere is free-wheeling, and students are expected to respond to criticisms of their experiments. "This is something every scientist must learn to do—the sooner, the better," he added.

"If you asked the biology faculty to identify the most rewarding aspect of the Howard Hughes Medical Institute funding, most would identify this research participation program," Dr. Gavin continued. "This is all above and beyond the standard curriculum for biology majors. There are students who spend all their non-class time in the lab, where they have a true mentor who is an enormous form of support."

The College's students represent diverse cultures and speak

Figure 47. A group of Brooklyn College biology students review scientific material with a tutor (*far right*).

more than 30 languages other than English as their mother tongue, Dr. Gavin pointed out. "Most of our students are first-generation college students and need the support that a mentor can offer." Thus, the Institute's program has provided a research participation center for biology students that has become "a home during the day on campus—giving the students a sense of identity."

"I started here planning to go to medical school," said Jorge Garces, a 1993 graduate of the College. "But I really want to do research." He credits Institute support as allowing him to concentrate on biology course work and get started doing research—in his case, investigating the contractile proteins that comprise the cortical feeding system in *Tetrahymena*. "Participation in this program has really helped me find a place in research," he said. "Before, I didn't know how to approach a professor, but I showed up for the introductory meeting, and afterward all that fear was gone. The faculty explained their work, and we got to pick what we liked. Programs like this help minority students especially, because we look for role models."

Biology major Sharon Moshel, a senior who is working in 1993 with Dr. Jack Collier of the Biology Department, has been interested in science since high school and now plans a career in molecular biology. "I've really been bitten by the research bug," she said. "I spend most of my time here in the lab every day. Sometimes it's frustrating, but good results make up for it." With Dr. Collier, she plans to use *Drosophila*-based gene probes to search a DNA library from a marine organism for developmental control genes. "We've started doing restriction mapping, and eventually we'll do gene sequencing," she said. That analysis will also help to address evolutionary questions about develop-

mental control by making comparisons between distantly related organisms, she noted.

Curriculum and Laboratories

Peer tutoring was one of two principal efforts that proved most "exciting" within the HHMI-supported program during 1992–1993 at the City University of New York Brooklyn College, according to Dr. Gavin. Over the fall and spring semesters, 12 tutors at a time helped to teach their fellow undergraduates in six different courses—three in introductory biology and chemistry and three in advanced biology or chemistry (Figure 47).

The initial success of the peer tutoring program, in which undergraduate students who are majoring in the sciences tutor students taking lower-level courses, "far exceeds anything we expected," Dr. Gavin said. Plans now call for expanding this effort into other areas of the science curriculum, including other intermediate-level courses in chemistry and physics. Although no formal performance analysis has been completed, it appears that the peer tutoring program has already helped cut the attrition rate in the introductory biology course, he noted. In addition, the tutoring has proved "an immeasurably positive experience" for the tutors. "I probably learned more by tutoring than I did by taking the course," said Jorge Garces, who recently completed his bachelor's degree at CUNY Brooklyn College and is continuing there in the biology doctoral program.

Institute funds supported curriculum and laboratory development in five different biology courses and acquisition of laboratory equipment for those courses. For example, equipment was purchased to conduct enzyme restriction digests and gel electrophoresis analysis of DNA as part of the introductory biology laboratory course. In addition, a thermal controller apparatus for the polymerase chain reaction is now available for use by undergraduates who take a course in recombinant DNA. Students used this equipment to synthesize a 270-base-pair probe to screen a gene library for a developmental control gene of the fruit fly *Drosophila melanogaster.*

Institute funds were also used to replace the outdated equipment of an undergraduate laboratory course in physiology. Kymograph drums that had been in service since the 1930s were replaced, and computer hardware and software were added for conducting and analyzing results from basic experiments in muscle contraction, nerve transmission, and heart functions.

Figure 48. Adepero Oduye, a student from Edward R. Murrow High School, using a pipette as part of a hands-on science experience.

Precollege and Outreach

In September 1992 Brooklyn College established a pilot science tutoring center at Edward R. Murrow High School. The center is located a few blocks from the College and has a 55 percent minority and 57 percent female enrollment. At first limited to biology, the program soon expanded to include more tutors and was extended to other science courses in chemistry and physics. By the end of the school year, four tutors from Brooklyn College were working three days per week at the high school, offering group sessions as well as one-on-one tutoring (Figure 48).

With HHMI support, the high school's 1993 Science Fair attracted 80 student participants, more than twice the number of the previous year. The College provided advanced science majors to serve as mentors to the high school students as they developed their projects, and faculty members to act as judges. This level of participation also brought college and high school faculty into close contact, offering them a means for setting up long-term informal networks. On a more formal level, faculty from the two institutions have been planning workshops to provide high school science teachers with an opportunity to improve their own understanding of the principles, equipment, and techniques used in research.

Institutional Profile	
Total Enrollment	11,211
Undergraduate Enrollment	9,195
Number of Faculty Members	626
Endowment (in millions)	$10
Annual Budget (in millions)	$74*

*tax levy

Colby College

Program Director
F. Russell Cole, Ph.D.
Oak Professor of
Biological Sciences
Department of Biology
Colby College
Waterville, ME 04901
(207) 872-3324
(207) 872-3555 (fax)
frcole@colby.edu
(E-mail)

Colby College is a private liberal arts institution in Waterville, Maine. In 1991 the Howard Hughes Medical Institute awarded the College $1,000,000 in support of (1) major revision of the biology curriculum and further integration of related disciplines in the natural sciences with biology, including the development of an interdisciplinary program in cellular and molecular biology/biochemistry, enhancement of laboratory components of courses in the biosciences, and introduction of new laboratory exercises in introductory chemistry, physics, and mathematics that include biological examples and computer analysis; (2) laboratory renovation and acquisition of equipment to implement the new curriculum; (3) increased opportunities for faculty in the biosciences to learn research and teaching techniques at major research centers; (4) expansion of student research opportunities on campus; (5) establishment of a center to enhance quantitative skills; and (6) development of outreach programs for science education, including a partnership with local schools and expansion of summer classroom and laboratory instruction for minority students from inner-city and rural high schools throughout the United States (including Native American students from Maine) and their teachers.

Student Research and Broadening Access

With HHMI support, Colby has created additional opportunities for undergraduates to gain experience in research, both during the summer and the academic year. Of the seven students who have been supported, Ramsey Ellis, a senior, worked in 1992 on a summer project in the laboratory of Dr. Paul Greenwood, Associate Professor of Biology. Ms. Ellis studied the calcium-binding proteins of nematocysts, which are stinging structures characteristic of marine invertebrates of the phylum Cnidaria. The research project was the first to reveal calcium-binding proteins in nematocysts and supports a role for calcium in the discharge of toxin. "Calcium is an important ion in so many systems, in muscle cells and in neurons.... This was a fantastic opportunity to further my career plans, and were it not for this experience I might not have had the chance to work at the Mayo Clinic the summer of 1993." After her senior year, Ms. Ellis plans to enroll in an M.D./ Ph.D. program (Figure 49).

Curriculum and Laboratories

In 1990 Colby College inaugurated a comprehensive plan for the development of its science programs. In addition to providing support to

Figure 49. Ramsey Ellis conducts an experiment as part of her research on the calcium-binding proteins of nematocysts. (Photo by Mary Ellen Matava)

faculty for extensively revising introductory, intermediate, and advanced courses in the Department of Biology, the HHMI grant is helping the College realize one of the key goals of the plan, the development of an interdisciplinary program in cellular and molecular biology/biochemistry. Three upper-division courses have been designed by faculty from the Departments of Chemistry and Biology: Biomolecules, Metabolism and Bioenergetics, and Molecular Genetics. The course in molecular genetics, which is the only one of the three that has been offered prior to 1993–1994, has received favorable student reaction. Dr. Jay Labov, Chair of the Division of Natural Sciences and program director, commented that Dr. David Bourgaize, Assistant Professor of Chemistry, and Dr. Jean Haley, Clare Boothe Luce Assistant Professor of Biology, have described this assignment as an unparalleled opportunity for students and faculty to explore the primary literature and use state-of-the-art laboratory techniques and equipment to enhance training in the exciting and rapidly expanding discipline of molecular genetics.

Construction of a new skyway that links the two departments has facilitated the merging of programs in chemistry and biology. In addition to connecting two buildings, the HHMI skyway contains two new faculty offices and a fully equipped, modern prep room that supports improvements in laboratory courses, helps to attract additional faculty by expanding opportunities for research, and underscores Colby's commitment to interdisciplinary programs in biology and chemistry (Figure 50).

Laboratories, including part of the biochemistry laboratory for the cellular and molecular biology/biochemistry program, have been renovated, using both HHMI and College funds. Scientific equipment has been purchased to serve a broad array of student needs, including increased opportunities for hands-on, investigative laboratory experiences. For example, new electronic balances and an ion chromatography system will enhance laboratory experiences in General Chemistry, and

Figure 50. The HHMI grant supported the development of a skyway joining two science buildings at Colby College and providing a physical link for interdisciplinary education in the biology and chemistry departments. (Photo by Mary Ellen Matava)

new microscopes, including a stereomicroscope with video capabilities, are being used extensively in many biology laboratories.

Faculty Development

Dr. Betsy Brown, visiting Assistant Professor of Biology, was hired with HHMI support to reduce teaching loads and facilitate development of the new biosciences curriculum. Dr. Brown is an invertebrate zoologist who taught a course entitled "Oceans and Organisms." Capitalizing on Dr. Brown's expertise and on the campus's proximity to the Maine coast, this course for non-science majors focused on marine biology and included field trips. Dr. Brown also taught two laboratory sections of the large Introduction to Biology course.

HHMI's support of sabbatical leave extensions from one semester to a full year has enabled Colby bioscientists to learn new laboratory techniques that can be incorporated into undergraduate courses and to develop new avenues of research that can produce expanded opportunities for student research projects. For example, during his sabbatical leave at Washington University, Dr. David Bourgaize conducted research on the translational control mechanisms of the protozoan *Volvox*. He commented, "I have learned about developmental biology, molecular genetics, and plant chemistry. All of this, as well as my new research program, will be of direct benefit to Colby students as we push forward in our efforts to redesign the cell and molecular biology/biochemistry teaching and research efforts."

Precollege and Outreach

A science equipment-lending library is one of the hallmarks of Colby's outreach program to local public and private schools, the Partnership for Science Education. The HHMI grant funded the purchase of scientific instruments for use in nearby primary and secondary classrooms. Decisions about what equipment to buy were made by a steering committee that included 20 local teachers representing all grade levels. After realizing, during the first year of operation, that some pieces of equipment were not being borrowed because the teachers were not familiar with their use, Colby initiated a series of workshops to explain the operation of this equipment and how it can be used for hands-on classroom activities. As a result of these workshops, a microscope with the video camera attachment, which had rarely been borrowed, became one of the most popular items in the equipment library.

Michael Gallagher, an elementary school principal, has found that the science equipment-lending library "made a great difference in implementing hands-on science instruction. The kids are even pulling me into the classroom to take a look." Mr. Gallagher noted that 4th graders' science scores on the Maine Educational Assessment Tests have increased by an average of 15 percent over the past two years, an improvement he attributes, in part, to the outreach program.

When local high school teachers wish to take science courses at Colby, they are no longer constrained by the lack of an available teacher to take over their classes during the classroom periods when they are away. With HHMI funding, Colby has provided a fully certified, full-time supplemental teacher so that local high school teachers from four area high schools can attend Colby classes. The supplemental teacher will rotate annually among the four high schools. Under a tuition waiver provided by the College, five teachers from one high school enrolled in nine different courses during the first year of the program. Martha Cobb, a science teacher at Waterville High School, reported, "The courses definitely had an impact on me and my students. The students saw me in a different light because I was a student too. And it gave me more empathy for them."

Institutional Profile	
Total Enrollment	1,720
Undergraduate Enrollment	1,720
Number of Faculty Members	185
Endowment (in millions)	$90
Annual Budget (in millions)	$52

Colgate University

Program Director
Richard April, Ph.D.
Dunham Beldon, Jr.
Professor of Geology
and Natural Sciences
Colgate University
Hamilton, New York
13346
(315) 824-7212
(315) 824-7187 (fax)

Colgate University is a private liberal arts institution in Hamilton, New York. In 1991 the Howard Hughes Medical Institute awarded the University $900,000 for support of (1) activities to develop students and broaden access in the sciences, including a summer research program to allow participating students to live in a designated science residence hall, increased instruction in science skills for underprepared students, collaborative faculty-student research at the National Institutes of Health, and special interdisciplinary seminars for first-year students; (2) faculty development and support for curricular enhancement to provide increased experimental work in introductory science courses and equipment for new introductory chemistry laboratories; and (3) an annual program of workshops for local high school teachers, who will provide ongoing training and curriculum assistance for teachers at their home institutions, including those with significant enrollments of minority students.

Student Research and Broadening Access

Institute support is helping to expand an initiative designed to attract students to science courses and research programs. For example, 13 Colgate biology students spent the 1992 fall semester at the National Institutes of Health campus in Bethesda, Maryland, where they took a special course in molecular biology and conducted research under the supervision of NIH scientists. This new NIH-based research program was deemed so successful that it was continued in 1993 and will likely be expanded in coming years.

The laboratory experience for the Colgate students was comparable to what graduate students or postdoctoral fellows encounter, according to Dr. Frederick Weyter, Professor of Molecular Biology.

"This was different from the usual research programs for undergraduates at NIH because each of the Colgate students got a full semester's academic credit for their lab and course work," said Dr. Weyter. "It proved to be a very innovative, well-rounded program–quite suited for undergraduates from a liberal arts institution. The students came back to the campus and were so enthusiastic that they easily recruited other students for the fall of 1993. And virtually every student who went down to NIH is going on in an area of biomedical research," either in doctoral programs or in medical school.

Michael Crutchlow (1994), who studied defects in intermediate filament formation in eukaryotic cells in the molecular biology lab of Dr. Michael Brenner at the National Institute of Neurological Disorders and Stroke, said that the NIH research experience put

Figure 51. Michael Crutchlow, a Colgate student, conducted research on cell filaments in a molecular biology laboratory in the National Institute of Neurological Disorders and Stroke during his semester at NIH.

him and his fellow students "at the cutting edge—a much different environment from the classroom." During the semester research program, Mr. Crutchlow learned a variety of principles and techniques, including DNA isolation, polymerase chain reaction amplification, agarose gel electrophoresis, mammalian cell culture, and immunohistochemistry (Figure 51).

Mwango Kashoki, a Colgate student from Zambia, worked in the laboratory of Dr. Bruce Citron at the National Institute of Mental Health, studying enzymes of the central nervous system as part of a long-term effort to identify biochemical markers and genes that play roles in mental illnesses, such as depression and schizophrenia. Dr. Citron, a Colgate alumnus, was instrumental in setting up the Colgate program at NIH, having had discussions about this possibility with his friend and former teacher Dr. Weyter over a period of several years (Figure 52).

Curriculum and Laboratories

Colgate faculty recently began offering intensive summer courses in several areas of science as a way of preparing academically and financially disadvantaged students to take the courses offered during the academic year.

Dr. Robert Arnold, Professor of Biology, developed a five-week preparatory course in biology, which was offered for the first time during the summer of 1992 to 12 incoming freshmen. In planning the course, his first objective involved identifying trouble spots in the introductory course—subjects such as mitosis, DNA and protein synthesis, and genetics—for presentation during the summer short course. The second was to provide the students with "study and learning skills.... by teaching them how to take notes, take exams, and put information in context," he said.

The students also participated in a two-hour laboratory section every week, where they learned basic skills such as how to keep a lab notebook. "The feedback we got from the students is that this course is of great benefit, not just in biology but for other courses."

Figure 52. Mwango Kashoki (*left*) working on enzymes involved in brain function during the summer and fall of 1992 with Dr. Bruce Citron in his laboratory at NIH.

Dr. Arnold also plans to act as a mentor to these students during 1993–1994 as they take the introductory biology course in their freshman year.

Similarly, in summer 1992, Professor Peter Sheridan of the Chemistry Department taught a new introductory chemistry course to 13 Colgate students before they began a rigorous two-semester chemistry sequence in their sophomore year. According to Dr. Sheridan, these students were better prepared for the academic year than were comparable students in previous years. He plans to add innovative laboratory exercises to the short course in 1993.

As part of a broader HHMI-supported effort to expand and revamp the science curriculum, the Biology Department recently appointed Dr. Barbara Hoopes, who studies gene expression and regulation in yeast. Dr. Hoopes, who received her Ph.D. in biochemistry from Harvard University in 1986, recently collaborated with Dr. Diane Hawley at the University of Oregon, where they studied transcriptional control in yeast.

Dr. Hoopes worked during the summer of 1993 with Professors Dietz Kessler and Frederick Weyter to design an introductory course in microbiology. "One of the goals of the course is to provide an alternate route into the biology or molecular biology concentration," said Dr. Kessler. The new microbiology course will have a discussion format to stimulate student participation. In addition, several of the laboratory projects will extend over two to three weeks, exposing students to a research-oriented, problem-solving approach instead of a more conventional series of unrelated lab exercises, he said. The course

was offered for the first time in the fall semester.

The classroom discussion approach to presenting introductory courses has already proved successful in several new offerings from the physics, geology, and computer science departments during the spring of 1993. "We are trying to enhance our introductory courses across the entire natural sciences division, not just in biology," said Dr. Richard April, Dunham Beldon, Jr. Professor of Geology and HHMI program director. Enhancing the full range of introductory science courses is expected to "attract students into the sciences, and we may end up with more students in biology," he noted.

Precollege and Outreach

Institute funds enabled 25 students from the University to attend regional and national research conferences. Moreover, Colgate faculty and students participated in several workshops that involved reaching out to the wider community.

For example, one workshop devoted to computer networking featured a demonstration of how weather satellite data could be captured in real time and transmitted through local computer networks. Such demonstrations helped to familiarize the teachers with the system and also serve to "kindle interest" more broadly in currently available tools for science and technology, Dr. April said.

Other workshops analyzed strategies for improving science teaching and aired discussions on reforming secondary school science curricula, focusing on how changes at that level could affect science education at the college level.

Institutional Profile	
Total Enrollment	2,677
Undergraduate Enrollment	2,673
Number of Faculty Members	197
Endowment (in millions)	$136
Annual Budget (in millions)	$48

College of the Holy Cross

Program Director
Frank Vellaccio, Ph.D.
Vice President for
Academic Affairs
and Dean
College of the Holy Cross
Box DEAN
College Street
Worcester, MA
01610-2395
(508) 793-2541
(508) 793-3030 (Fax)

The College of the Holy Cross is a private liberal arts institution in Worcester, Massachusetts. In 1991 the Howard Hughes Medical Institute awarded the College $600,000 to support (1) development of an undergraduate program in neuroscience, to include new laboratory instrumentation and books and enhancement of the science library; (2) stipend and research support for students, including minority students and women, to work with faculty scientists each summer in laboratory research; (3) opportunities for faculty members to enrich their knowledge of research and teaching in neuroscience by attending training workshops at such centers as the Marine Biological Laboratory; (4) a program for 6th-, 7th-, and 8th-graders from Worcester public schools that will provide on-campus science activities and educational programs for students and their families in conjunction with the New England Science Center; and (5) expansion of a year-long training program in the sciences for teachers from Worcester public high schools, who will be replaced during their year of training by Holy Cross science graduates.

Student Research and Broadening Access

Eight students in the psychobiology concentration completed their required senior theses by designing and carrying out an original year-long research project.

One of those students, Sara Toomey, investigated the role of calcium channels in the development of Duchenne muscular dystrophy. She presented her findings at the Eastern New England Biology Conference in April. She was awarded a Rhodes scholarship and will study at Oxford University for two years before entering medical school.

"The concentration is attracting the very best students at Holy Cross.... ," said Dr. John Axelson, Chair of the Psychology Department. "The field of neuroscience or psychobiology is interdisciplinary," he noted. It is important to be able to show students "that answering questions in this field involves an understanding of biology, chemistry, physiology, and psychology," he said.

Ms. Toomey got a head start on her senior year of research as one of the first six students selected to participate in the student development program during the summer of 1992. That summer, she learned protein purification and immunoblotting techniques (Figure 53).

Twenty-five students applied for the six slots. Each student received a stipend and allowance for research supplies. Ms. Toomey was one of three students who worked on projects supervised by faculty in the Biology Department. Cesar Sanz also worked with Dr. Mary Morton, Assistant Professor and Dana Faculty Fel-

Figure 53. Sara Toomey investigates the role of calcium channels in the development of Duchenne muscular dystrophy.

low, to determine if insulin regulates proteins in the brain in a manner similar to the effects it has on the heart. Paul Schmidt worked with Dr. Robert Bertin, Associate Professor, on a study of the performance of different pollen donors on dioecious plants.

Barbara O'Brien worked with Dr. John Axelson on a study of how prenatal manipulations with stress or an anti-androgen agent can affect sex differences in the social behavior of rats after birth, and also learned immunocytochemical procedures for identifying steroid receptors and neuropeptides.

Patrick McEnaney worked with Dr. Timothy Curran, Assistant Professor in the Chemistry Department, on the synthesis of tertiary amides that could mimic the activity of cyclosporin A in blocking the activation of the immune system. All the students carried out 10 weeks of research, and then continued their research during 1992–1993.

Curriculum and Laboratories

The HHMI grant enabled the Biology Department at the College of the Holy Cross to offer a new cellular and molecular neurobiology laboratory course to eight students in the fall of 1992.

Students studied the brain, nerves, heart muscle, and skeletal muscle, and did a short independent project using a combination of techniques on tissues and cells studied in the course.

"They loved it," said Dr. Morton. "Neurobiology has expanded to include molecular approaches, and we owe it to our students to give them a true representation of the field."

In their work the students used neurotransmitter receptor binding assays, localization of receptors and ion channels by immunofluorescence, qualitative mRNA studies by Northern blot analysis, quantifying of mRNA by solution hybridization, localization of mRNA by *in situ* hybridization, and other cell and molecular biology techniques. Through the course, students acquired skills of data analysis, statistics, and experimental design. Individual research projects are required to complete the course.

Other HHMI-supported curriculum activities include:

■ Expanding the Introduction to Neuroscience seminar into a team-taught laboratory course, with different faculty members teaching two-week projects. For example, students studied computer-simulated action potentials in nerve preparations. Students also analyzed conditioned response rates by using operant techniques.

■ The new psychobiology concentration, which is a partnership between the biology and psychology departments to study the relationships of brain and behavior, received equipment, supplies, library materials, and start-up funds to enable two faculty members to get their research going with undergraduate student participation.

New equipment included a refrigerated ultracentrifuge, a computer system for controlling and monitoring research, and a spectrophotometer. Over 130 important reference works in neuroscience and a number of journals were purchased.

Faculty Development

The HHMI grant supported several faculty development programs, including an on-campus course on scanning electron microscopy. Five members of the Biology Department and one member of the Psychology Department took the three-day instruction on use of the new microscope. The skills will be used in teaching Introductory Biology, Developmental Biology, Cell Biology, Physiological Psychology, and Introduction to Neuroscience, and also in mentoring undergraduate research projects.

Individual faculty also attended courses on light microscopy, modern human virology, and steroids and brain function.

Precollege and Outreach

Minority students in grades 6–8 visited the College in 1992–1993 to study science and mathematics with college professors under the Youth Exploring Science Program.

Twenty students from Worcester East Middle School and Chandler Elementary Community School participated during their winter vacation, and 20 students from Goddard Elementary and Forest Grove Middle School visited the College during their spring vacation. These schools contain a significant number of students from underrepresented minority groups.

In a biology class at the college campus, the students learned how to extract energy from waste products, and saw by means of a videomicroscope how a piece of muscle moved and twitched when certain chemicals normally occurring in the body were added to it.

In physics, students worked with lasers, observing the beam actually bend and change in

thickness as a piece of metal with large and small slits was passed in front of it.

The students also had classes in chemistry, mathematics, and psychology. In a chemistry laboratory, they were taught how basic chemical compounds work. Then a forensic specialist showed them how he uses those chemicals in solving crimes. For example, he explained how he can determine whether blood was spilled an hour or a day ago.

"Children in general tend to lose interest in science at the junior high age or earlier," said Dr. Frank Vellaccio, Vice President for Academic Affairs, Dean of the College, and program director for the HHMI grant. "They don't start out with an inferiority complex concerning their science ability, but somehow in the early grades, that develops," he said. "When students this age get involved in a program like Youth Exploring Science, they realize they can understand science and that it can be interesting and fun."

The students ended their week at college with a workshop on how to prepare for college, including what courses they should take in the 8th through the 12th grades.

They also received year-long family memberships from the New England Science Center and attended seasonal programs there. One program that uses an interactive video screen, the Jason project, allowed students to talk with marine biologists in a submarine about fish, sea animals, and a coral reef.

In another part of the outreach program, the Worcester Public Schools selected two high school teachers to participate in a return-to-college program for a year to improve their science backgrounds and update their knowledge in science and mathematics (Figure 54).

"There are some unique problems in high schools now," Dr. Vellaccio said. "Schools haven't been able to hire new teachers or provide sabbaticals. They need rejuvenating. If high school kids haven't taken a solid biology course, for example, they come here and start off with a real deficit. We need high schools to be good and we need to help them. We must look at the kindergarten–16 continuum and work toward improving the entire pipeline."

Richard Pahigian, teacher of biology and general science at South High School, found that college biology contains much more advanced chemistry than when he took it two decades ago. And there was "a lot more on protein synthesis and DNA than was in my high school text," he said.

Other updates included new information on how the brain functions, the endocrine system, botany, chemical and biological controls in farming, land management, pollution, and the environment and ozone. "I feel I have been updated and will be

Figure 54. Professor Michael McGrath (*left*) in the chemistry laboratory with Worcester high school teachers Richard Pahigian (*center*, South High School) and Vincent Giarusso (North High School).

able to teach a lot better." Mr. Pahigian said.

But the year at ' ›ly Cross taught the teachers more than new facts. "Going back and being on the other side of the desk gives you a new perspective," said Mr. Pahigian. Being a student "wasn't easy." The experience will give him "more empathy toward students who need a little more help," he said. "I think I'll be more patient, more understanding."

Institutional Profile	
Total Enrollment	2,742
Undergraduate Enrollment	2,742
Number of Faculty Members	212
Endowment (in millions)	$140
Annual Budget (in millions)	$75

Fisk University

Program Director
Mary E. McKelvey, Ph.D.
Chairman, Department of Biology
Fisk University
1000 Seventeenth Avenue North
Nashville, TN 37208-3051
(615) 329-8796
(615) 329-8715 (fax)

Fisk University is a private, historically black, liberal arts institution in Nashville, Tennessee. In 1991 the Howard Hughes Medical Institute awarded the University $700,000 to support a "pathway" program in the sciences that includes (1) a summer program to introduce students from a nearby science magnet high school to college-level science; (2) academic preparation in the sciences and mathematics for students during the summer prior to their freshman year; (3) tutoring and computer-assisted instruction for introductory-level students in the sciences and mathematics; (4) support for year-long laboratory research experiences for undergraduates through the faculty development component; and (5) ongoing support for students preparing for science graduate studies or medical school.

Student Research and Broadening Access

A Science Learning Center supported by the HHMI grant opened at Fisk University in fall 1992, serving as a tutoring hub and augmenting science courses with a computer laboratory and other equipment. Any student taking a science or mathematics course may request tutoring. In 1992–1993, 80 to 90 students were tutored in 300 sessions. The largest number of tutoring requests was for mathematics (Figure 55).

The director of the Learning Center, Mrs. Karen Martin, concerned that some students are not coming often enough for tutoring, is working to increase the profile of the new tutoring program and expects it to grow. "We'll go into more classes next year, and we'll get on the agenda for incoming freshmen and their parents," she said.

Last year five tutors were trained: two seniors, two juniors, and one sophomore. Tutors must receive a recommendation from a faculty member at the university in the subject they will tutor. The number of students they tutor determines their pay.

Raynese Scott, an incoming senior chemistry major, began tutoring calculus and precalculus in January. Some students "were just having trouble with fundamental concepts, and once they grasped those concepts, they were all right," she said. Other times, a student wanted to go over some calculus problems. Ms. Scott thought the experience was beneficial to both tutors and students who were tutored. "They appreciated my help," she said. "Tutoring reinforced my skills."

Two-thirds of the student-tutor contacts occurred during the first semester. Fewer requests during the second semester may have resulted from the opening of the computer laboratory that semester, said Dr. Mary E. McKelvey, Chair of the Biology Department and HHMI program director. The

computer lab was equipped with six personal computers and a laser printer. Three other systems with printers were also available to students. Through computer software programs, students can do problems in calculus, algebra, and trigonometry and can take tests in anatomy, genetics, and cell and molecular biology. The students can then see if their answers were correct. There are also computer games in logic, problem solving, and spatial reasoning (Figure 56).

In biology, students can view a program that reviews biology for the Medical College Admissions Test (MCAT) and can use software programs to study chemistry and zoology. There were about 50 student visits to the computer laboratory in spring 1993.

Other equipment purchased for the learning center included a VCR-television system, panels that can be connected to the computers to display material, and projectors. Faculty may borrow the projection panels and an overhead projector for classroom use.

A satellite area for the Learning Center, which is located in the Science Laboratory Building for biology, may also be used by the students. It is being equipped with 10 student stations that have computers connected to a printer.

The University also plans to use the Learning Center to improve student performance on entrance exams. "For whatever reasons, minority students have a history laden with statistics about low performance on standardized examinations," said Dr. McKelvey. "Hence, our students are often viewed as underachievers. It is imperative that this stigma be eliminated. We are hoping that Mrs. Martin, who is familiar with testing techniques and skills and strategies, will provide some special training for students," she said.

Figure 55. Regina Arvon, senior biology major, tutors a freshman student in the Learning Center.

In April the science and mathematics faculty was surveyed to find out how the Learning Center could be of most help. A faculty member proposed placing a tutor in the class who would later conduct problem-solving sessions for that subject with a small group of students. The University is planning such a pilot program for the spring semester.

The HHMI grant also supported workshops to prepare students for graduate and medical

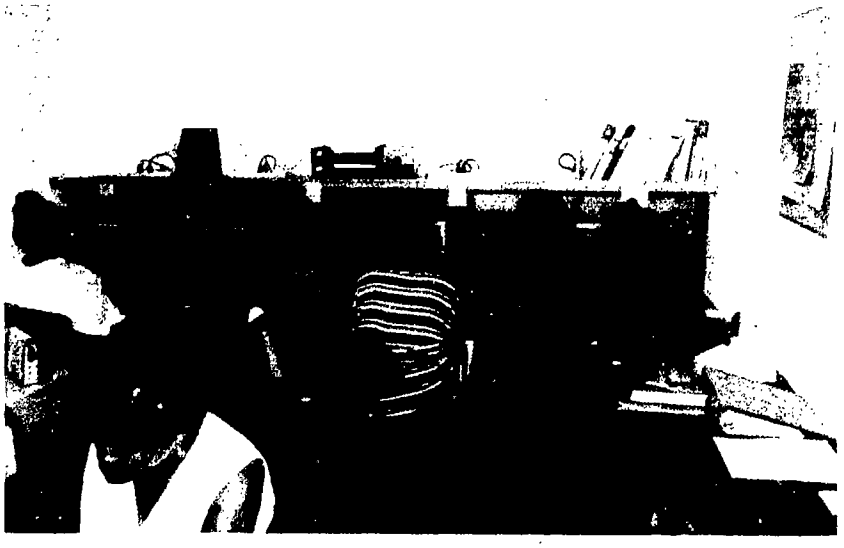

Figure 56. Precollege Summer Science Program students using the computer laboratory at the Hughes Science Learning Center: (*foreground*) DeYuna Howard; (*background, left to right*) Zuri Buntin, Marion Kpabar, Kelly Miller, Joyce Wilburn, Kena Alexander, and Tsika Paspanodya.

school. In 1992–1993, assistance was provided to juniors planning to take the MCAT.

Also funded through the HHMI grant, four students received support to participate in the Fisk–Meharry Joint Program in Biomedical Sciences, a major link in the pathway to graduate and professional schools in the biomedical sciences.

A joint committee from Fisk and Meharry Medical Colleges selected the students, based on their high school performance, their first semester of academic work at Fisk, recommendations from faculty, and interviews. Requirements included a minimum 3.2 grade average for the first semester at Fisk and a high school grade average of B+ or better.

The students attend Fisk for three years and then are admitted to Meharry. After successfully completing one year at Meharry, they receive a bachelor's degree from Fisk. The program has a capacity of 48 students.

Faculty Development

Fifteen faculty members received small grants to attend conferences and workshops or for mini research projects or supplies. For example, Dr. M. Gunasekaran, Professor of Biology, who has primary teaching responsibilities for biotechnology at Fisk, attended a workshop on restriction fragment length polymorphisms at Brigham Young University. While there, he also increased his knowledge of interactive video disc systems.

Precollege and Outreach

Fifteen high school graduates participated in the first session held June 8–July 17, 1992, at Fisk. All were minority students and nine were women. In 1993, 21 students were in the program, including 19 high school graduates and 2 seniors.

A long-term goal of the Pre-College Science Program is to increase the number of minority students who get graduate degrees in the biomedical sciences, said Patricia McCarroll, who directs the program. "Short term, we're hoping to provide strong backgrounds in the sciences so that students do well when they enter college in the fall." To be eligible for the summer program, students must be interested in pursuing a biomedical or medical career and must have attained a certain grade point average.

The students were given basic introductory college-level courses in biology, chemistry, and algebra, a computer instruction course in hardware and software, and a course that emphasized reading comprehension and vocabulary building.

The reading course included lectures on critical thinking, test-taking skills, time management, writing assignments, note taking, and study methods. Readings were done both in and outside the sciences. The chemistry course included measurements in chemistry, matter and energy, atomic structure, solutions, and chemical bonds. The biology course was about the chemical basis of life, cell structure and function, DNA replication, protein synthesis, genetics, biochemical pathways, and ecosystems.

A few of the students who participated last summer came from states other than Tennessee. Notice of the program appeared in a national publication, *Black Issues in Higher Education*, in July 1992. "We received responses from all over the country as a result of that," Ms. McCarroll said. She also gave brochures on the program to her university's recruiters. In summer 1993, 21 students were in the program, including 19 high school graduates and 2 seniors.

At the end of the program, the overall academic performance of students was evaluated. The evaluation indicated that students participating in the program showed improvement in their academic performance, Ms. McCarroll said. Twelve are pursuing premedical or health sciences fields and one is in engineering.

Two students who participated in the program last summer, Ivane Baker and ViKisha Fripp, were accepted as incoming freshmen in the Fisk–Meharry Joint Program in Biomedical Sciences.

"I gained a lot from the program," Ms. Fripp said of her summer preparation for college. She had planned to be a chemistry major, but after taking both chemistry and biology that summer, she decided to switch her major to biology because she liked it better. That fall, she got an A+ in biology at Fisk, and a B

in chemistry, and she pulled the B up to an A in second-semester chemistry. She also got A's in two other science courses.

"I wouldn't have gotten such good grades without the [summer] program," she said. "I got a jump start on everybody." Ms. Fripp said she also found it very helpful that she was encouraged in the summer program to learn concepts rather than just memorize facts.

Institutional Profile	
Total Enrollment	867
Undergraduate Enrollment	841
Number of Faculty Members	64
Endowment (in millions)	$5
Annual Budget (in millions)	$15

Fort Lewis College

Program Director
William R. Bartlett, Ph.D.
Professor of Chemistry
Fort Lewis College
Durango, CO 81301
(303) 247-7133

Fort Lewis College is a public comprehensive institution in Durango, Colorado. In 1991 the Howard Hughes Medical Institute awarded the College $800,000 in support of a program for (1) increased opportunities for students, especially Native Americans, Hispanics, and those from other underrepresented groups, to participate in undergraduate laboratory research with faculty scientists; (2) development of new courses and laboratories in such areas as biophysics, molecular genetics, and biochemistry; (3) revision and integration of current courses in biology and chemistry to emphasize biochemical and molecular approaches to biology as well as computer analysis; (4) acquisition of new laboratory instrumentation and scientific periodicals to implement the curricular enhancements; (5) appointment of a new faculty member in either human physiology or biochemistry; and (6) an outreach program in the sciences for local elementary, middle, and high schools, especially those serving substantial numbers of Native American, Hispanic, and other students underrepresented in the sciences, and increased activities with area community colleges.

Student Research and Broadening Access

Fort Lewis College's commitment to students was profiled by Sheila Tobias in her book *Revitalizing Undergraduate Science*. Dr. Tobias highlighted the college's efforts to employ "research [as] a strong catalyst for students' development." Institute support has contributed to the creation of summer research opportunities, especially in the biology and chemistry departments. When the HHMI-supported program began in 1991, four students were supervised by two faculty members. During the summer of 1992, nine students—most of whom were women or Native Americans—worked with four faculty members.

Dr. John Condie, a geneticist in the biology department, worked with students Scott Hecht and Carol Begay, a Native American, to isolate mutations affecting expression of the *engrailed* gene in *Drosophila* and to immunopurify chromatin fragments containing the engrailed protein. The students were able to mutagenize 50 male flies, isolate 523 individual offspring, and establish 375 lines. While no mutants with the expected phenotype were isolated, Ms. Begay developed an ongoing interest in research and secured a laboratory position in plant pathology with the Navajo Agricultural Project during the summer of 1993. Mr. Hecht received a summer research position in molecular biology at the Eppley Institute for Research in Cancer in Omaha, Nebraska (Figure 57).

Another 1992 summer research student was Sarah Logan,

Figure 57. Carol Begay, a Fort Lewis biology major, participating in a genetics research project using mutant fruit flies grown on agar.

a chemistry major interested in medicine. Her project in Dr. William Bartlett's laboratory in the Department of Chemistry focused on natural anti-tumor and anti-viral agents contained in plants. After researching the folk medicine traditions of the Native American and Hispanic cultures, she chose to study milkweed plants of the genus *Asclepias* because these plants are indigenous to the Fort Lewis area. She collected 10 pounds of the plants, not an easy task given their remote habitat, and returned to the laboratory to extract a class of steroid glycoside compounds called cardenolides, which have been studied for their anti-tumor activity. While not successful in obtaining a highly purified sample, she hopes that "by looking at the milkweed plant that's native to our area, we can find a compound with some medical uses." During the summer of 1993, Ms. Logan continued her research at the Los Alamos National Laboratory.

Dr. Ron Estler, a physical chemist in the Chemistry Department, has built a time-of-flight mass spectrometer for trace analysis of metals. He has used HHMI grant support to expand his studies into matrix-assisted laser desorption as a tool for analysis of macromolecules. The technique uses a laser to vaporize a target compound embedded in a matrix of a compound that absorbs light at the frequency of the laser. Some of the matrix compounds become ionized, and the biomolecules develop charge upon colliding with the matrix ions. These compounds are then accelerated down the time-of-flight mass spectrometer and detected, with a minimum of fragmentation of the protein ions to smaller ions.

Chemistry major John Beene, before he graduated and took a position in the chemical industry, helped to apply this technique to the analysis of proteins with masses between 10,000 and 200,000 daltons. Dr. Estler's other students in the 1992 research program included Gretchen Rothschopf, currently a graduate student in chemistry at the University of Utah, and Rob Lewis, a

chemistry/physics double major. Dr. Estler is continuing in 1993 to refine the technique in summer research with chemistry student Jennifer White.

Another contribution of the Institute grant was the sponsorship of 19 undergraduates at the National Conference on Undergraduate Research at the University of Utah in March 1993. At this annual conference, students present their findings and meet other students who are engaged in research. Fort Lewis student Cally Duncan displayed her poster on the structure of myosin, the muscle protein. With the aid of nuclear magnetic resonance spectroscopy, Ms. Duncan sought to determine which regions of this high-molecular-weight protein were rigid and which were flexible, in order to understand how muscle contracts. NMR helps provide information because the rate of decay of a signal from a protein region depends on whether the region is static or moving.

Curriculum and Laboratories

The biology and chemistry departments at Fort Lewis have witnessed changes in the classroom and the laboratory. Many courses have been modernized, laboratories enhanced, and manuals rewritten. Among the courses that have been revised is the Introductory Biology Laboratory course, which had a 1992 enrollment of 470 students. The new course is designed to heighten student interest, encourage accurate laboratory write-ups, and foster independent problem-solving. Dr. Condie, the course instructor, remarked, "Students designed and carried out some of their own experiments, such as determining whether an herbal tea was a respiratory depressant. By measuring CO_2 output in mice, students discovered that the tea was a stronger respiratory depressant than the sedative pentobarbital."

Another development is an intensive two-week summer course, Introduction to Pharmacology, taught for the second time to a select group of upper-division students by Dr. Allan Collins, a pharmacologist from the University of Colorado. The HHMI grant enabled the college to bring Dr. Collins to Fort Lewis to teach the course and work with students.

Fort Lewis also created a new lecture series that brings biomedical scientists to campus. One of the speakers was Nobel Laureate Dr. Thomas Cech, HHMI Investigator and Professor of Chemistry and Biochemistry at the University of Colorado at Boulder, who spoke about his research on ribozymes. Dr. Wilfred Denetclaw, Jr., a Navajo alumnus of Fort Lewis who received his Ph.D. from the University of California–Berkeley, spoke

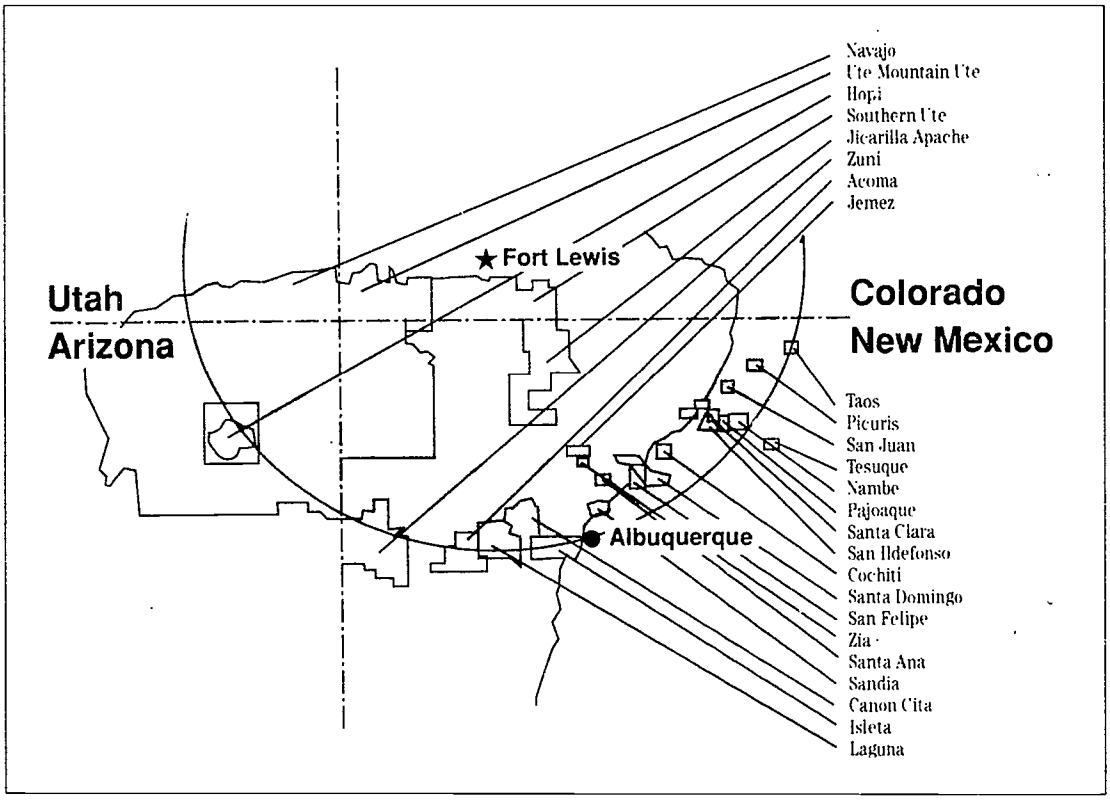

Figure 58. Indian reservations within a 150-mile radius of Fort Lewis College.

about his work on Duchenne muscular dystrophy.

Faculty Development

The HHMI grant enabled the College to recruit protein biochemist Dr. Les Sommerville as Assistant Professor of Biochemistry. Dr. Sommerville's expertise involves biological applications of NMR spectroscopy, fluorescence spectroscopy, and protein separations and characterizations. After receiving his Ph.D. in biochemistry from the University of Minnesota, Dr. Sommerville has acted as a link between the Biology and Chemistry Departments by collaborating with colleagues to develop a variety of undergraduate courses, including introductory chemistry and cellular biochemistry.

He has not only sponsored summer students at his campus laboratory but has secured a Department of Energy grant allowing him to perform summer research at the Los Alamos National Laboratory on high-field NMR and biochemical methods of soil remediation. Under the Institute's grant, Dr. Sommerville took two undergraduate biology majors—Andrew Liimatta and Emery Namingha, a Hopi Tribal member—to professional meetings of biochemists and biophysicists in Houston.

Figure 59. As part of Fort Lewis College's outreach efforts, biology major Shana Dalton demonstrates how to make nylon to Durango area elementary school students.

Precollege and Outreach

Fort Lewis College is situated within a 150-mile radius of 25 Indian reservations with 450,000 inhabitants (Figure 58). Through a variety of programs, Fort Lewis is working to cultivate an interest in science among area secondary and primary students (Figure 59). One program, the Summer Science Enrichment Program, was developed by the science and engineering faculty at the College. For the past two summers, 40 high school students from four different schools have participated. Students learn laboratory techniques such as the use of electrophoresis in protein analysis. They also become competent in computer-based data analysis and literature searches and take field trips to such locations as the Navajo Agricultural Project in New Mexico and Hewlett-Packard in Denver. The HHMI grant finances travel, faculty salaries, and stipends for the students, 50 percent of whom are women or minorities.

To ease the transition to college life, Native American students entering Fort Lewis are offered Institute-supported tutoring and counseling. Twelve experienced Native American upperclassmen have been trained to provide for the special needs, both academic and personal, of their younger counterparts, 54 of whom received tutoring during the 1992–1993 academic year. The Institute grant contributes to weekly stipends for these tutors and to computer purchases for the tutoring site. Vernon Willie, a Navajo math

major and former adviser, who has since graduated, was enthusiastic about the program because of the difficult transition faced by Native American freshmen, especially those from reservations. Upon leaving the reservation and sometimes being the first in their family to attend college, Native American students can "feel the full effect of being a minority for the first time," Mr. Willie said.

Institutional Profile	
Total Enrollment	4,010
Undergraduate Enrollment	4,010
Number of Faculty Members	160
Endowment (in millions)	$2
Annual Budget (in millions)	$27

Gettysburg College

Program Director
Ralph A. Sorensen, Ph.D.
Associate Professor and Chair
Department of Biology
Gettysburg College
Campus Mail Stop 392
Gettysburg, PA 17325
(717) 337-6168
(717) 337-6008 (fax)

Gettysburg College is a private liberal arts institution in Gettysburg, Pennsylvania. In 1991 the Howard Hughes Medical Institute awarded the College $850,000 to establish a new program in biochemistry to include (1) recruitment of two new faculty scientists, one in molecular genetics and one in biochemistry, who will collaborate with current faculty in the development of curricula and research programs in biochemistry; (2) acquisition of new equipment to implement the teaching laboratories for new courses in molecular genetics, biochemistry, and comparative metabolism, and to provide laboratory start-up for the new faculty appointments; and (3) support for summer laboratory research for faculty and students.

Student Research and Broadening Access

Dr. Steven James, Assistant Professor of Biology, has brought nearly a dozen undergraduates into his laboratory to study genetic control of the cell cycle in the fungus *Aspergillus nidulans*. The overall project entails expressing, cloning, and sequencing genes to determine whether they are essential for regulating the organism's cell cycle. "During the 1993 spring semester, two seniors really helped push the project forward," he said. One of them, Kristyne Bullock, "fished out five independent clones from the *nimO* gene, which we're studying." The second student, James Ross, attempted to analyze messenger RNA as it is expressed during the cell cycle. "He did all the techniques successfully... and, from a training perspective, had an excellent experience," Dr. James said.

Ms. Bullock and Mr. Ross, both of whom took research positions after graduating from Gettysburg in 1993, plan to do graduate work in biology. Mr. Ross, who did research in forensic science at the Walter Reed Army Medical Center during the summer of 1993, said that the laboratory work he did trying to isolate RNA at the College "more than qualified me to work with DNA at Walter Reed. I can hold my own." His unsuccessful efforts to purify messenger RNA were "frustrating at first, but I was not discouraged. Dr. James was supportive...and I learned what research is about. It was a great learning experience."

Ms. Bullock said that she signed up for Dr. James's course in molecular genetics on an impulse, and it "ended up being my favorite class. It started my interest in basic research." The way the laboratory component was presented—as a large project that unfolded over the semester—prepared her to work on an independent project during her final semester at the College. "I applied concepts from the class, but Dr. James pretty much let me solve problems on my own," she said.

She contributed to a larger effort by isolating and screening cDNA from the *nimO* gene of *A. nidulans*. Her successors in Dr. James's lab will try to determine the sequence of that gene.

Since her graduation, Ms. Bullock has worked at a small company associated with the University of Pennsylvania, where she is helping to develop a stable expression system for a human ion channel receptor gene. "I'm able to apply all the tools I learned at Gettysburg, and I'm already working virtually alone. But if I hadn't taken the class that the Hughes grant made possible, I probably wouldn't have done something in science. This was the niche I needed to use."

Dr. Koren Holland, Assistant Professor of Chemistry, who was recently appointed through the HHMI grant, is in the beginning stages of a project in which undergraduates will help collect blood specimens to determine gene sequence information from the Amish communities in eastern and central Pennsylvania. "The overall purpose is to study D-loop hypervariable regions of mitochondrial DNA...to look for genetic trends in this region from people in the small Amish community who don't integrate with the gene pool of the rest of the U.S.," she said. The DNA sequence database from the Amish communities will be compared with similar databases being established by researchers at Walter Reed Army Medical Center for forensic purposes. Amy Landis, who will be a senior at the College in the fall of 1993, wrote the proposal for the project and will probably continue in forensic science when she finishes her degree, Dr. Holland noted.

Curriculum and Laboratories

In the spring of 1993, Gettysburg College approved a new major in Biochemistry and Molecular Biology. According to Dr. James, the rapid acceptance of the new program came as a surprise. "Passage of a new major at the College usually takes years." A few juniors signed up for the courses that are required to complete this major in their senior year, but mostly first- and second-year students have been attracted into the new program, which is taking off well, said Dr. James. For example, the program instituted a seminar series during 1992–1993, and the budget was approved to continue that program in the following academic year.

HHMI funding also enabled the College to implement an undergraduate research program and to introduce several new courses in chemistry and biology as part of the new major. Institute funds have been used to equip an instrument laboratory in the Chemistry Department for teaching biochemistry and are being

used to create a research laboratory for Dr. Holland.

In fall 1992 Dr. James introduced an upper-level course in Molecular Genetics, with both lecture and laboratory components. The lecture part of the course focuses on how genes are transcribed and translated and how gene expression is regulated. The laboratory portion of this challenging course is centered on a semester-long project involving the isolation and characterization of a particular segment of human mitochondrial DNA, with students using their own blood cells as starting material.

The approach proved successful, in part because students find it "inherently exciting to work on their own DNA and to show the variation from individual to individual in the class," Dr. James said. This approach also gives undergraduate students "an idea of what it's like to do a typical project as a graduate student." Of the nine students who took this course as seniors, three went on to positions in academic or industrial laboratories with plans to do graduate work in molecular biology. Other students who took the course are continuing their studies in biology or in medical school, and one plans to teach biology at the secondary school level.

With HHMI funds, the Chemistry Department acquired major biochemical equipment that is used both for teaching purposes and for research, including independent student research projects, according to Dr. Holland. Among the items purchased during the 1992–1993 academic year were a flask shaker/incubator, a chromatography cabinet, a high-speed centrifuge, a high-performance liquid chromatography apparatus, and equipment for running electrophoresis experiments. Several students who took the biochemistry course are planning to take graduate courses in related areas, including biochemistry at Brown University, Dr. Holland noted. Another student who plans to study organic chemistry told her that what he learned in biochemistry has encouraged him to concentrate on natural product synthesis in his graduate education.

Institutional Profile	
Total Enrollment	2,155
Undergraduate Enrollment	2,155
Number of Faculty Members	147
Endowment (in millions)	$39
Annual Budget (in millions)	$45

Harvard University

Program Director
Stephen C. Harrison, Ph.D.
Professor of Biochemistry and Molecular Biology
Investigator
Howard Hughes Medical Institute
Harvard University
7 Divinity Avenue
Cambridge, MA 02138
(617) 495-4106
(617) 496-6148 (fax)

Harvard University is a private research institution in Cambridge, Massachusetts. In 1992 the Howard Hughes Medical Institute awarded the University $1,100,000 to support (1) development of the upper-division bioscience curriculum to include new project laboratories in developmental biology, genetics, and neuroscience; (2) enhancements in the introductory-level chemistry and physics curriculum and creation of a computer laboratory for modeling macromolecules for a course in organic chemistry; (3) research experiences in university and medical school laboratories for undergraduates, particularly women and underrepresented minority students; and (4) activities to enhance high school biology through laboratory experiences for teachers and students, lectures and demonstrations by faculty members, and development of laboratories for advanced placement biology courses.

Student Research and Broadening Access

This component of the Institute program is in its start-up phase. Thus, for the summer of 1993 the University appointed eight undergraduate students to do research with University faculty members, including Professors Nancy Kleckner, Mark Ptashne, and James Wang of the Department of Biochemistry and Molecular Biology; Professors Margaret Baron and William Gelbart of the Department of Cellular and Developmental Biology; Professor Stuart Schreiber of the Department of Chemistry; and Drs. Gary Gilliland and Carl Schmidt at Brigham and Women's Hospital.

Of the eight students chosen to participate, four are women and two are black; none have completed more than a year or two of study. "It can be difficult for younger students to find laboratories," according to Dr. Stephen Harrison, Professor of Biochemistry and Molecular Biology, HHMI Investigator, and program director. Their inexperience in the laboratory and the relatively few science courses they have taken "puts them at a disadvantage" particularly when Federal funds are decreasing. He and his colleagues plan to monitor the impact of the students' summer laboratory experiences on their academic careers and see how many continue to pursue research in the coming years.

Curriculum and Laboratories

Curriculum development efforts focused on two laboratory courses, one in experimental embryology and the other in organic chemistry. The experimental embryology course is taught by Professor Douglas Melton of the Department of Biochemistry and Molecular

Biology. HHMI funds enabled him to purchase new stereomicroscopes and to revise and restructure course materials so that the course accommodates a greater number of students. Moreover, the range of experiments was expanded to include exercises involving chickens and zebra fish. Written materials used for teaching the course are being assembled into a publication for use at other institutions. Dr. Melton's course in experimental embryology is being used as a model for developing other laboratory courses.

Institute funds enabled Professor Gregory Verdine of the Chemistry Department to obtain four SGI Indigo computers and appropriate graphics software for use in chemistry and biochemistry courses. Although first-year use of this system in introductory organic chemistry was not mandatory, more than 40 percent of the class participated. Special projects included analysis of catalysis by the enzyme triosephosphate isomerase, stereospecificity of the enzyme alcohol dehydrogenase, geometry of disulfide bonds in small molecules and proteins, and modeling of C76 buckminsterfullerene. The success of this phase of the project led to funding from other sources for the purchase of three additional SGI graphics computers, which will allow the entire class to have access to the computer graphics laboratory in future years.

Precollege and Outreach

The program with the neighboring Cambridge Rindge and Latin School, the first association between a Harvard science department at the University and the city's public school system, went very well, Dr. Harrison said. Minority students are in the majority at the high school, the only public secondary school serving the Cambridge community.

An important component of the outreach program was a series of lectures by University faculty members to the Advanced Placement Biology class of 21 students at the high school. Rami Alwan, the biology instructor at the school, serves as the primary link with the University. He met with the lecturers in their laboratories to discuss the curriculum and goals of the Advanced Placement Biology course and how to provide a sense of what his students had been studying in biology and how to pitch their talk. Dr. Harrison said that virtually all of his colleagues were "extremely impressed that the high school students had such a good grasp of the materials they taught."

"The students saw many different styles among the 12 guest lecturers," said Mr. Alwan. "Some of them described the excitement of working at the cutting edge of research; others also described the path they followed to get where they are as scientists. All of them had a real impact. The students don't have a clear vision

of lab research and how demanding and consuming it can be."

Mr. Alwan credits the guest lecture series and the new alliance between the high school and the University's biology faculty with reinforcing the commitment of an unusually high number of his students to pursue biology or other science courses when they go to college. "I had 21 students [in 1992–1993], and almost half are planning to go into science," he said. "That's very, very rare; usually it's only two or three. The Harvard professors were open and showed they cared about these students—and that goes a long way with high school students. My sense is that the program really made a difference."

Five students from Mr. Alwan's class began to work in Harvard laboratories during the summer of 1993. For example, one student worked with Professor Douglas Melton, Department of Biochemistry and Molecular Biology, on mesoderm induction in *Xenopus* embryos. Another student worked with Dr. Harrison on crystallization of reverse transcriptase from human immunodeficiency virus. "This is a new experience for Harvard faculty and a completely new program, so we've concentrated on finding motivated and committed students and on finding labs that understand the kind of direction they will need," Dr. Harrison said. "We intend to expand this program slowly and to monitor it closely." In addition to including more students in this summer research program next year, Mr. Alwan explained that one or more of the high school teachers will also pursue research at Harvard during the summer. "We want the high school faculty to be re-energized by lab work, too. That's another really powerful piece of this program," he said.

Institutional Profile	
Total Enrollment	18,273
Undergraduate Enrollment	6,575
Number of Faculty Members	2,278
Endowment (in billions)	$5.1
Annual Budget (in billions)	$1.1

Harvey Mudd College

Program Director
William K. Purves, Ph.D.
Stuart Mudd Professor
of Biology
Department of Biology
Harvey Mudd College
Claremont, CA 91711
(909) 621-8021
(909) 621-8465(fax)

Harvey Mudd College is a private engineering institution in Claremont, California. In 1991 the Howard Hughes Medical Institute awarded the College $500,000 to assist in the development of a new major in biology, including (1) the addition of a new faculty scientist in molecular developmental neurobiology to create new courses and supervise student research; (2) opportunities for biology students and for students in other science departments to conduct summer research on biologically related problems with faculty members: and (3) development of new laboratory curricula and acquisition of equipment for courses that will integrate biology with related fields of chemistry, physics, and mathematics.

Student Research and Broadening Access

The student development program began in the summer of 1992, with 10 undergraduates participating. In 1993 a dozen students were in the program. Students are selected by the faculty and assigned to laboratories in chemistry, physics, biology, and engineering. Many students continue the work they began in the summer during the academic year. Several may work in the same laboratory and share a mentor.

These are examples of the research in which some of the first students participated:

- Michelle Cooper, a biology major, worked in marine evolutionary ecology with Dr. Catherine McFadden, Assistant Professor of Biology, on a genotype analysis of larval soft coral. Her goal was to compare larval genotypes to known parental genotypes by analyzing protein band patterns, using cellulose acetate electrophoresis. The objective was to determine the extent of inbreeding in coral populations.
- Peter Russo, a biology major, used light-scattering techniques to monitor the interaction of lanthanide cations with the thylakoid membranes of plant chloroplasts. The positively charged lanthanide cations bind to the surface-exposed carboxyl groups of thylakoid membranes, thereby neutralizing the negative charges on the membranes, which undergo a conformational change. The membrane compression is detected as an increase in scattered laser light. Chemistry Professor Kerry K. Karukstis, his mentor, said his data suggested that the techniques could provide a sensitive view of cation-membrane interactions.
- Biology major Eric Salmon undertook to introduce the crucifer *Arabidopsis thaliana* as a

Figure 60. Tabitha A. Staley, a member of the first graduating class of biology majors at Harvey Mudd College, has conducted research projects in analytical chemistry, biochemistry, and molecular evolution.

research object in the laboratory of Dr. William Purves, Professor of Biology and program director. Mutants of *A. thaliana* are used for studies of plant development. Mr. Salmon began screening for growth-regulator mutants from mutagenized seed, a process he continued during the subsequent academic year.

Curriculum and Laboratories

Harvey Mudd College graduated its first eight biology majors in 1993, the result of a new biology department and a new major developed in part with HHMI support (Figure 60). Next year the number of graduating biology majors is expected to double.

"Given our strengths in the physical sciences, math, and engineering, and given the interdisciplinary nature of some of the most exciting areas in biology and biomedical science, we resolved to initiate a major in biology," said Dr. Purves. The biology major was planned for students interested in experimental biology.

In 1991–1992 the HHMI grant supported the development of a two-semester Junior Biology Laboratory, which is required of biology majors in the junior year. Institute support provided some laboratory equipment and half-time support for a technician, whose principal responsibility was to help develop the laboratory.

The course teaches students how to write a scientific paper and how to conceive and design an experiment. In the fall semester, the course focuses on cell and molecular biology, and in the spring semester the focus shifts to neurobiology and ecology. "We want all of our biology graduates to have an excellent introduction to cellular and molecular biology, since that's so important for everything else," said Dr. Purves.

Students learn how to isolate the piece of DNA they want to study by using restriction enzymes to cleave DNA at specific sites and then put it into a bac-

terial cell to produce large amounts that can be studied in detail.

"The ability to manipulate DNA at the molecular level is absolutely fundamental to biomedical research and even is becoming very important in the practice of medicine," said Dr. Purves.

Faculty Development

Dr. James R. Manser, Assistant Professor of Biology, was appointed to the College faculty with HHMI support that covers his salary and startup funds for his research. Dr. Manser received a B.A. in chemistry summa cum laude from the University of California–San Diego, and a Ph.D. in biology from the University of Colorado–Boulder. He came to Harvey Mudd from Cambridge, England, where he was an NIH postdoctoral fellow and staff scientist at the Medical Research Council Laboratory of Molecular Biology for four years.

Dr. Manser is studying how a single cell embryo develops into a multicellular organism. He is especially interested in how cells know where to move in an organism to assume their proper position and shape—"when to move, where to move and when to stop." His strategy is to try to identify genes involved in those cell movements.

Three undergraduate students began working with Dr. Manser in summer 1993 on developmental biology and developmental genetics of *Caenorhabditis elegans*, a 1-millimeter-long transparent worm with fewer than a thousand cells. Sarah Moskowitz, an upcoming senior, is characterizing the *mig-10* gene at the molecular level, looking at the genetic information the gene contains, and defining what protein sequence it encodes.

Tonya Fagerwold, also a senior, is looking at another gene, *mig-11*, in which the laboratory has identified a mutation that causes defective cell movement. She is trying to locate the precise position of the mutation on the chromosome.

Wayne Fang, a junior biology major, is doing computer analysis of DNA and protein sequences and will help look for other mutants. He uses the computer to compare protein sequences of the *C. elegans* to similar proteins in other organisms where the function of those proteins is known—for example, proteins in mice and humans.

In 1993–1994, Dr. Manser will have four senior research students in his laboratory working with genes involved in cell migration in the worm. Last year Dr. Manser taught Introduction to Molecular and Cellular Biology, including the study of both prokaryotic and eukaryotic cell structure and function. The course is fundamental, he said, because any course students take later on "is going to require

Figure 61. Matthew Harris, another member of the first graduating class of biology majors, did a senior research project on the *mer* operon.

them to know the basics of cell structure and function."

Dr. Manser says he is excited about being at the College because "students will not only know biology when they leave, but they'll know how to apply it. They'll be unusually skilled, coming out of a college that emphasizes both biology and engineering."

Biology major Matthew Harris graduated at the top of his class of 117 in spring 1993 and is planning a research career in microbiology. In the summer of 1993 he worked in the molecular microbiology lab of Dr. Nancy Hamlett, Professor of Biology, whose interest is in bacteria that are resistant to mercury in the environment (Figure 61). "I'm working on determining the topology of a membrane protein involved in the transport of mercury ions," Mr. Harris said. "That will help us understand the function of the protein. This protein I'm studying is one of several involved in the resistance."

One possible outcome of the research: bacteria may be able to clean up mercury spills in the environment. "The bacteria take the mercury in and reduce it to a form that is nontoxic," Mr. Harris explained.

"What helped me is just perseverance and working hard," said Mr. Harris, who, despite daily commitments to the ROTC, graduated with the highest four-year grade point average in his class, with high distinction, and with honors in biology, the humanities, and social sciences.

Mr. Harris plans to pursue a Ph.D. in biology at the University of California–San Diego. Then he wants to conduct research in microbiology, working either with bacteria or viruses.

Mr. Harris said he feels that the broad education he received at Harvey Mudd in science, mathematics, engineering, and the humanities will profit him not only as a person but as a sci-

entist. "It gives you kind of a feel for what other people are doing, gives you sort of a common language," he said, "so that you can talk to other scientists and engineers and understand what they're doing."

Institutional Profile	
Total Enrollment	578
Undergraduate Enrollment	568
Number of Faculty Members	62
Endowment (in millions)	$62
Annual Budget (in millions)	$20

Jackson State University

Program Director
Arthur Jones, Ph.D.
Chair, Department
of Biology
Jackson State University
P.O. Box 18540
Jackson, MS 39217
(601) 968-2586
(601) 968-2058 (fax)

Jackson State University is a public, historically black, comprehensive institution in Jackson, Mississippi. In 1991 the Howard Hughes Medical Institute awarded the University $700,000 to support (1) a major revision of the science curriculum, particularly the introductory courses, to emphasize instruction in scientific reasoning and methodology, basic skills, and laboratory techniques in biology and related fields of chemistry, physics, and mathematics; (2) a two-part outreach program for teachers and students from Jackson-area public high schools, to provide training for students in the sciences and other areas during the summer and academic year, as well as workshops in modern science for teachers of biology and related fields; (3) undergraduate research opportunities during the academic year with University faculty and during the summer in off-campus research institutions; and (4) appointment of a biochemist with expertise in molecular biology to develop new courses and laboratory programs for students.

Student Research and Broadening Access

Research opportunities for Jackson State University undergraduates are available during the academic year. Since the inception of the Institute grant in 1991, 19 students, all underrepresented minorities, have been supported. Valerie Palmer, a senior, performed research in the laboratory of Dr. C. H. Spann, Professor of Biology. Ms. Palmer examined the histopathological effects of varying degrees of vitamin C deprivation and endotoxin shock. Dr. Spann observed, "Ms. Palmer found that with increased vitamin C deficiency, some tissues like lung, liver, and pancreas were more sensitive to endotoxin shock. As a result of her exposure to the laboratory, she became very comfortable with histopathology, tissue staining, and light microscopy." Using this experience as a springboard, Ms. Palmer says she "plans to go to dental school, and I might be interested in becoming a dental researcher."

Curriculum and Laboratories

At Jackson State the major objective of the HHMI-supported program is to revise the science curriculum by stressing scientific reasoning and principles, basic skills, and laboratory techniques. To achieve this goal, Jackson State faculty have redesigned several courses in both the biology and the physics departments, based on HHMI-supported laboratory equipment acquisitions.

Five biology laboratory courses have been revised: General Biology, Microbiology, Plant Physiology, Cell Biology, and Human Physiology. The equipment purchased included spectrophotometers, electronic balances, centrifuges, ovens, incubators, and water baths.

In addition, two lecture courses, General Biology and General Chemistry, and their accompanying laboratory courses are undergoing revision to create a "Super Course," a fully integrated two-course approach that introduces complementary concepts at similar times during the semester. According to Dr. Arthur Jones, Professor of Biology and HHMI program director, "We plan to literally rewrite the book on teaching general biology and general chemistry."

Dr. Mark Hardy of the Department of Biology and Dr. Jeffrey Zubkowski of the Department of Chemistry are introducing the new curriculum in the fall of 1993. Coordinating the material and creating experiments that rely on critical thinking and problem solving are the goals. Some of the new experiments focus on Charles's Law, acid-base titration, and electrochemistry. HHMI funds are being applied toward the purchase of computer equipment, such as computers that are used for data acquisition and manipulation. The interface between the computers and the laboratory equipment is made possible with a newly purchased software/hardware combination.

A two-semester physics course, Physics for Premed Majors, was introduced during the 1992–1993 academic year. This course was similar to the introductory physics course, but was geared for students preparing for the physics portion of the Medical College Admissions Test (MCAT). The instructor, Dr. Floyd James, Assistant Professor of Physics, stated, "Although the students found my class more difficult, they scored an average of 50 percent higher on a practice MCAT than did students in the introductory physics class whose grade point averages were similarly distributed. I was thrilled."

Faculty Development

In 1992 Dr. Bernice Spurlock joined the faculty as Assistant Professor of Biology, with three years of salary support from the HHMI grant. Dr. Spurlock holds a Ph.D. in biochemistry and nutrition from Howard University. Students benefited from her expertise in experimental nutrition when she taught a new biochemistry course that surveyed introductory biochemical principles for advanced undergraduates. Dr. Spurlock commented, "The students reacted very posi-

tively and it was most rewarding for me. I was very touched when my top student took a position teaching high school science in a small town in Mississippi."

Precollege and Outreach

With Institute support, Jackson State University has initiated two summer outreach programs, one for high school science teachers and the other for high school students. The program for teachers is intended to heighten awareness of contemporary science concepts and laboratory skills. Two-week intensive workshops given by several JSU faculty in the summers of 1992 and 1993 were attended by 48 high school teachers, 38 of whom are from underrepresented minority groups. The teachers come from 15 secondary schools in the tri-county Jackson area and receive stipend support from the HHMI grant. Through lectures and laboratories, the 1992 summer workshop, designed exclusively for biology teachers, covered concepts in biochemistry, neurophysiology, molecular biology, ecology, and botany. One idea that emerged from this program was a science equipment-lending library for local teachers. HHMI funding enabled the University to take the initiative in purchasing essential laboratory equipment, such as a spectrophotometer, for use by area school systems. Twenty-six high school teachers have already borrowed equipment.

High school students can take advantage of a four-week summer program that continues through the academic year on Saturday mornings. This program focuses on preparing students for the college science curriculum. Thirty-two students, all of whom are underrepresented minorities, have participated thus far. The Institute grant provides salaries for Jackson State faculty teaching in the program and stipends for students. Lectures, laboratory visits, field trips, and other organized activities help to strengthen students' backgrounds in biology, chemistry, mathematics, and communication skills. During the summer of 1992, the chemistry lectures and laboratories concentrated on stoichiometry, properties of liquids and solids, and aspects of synthetic organic chemistry. In the accompanying laboratory, the students synthesized and characterized aspirin.

Responding to requests by local teachers, Jackson State faculty have established a program to visit local elementary schools to enhance science education and to serve as role models. Faculty visit four local schools at least once every two weeks, giving lectures and talking to students on such topics

as anatomy and botany. According to Dr. Jones, the program is especially designed for young males who "need more exposure to male role models. We envision this activity as a primary recruitment and retention mechanism for students in college and the sciences."

Institutional Profile	
Total Enrollment	6,838
Undergraduate Enrollment	5,793
Number of Faculty Members	301
Endowment (in millions)	$4
Annual Budget (in millions)	$42

Kansas State University

Program Director
Terry C. Johnson, Ph.D.
University Distinguished Professor and Director, Center for Basic Cancer Research
Ackert Hall 233
Kansas State University
Manhattan, KS 66506
(913) 532-6705
(913) 532-6653 (fax)
TERRYJ@KSUVM.KSU.EDU (Bitnet)

Kansas State University is a public research institution in Manhattan, Kansas. In 1992 the Howard Hughes Medical Institute awarded the University $1,200,000 to support (1) a program to attract and retain nontraditional students in the sciences, particularly women and underrepresented minorities, to consist of tutorials, academic counseling, stipend support, and research experiences in faculty laboratories; (2) training in molecular biology and genetics for teachers at local and regional secondary schools and community colleges, to include laboratory equipment and supplies to develop new experiments and curricula for their classrooms; and (3) equipment acquisitions and faculty and course development in areas including molecular genetics, virology, microbiology, and immunology, and enhancements in mathematics courses.

Student Research and Broadening Access

The Institute-funded program at Kansas State University is designed to attract and retain students, particularly nontraditional students (25 years and older) and underrepresented minority students, to biological science. Such students make up 15 percent and 7 percent of the student body, respectively, and many have difficulty pursuing their education on a campus geared to traditional 18-to-22-year-olds. The undergraduate science program provides financial help, faculty and peer support, and monthly seminars on topics of interest to the students.

"These students are well motivated," said Dr. Terry Johnson, University Distinguished Professor and Director, Center for Basic Cancer Research, and program director. "They are high achievers, but many are having difficulties financially, socially, and psychologically."

The program provides for tuition, books, and child care, if needed. It also includes tutoring, faculty and peer mentoring, and a monthly seminar on issues such as campus resources, career preparation, and stress management. Forty students applied, and 16 were selected for spring 1993: 9 women and 7 members of minority groups underrepresented in the sciences. In addition, 12 of the 16 were nontraditional students. According to Dr. Johnson, the program appears to have boosted self-confidence among the participants, provided them a valuable network of faculty and peers, and reduced their financial barriers.

Carmen Chase, a 32-year-old biology major aiming for medical school, said the program allowed her to continue her studies full-time, care for her two children, and complete her undergraduate studies more quickly. "I can finish school on schedule," she

said, adding, "The honor of being an Institute-funded student showed me I could accomplish anything" (Figure 62).

Dr. Johnson said that the monthly special-interest seminars conducted by the program were immediately popular, even though held at 7:30 on Friday mornings. They provided a variety of career information and the chance to interact with faculty and peers. Many of the HHMI-funded students asked to include their friends, so the seminars were opened to other students, increasing participation to 49.

The participants again went beyond program plans and organized two support groups. One concentrated on the concerns of nontraditional students; the other addressed issues facing pre-med students. The latter group brought in seniors already accepted at medical school to explain the application process and allay concerns.

"The thing that is important ... is the personal interactions that the students feel with this program," Dr. Johnson said. Because the program focuses on many nonacademic needs of the students, it is less like an academic advising office and more like a home away from home.

Second, student development program grants for summer 1993 were awarded to five undergraduates—four women and one minority—to conduct research in faculty laboratories in biochemistry, physics, biology, and mathematics. Nina Ikeda investigated the role of protein kinase C in diabetes-induced noninflammatory disease of the retina with Dr. Dee Takemoto.

Figure 62. Carmen Chase prepares a pipette as part of a program for students returning to college.

"I'm doing primary cultures [of the retinal cells] and then running Western blots," explained Ms. Ikeda, who will enter her sophomore year in the fall and is considering graduate or pharmacology school. "We add antisera for different isoenzymes of protein kinase C to see what protein bands in the cells react." Her results and those of other participants were presented at a research symposium at the end of summer.

Angela Lambley studied antibiotic-resistant bacteria, which can develop as a result of the antibiotic feed used on hog farms and cattle feed lots. She performed studies on some of these bacteria to determine whether they carry plasmid DNA that could be transmissible to other organisms. Plasmids generally carry the antibiotic-resistance genes.

Curriculum and Laboratories

The high cost of laboratory equipment can hobble efforts to teach modern biology and state-of-the-art scientific techniques to undergraduates. The Institute grant has therefore provided funds to develop and equip two new biological science laboratory courses and to enhance equipment in three existing ones. Some 400 students have already used the new equipment in the existing courses: Immunology, Microbiology, and Structure and Function of the Human Body.

The biology faculty teach recent advances in molecular genetics and molecular biology but have not offered a laboratory course involving recombinant DNA technology and other techniques used in these areas. The two new laboratory courses will serve as "capstone" courses for biological science students. Molecular Genetics will be offered in fall 1993, and Molecular Virology in spring 1994. Under the HHMI grant three undergraduates are learning to set up experiments and helping to ensure that they can be conducted by undergraduate students.

The two new courses will occupy a laboratory with the enhanced immunology course and share much of the equipment. Some of the new equipment includes a CO_2 incubator and a magnetic-activated cell sorter for the immunology laboratory, as well as laminar-flow hoods, an ultra-low-temperature freezer, shaking platforms, a spectrophotometer, gel electrophoresis equipment, a vacuum pump, microscopes, and computers.

The HHMI grant has funded purchases of six computer laboratory stations, each with a computer, monitor, printer, and the Intellitool hardware and software to run physiology laboratory exercises for the course on structure and function of the human body. The stations replaced antiquated 25-year-old equipment for which parts were no longer available. Three refrigerated incubators have been purchased for the microbiology course, and an automated system of microorganism identification will be procured.

The HHMI grant is also funding the development of mathematics workshops to help students, particularly women and

underrepresented minorities. A workshop on algebra was offered this year, and trigonometry and calculus will be offered in 1993–1994 and 1994–1995, respectively. These workshops emphasize academic excellence and collaborative, small-group problem solving. Students attend the regular class and the twice-weekly, two-hour workshops, where they work in groups of three on specially prepared worksheets of advanced mathematical concepts under the tutelage of a facilitator. Eight of nine workshop students in the fall and five of six in the spring earned an A or B in the algebra class.

Precollege and Outreach

Interest in the HHMI-funded outreach program in genetics education has been more widespread than anticipated. The program is offered to teachers in the central Great Plains. But when it was announced in 1993 in a wide-circulation newsletter, queries came in from Minnesota, California, Florida, New Hampshire, and even the Netherlands.

"There is all of this interest around the country in doing these kinds of activities in the classrooms," said outreach coordinator Dr. Thomas Manney, Professor of Physics, "and there are also a lot of geneticists out there who are willing to help."

The outreach program evolved from the University's efforts since 1985, including Genetics Education Networking and Enhancement, a four-year program to enhance genetics education through laboratory experiments with, for example, yeast and ultraviolet radiation. It develops classroom instructional materials for genetics and radiation biology and instructs a cadre of lead teachers from middle schools, high schools, and two- and four-year colleges—often pairing college faculty with precollege teachers—in how to train colleagues to present the laboratory exercises (Figure 63).

Lead teachers attend summer seminars at the University and, in turn, train fellow teachers in one-day seminars. Newly developed classroom and in-service materials (kits with laboratory materials; video tapes demonstrating laboratory techniques) are provided for the teachers as well as a scientist to assist in the seminars. The program also provides a network for the scientists, teachers, and students involved in the program. According to Dr. Manney, the program has the potential to train 560 teachers and to reach a large number of students during its four years.

In 1992–1993 the program developed materials with a primary focus on using living cells (baker's yeast) to explore the lethal effects of solar ultraviolet

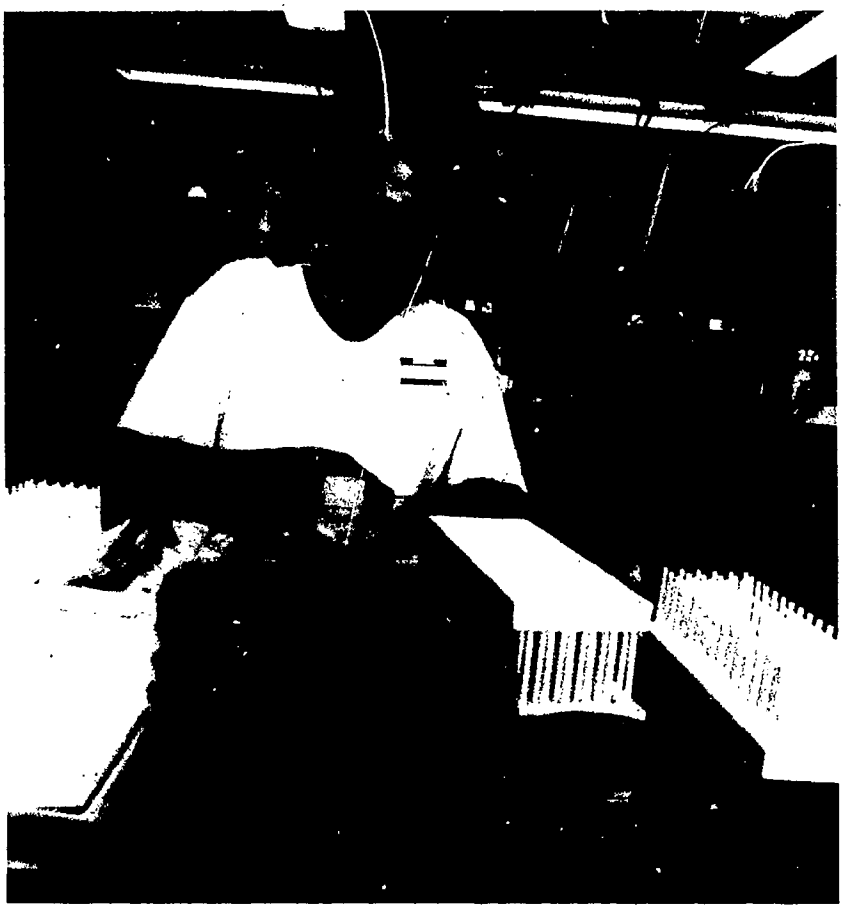

Figure 63. In a 1993 genetics workshop at Kansas State University, Lois Glasscock, a high school teacher from Texas, mixes yeast for mating in a yeast life-cycle experiment. (Kansas State University)

radiation. An ultraviolet irradiation box using artificial sources has been developed that provides a safe source of ultraviolet B or C radiation. The first of four annual seminars was conducted in June 1993.

Institutional Profile

Total Enrollment	18,059
Undergraduate Enrollment	15,694
Number of Faculty Members	1,380
Endowment (in millions)	$74
Annual Budget (in millions) (main campus)	$245

Oklahoma State University Main Campus

Program Director
Alan R. Harker, Ph.D.
Associate Professor
Department of Microbiology
307 LSE
Oklahoma State University Main Campus
Stillwater, OK 74078
(405) 744-5929
(405) 744-6790 (fax)

Oklahoma State University Main Campus is a public research institution in Stillwater, Oklahoma. In 1992 the Howard Hughes Medical Institute awarded the University $2,000,000 to support (1) development of a research track within the biology curriculum that will provide students at the introductory levels with opportunities for laboratory research and with seminars and symposia to present research results; (2) expansion of programs to enrich science education at rural Oklahoma elementary, middle, and high schools, particularly those serving Native American students, providing laboratory, classroom, and field training during the summer; and (3) ongoing linkages with teachers and students during the school year through a "footlocker" program to provide laboratory equipment and curricular materials and through a program to develop advanced placement biology at schools in outlying districts.

Student Research and Broadening Access

An undergraduate research program had been projected for fall 1993 at Oklahoma State University. Each year for the next five years, five freshman Native Americans would receive four-year stipends and, beginning in their sophomore year, would join a laboratory for research in the biological sciences. Student demand, however, moved the program up a year.

"The publicity that went out elicited a tremendous response from students," Dr. Alan Harker, Associate Professor in the Department of Microbiology and program director, explained, so four students were selected to begin the program in 1992–1993. "Two of the students ... were just so outstanding that one ended up going into a research laboratory during her spring term and the other one has started work in a research laboratory in the vet school this summer."

Donna Reynolds, of the Creek tribe, worked on the construction of a cloning vector for use in the characterization of a transposable element in *Streptococcus* in the laboratory of Dr. Moses Vijayakumar. Billy Starr, of the Cherokee tribe, was involved through the School of Veterinary Medicine with field trials of vaccines developed against tick-mediated infections in cattle.

In fall 1993 several programs will be initiated to support student researchers. Participants at the sophomore level will begin the year with an intensive course to introduce them to research fundamentals and laboratory techniques. The course is scheduled for nine evening sessions during the first three weeks of class, rather than dur-

ing the summer, in order to avoid conflict with powwows and other tribal activities that keep students connected with their communities. A seminar series will feature Native American scientists and other experts. Plans for a study lounge are being discussed, and an annual research symposium is being considered.

As participants progress through the program, they will become role models for younger rural Native Americans, Dr. Harker said. Donna Reynolds, for example, served as a counselor in the summer science camp for 8th and 9th graders in 1993. Older students in the University chapter of the American Indian Science and Engineering Society have already provided unanticipated mentoring and role modeling.

Curriculum and Laboratories

According to Dr. Harker, the curriculum component of the HHMI-supported program expanded unexpectedly in 1992–1993 to focus on establishing problem-centered laboratories. Two course laboratories, in microbial physiology and biotechnology, are being restructured and will be tested in spring 1994.

The idea for restructuring the laboratories evolved from a faculty workshop to prepare for the 8th- and 9th-grade summer science camp. Professors attending the workshop thought the new teaching method should be implemented in college-level biology courses, too.

"What we are attempting to do," Dr. Harker said, "is create a more problem- or experience-oriented environment to engage the students in a real-life problem so they will seek to learn those principles that will allow them to solve the problem."

With the help of HHMI funds, the laboratories will be equipped as a research facility. At the beginning of the term, students will be given a research problem and must establish a protocol for completing it. Students can come and go as needed, and an instructor will be available during lab hours to advise and monitor students. In microbial physiology, students will purify and characterize a bacterium selectively isolated under conditions of their own choosing. In biotechnology, students will clone a gene, express the gene product, and perform scale-up production and purification of the product.

The program is also putting an unexpectedly strong emphasis on computer-aided instruction and multimedia presentation. The effort grew out of a workshop involving Dr. Clark Gedney, supported by HHMI funding at Purdue University,

and Dr. John Gelder of the Oklahoma State University Department of Chemistry. As a result, the project has assembled a Macintosh multimedia workstation and two networked workstations. The technical coordinator now trains faculty and students in the biological sciences to use the equipment for curriculum and presentation development.

Precollege and Outreach

Among the 50 states, Oklahoma has the largest population of Native Americans, numbering more than a quarter million. They make up 8 percent of the state's population overall and 10 percent in rural areas, where limited personal and school resources leave them at an educational disadvantage. At Oklahoma State University, the HHMI grant funds a program Native Americans in Biological Sciences, which seeks to attract more rural Native Americans into the biological sciences and keep them there.

The key to this effort, says Dr. Harker, who directs the program, is the involvement of community leaders. In its first year, advisory boards were organized representing community, tribes, and schools in three rural school districts—Pawnee, Ponca City, and Frontier (in Red Rock). Their input, Dr. Harker said, has been "very dramatic, much more dramatic than I thought it would be."

The projected outreach program calls for three levels of summer science camps, enrichment programs broadcast from the University, high school science study groups, and footlockers of scientific equipment and supplies for use by the schools.

The three advisory boards have already begun to reshape the outreach programs. When the University suggested broadcasting educational programs to the districts, the boards asked for programming that teachers could use to stimulate activities around biological issues. These programs are now being developed. At the suggestion of a program adviser in Ponca City, the first footlocker was developed to focus on computer learning.

The advisory boards also play a crucial role in bringing Native American students into the program. Two of the four participants at the University in 1992–1993 were named by an advisory board, and the boards have submitted names of other candidates for the next academic year. The boards recruited students for the 1993 summer science camp for 8th and 9th graders; one board exceeded its recruitment goal by 50 percent.

Most University departments have recruited Native Americans from the state's major

cities. This program, however, targets rural Native Americans, who are usually much more involved in tribal culture. The community advisory boards, Dr. Harker said, "will make or break the program from the point of view of putting and keeping students in the pipeline."

In summer 1993, 18 8th and 9th graders were brought to the University campus for a four-week science camp. The Pawnee advisory board sent four extra students to fill vacant slots. "We'd like to put as many as we can in there," said Robert Chapman, an adviser to the program and a tribal councilman. "Indian children ... really don't have the opportunities that we'd like to see them have. [The summer camp] opens up another dimension of the world to them."

This camp generated much enthusiasm among the students, Dr. Harker said, because it used a problem-oriented instructional approach to a real-life environmental problem in the nearby city of Cushing. In the 1980s, the city built a wastewater treatment plant meeting current regulations. But recently the state upgraded the classification of the stream where the wastewater is dumped, so the facility now needs $2 million of improvements to meet the new standards.

"This is a real-life problem with a lot of biological and engineering aspects to it," Dr. Harker said. At the summer camp, students were introduced to different types of research and then formulated their own research programs for the Cushing problem. Graduate students acted as resource persons for research groups, which collected stream samples for microbiological testing, seined for fish to study their populations, investigated macro- and micro-invertebrates, interviewed state and city officials, sampled public opinion, and explored legal aspects of the issue.

Each school district conducts a local two-week summer science camp for 18 to 20 elementary school students, and the Institute grant provides supplies. These camps, begun in 1993, include general activities in biology, chemistry, physics, and geology. They also focus on problem-oriented instruction. In one, for example, the teacher set up an aquarium in the first week. At the beginning of the second week, the teacher poured oil on the water, announced an "environmental disaster," and asked the children what they could do about it. "The kids had a lot to say [about] how devastating that was and what work it took to save the fish," Dr. Harker said. "It was an interesting approach" (Figure 64).

A third summer camp, to begin in 1994, will include

Figure 64. Shelby Palmer (*left*), from Pawnee High School and a member of the Pawnee and Kiowa tribes, and Lyndsey Warrior, from Ponca City Mid High and a member of the Ponca tribe, carry out a microbiology experiment as part of a summer laboratory training program for Native American students at Oklahoma State University.

senior high students. It will focus more on individualized research under faculty tutelage.

At the high school level, plans include the organization of science study groups that will participate in field trips, science fairs, and other science-related out-of-class activities. The senior high students in the groups will also be asked to visit elementary and junior high schools to share their experiences, put on science demonstrations, and act as mentors. Lead teachers have been selected to organize the first study groups in 1993–1994.

A footlocker program is being developed, modeled after an HHMI-funded program at the University of Illinois at Urbana–Champaign. Many small school districts do not have money for the equipment and supplies needed to do modern biology experiments. The footlockers involve putting together materials for a two- or three-week course plus the required equipment and supplies. Footlockers will be shipped to a school district when needed and brought back to the University for refurbishing.

Footlockers for computer-aided learning and for video microscopy were completed in 1992–1993 and two others are under development for biotechnology and water quality analysis. The computer footlocker contains a Macintosh IIvx, a color printer, video capture equipment, and software, including word process-

ing, database, Labview, SimLife, and other programs. The video microscopy footlocker contains a microscope, a high-resolution video camera, and a 20-inch monitor with integral VCR. There is also a resource library to lend books, videotaped programs, software, and other materials.

Institutional Profile	
Total Enrollment	15,857
Undergraduate Enrollment	13,411
Number of Faculty Members	1,464
Endowment (in millions)	$40
Annual Budget (in millions)	$279

Spelman College

Program Director
Pamela J. Gunter-Smith, Ph.D.
Professor of Biology and Chair, Biology Department
Spelman College
Box 271
350 Spelman Lane
Atlanta, GA 30314
(404) 223-7643
(404) 223-1449 (fax)

Spelman College is a private, historically black, liberal arts institution in Atlanta, Georgia. In 1991 the Howard Hughes Medical Institute awarded the College $900,000 to support (1) appointment of a new faculty neurobiologist and opportunities for biology faculty to conduct research at major research universities during the summer; (2) year-long research experiences for high school teachers in college laboratories and a nonresidential summer program in the sciences for high school students; (3) equipment upgrades and laboratory enhancements for the development of new courses in such areas as neurobiology and molecular biology, and modifications in the existing curriculum with the assistance of visiting scientists; and (4) undergraduate research experience at major universities.

Student Research and Broadening Access

Spelman College faculty placed 29 undergraduates in research settings on the College campus and at other universities, industrial settings, government laboratories, and hospitals during the summer of 1992. HHMI funds supplemented the stipends provided by most of the host institutions. Five of the summer researchers will be listed as co-authors on published papers, and four were accepted into Ph.D. programs, beginning in the fall of 1993.

"Some of our students didn't produce a lot of data, but the research experiences were good," noted Dr. Rena T. Jones, Professor of Biology and program director until July 1993. Equally important, they were exposed to research situations and had opportunities to use analytic equipment that is not available at the College. "Often our students come here with their career goals somewhat set, and many of them want to go into the health field," she said. But the summer research experiences helped some of them to change their minds. "Four of our HHMI students are entering Ph.D. programs in 1993, even though only one of them wanted to go to graduate school when she came here."

The 1992 summer research program participants described their broad array of undertakings with considerable enthusiasm. For instance, Shawnda Ganter spent her summer at Merck, where she worked with Dr. Denise Pretzer and helped to determine the precise composition, equilibrium solubility, and other pharmacokinetic properties of a new pharmaceutical product. This exposure to a working laboratory gave her a good practical sense of what a research environment is like. Perhaps more important, it helped her overcome certain anxieties about working in such

an environment, she said. Instruments that at first were intimidating to her "were like my best friends" by the end of the summer.

Erika Brown, who spent her summer at Upjohn, was surprised but also pleased with the open and relaxed atmosphere that she found while working in the laboratory of Dr. Ake Elhammer, whose research focus is very basic. Her work on glycosyl transferase enzymes was incorporated into a paper that was submitted to *Biochemistry*, and she is now planning to pursue a Ph.D. in medical genetics.

Several students studied retroviruses during summer 1992. Tiffany Pinkney worked in the research group of Dr. Peter Shank at Brown University, developing a polymerase chain reaction-based assay to detect the AIDS virus in newborn infants. Because antibodies to the virus transferred to such children from their mothers obscure infection in the children, alternative analytic methods are sorely needed. Although the new test proved "not as sensitive as we'd like," the opportunity to learn how to use the powerful DNA-amplification technique was "really neat," said Ms. Pinkney. Meanwhile, her classmate Lia Haynes spent the summer of 1992 in the laboratory of Dr. Carlos Mora at the National Institutes of Health, learning how to apply immunochemical-based assays to detect the retrovirus known as HTLV-1 in the central nervous system and in muscle tissues. "I want to continue work in neuroimmunology and retroviruses and to go into neuroscience in graduate school," she said.

Some students, such as Nikita Ferguson, continued their research projects beyond the summer of 1992. Working in Dr. Edward Morgan's laboratory at nearby Emory University, Ms. Ferguson is studying the effects of several agents, including vanadate and endotoxins, on the P-450 cytochrome system in rats. During the 1992–1993 academic year, Ms. Ferguson continued to spend time on this research project, traveling to the Emory campus three times a week to conduct experiments there.

Curriculum and Laboratories

Four faculty members at Spelman College received HHMI support that has had a direct impact on the development of their students. HHMI funds enabled Dr. Jones to spend the summer of 1992 conducting research on regulation of the *carAB* operon in *Salmonella typhimurium* with Dr. Ahmed T. Abdelal at Georgia State University. This research will be continued at the College by HHMI-supported undergraduates during the 1993–1994 academic year, according to Dr. Jones.

HHMI funds enabled the Biology Department to recruit Dr. Michael McGinnis, Professor of Neurobiology, in 1992. He received his Ph.D. in developmental biology from Purdue University in 1985, where he subsequently worked as Assistant Professor, Department of Anatomy, School of Veterinary Medicine. Since coming to the College, he has revamped the neurobiology course, which in 1993–1994 will include wet labs and computer simulations for the first time. He also has directed research projects for five students, one of whom was a summer scholar in 1992. Dr. McGinnis arranged for several undergraduates to attend the Society for Neuroscience annual meeting in California during the fall of 1992.

One of these students was Marsha Maxwell, a chemistry major, who graduated in May 1993 and enrolled in the Ph.D. program in the neurosciences at the California Institute of Technology. Her work in neuroscience and computer science with Dr. McGinnis was conducted in part at the Georgia Institute of Technology and concerned the human-machine interface. Another student, Karimu Smith, a biochemistry major, who graduated in May 1993 and enrolled in the University of Medicine and Dentistry, Robert Wood Johnson Medical School, conducted research on the effects of electrical fields on the development of the nervous system of chickens. This project is being continued by Angela Powell, a junior biology major, who also attended the Society for Neuroscience annual meeting.

Dr. Godwin Ananaba also joined the Biology Department in 1992, and the HHMI grant provided him with research start-up funds for the 1992–1993 academic year. During the spring semester of 1993, he was granted released time to revise his genetics course and set up his research laboratory. Dr. Ananaba completed his Ph.D. in cell and molecular biochemistry at Atlanta University in 1988. Before coming to the College, he was Visiting Research Scientist, Division of Viral and Rickettsial Diseases, at the Centers for Disease Control and Prevention.

Dr. Victor Ibeanusi, an environmental biologist, established a research collaboration with Dr. Joseph Gould at the Georgia Institute of Technology. Dr. Ibeanusi has mentored several undergraduate research students at the College, including two who received HHMI stipends during the summer of 1992.

Five of the College's core biology courses were evaluated during the 1992–1993 academic year. Dr. Lafayette Frederick, a botanist from Howard University, suggested that students use a dichotomous key to identify plants on the campus as part of a practical exercise. Other recommendations are being imple-

mented with the help of the Institute grant.

In evaluating the microbiology course, Dr. Linda Fisher of the University of Michigan, Dearborn, recommended that students be asked to identify unknowns as part of the laboratory component of the course and that serious consideration be given to independent laboratory group projects.

Visiting professor Dr. David Nelson, a biochemist from the University of Wisconsin, recommended that the Departments of Chemistry and Biology work more closely to eliminate unnecessary duplication between subjects taught in three biology courses—Genetics, Cell and Molecular Biology, and Biomolecules—and in the year-long organic chemistry course. He also suggested that certain topics common to these courses be taught in separate "mini" courses, particularly in the area of molecular physiology. This evaluation by Dr. Nelson will have "a real bearing on the curriculum here," said Dr. Jones.

Institute funds helped the Biology Department to purchase several important pieces of laboratory equipment during the 1992–1993 academic year, according to Dr. Jones. A new autoclave is a "wonderful and an essential addition to the department, and it is having a major impact on our work in microbiology and cellular and molecular biology," she said. The equipment that it replaced broke down so often that faculty members often traveled to neighboring campuses when they wanted to prepare media for their experiments or laboratory courses. "We've now eliminated that cumbersome practice," she noted.

Precollege and Outreach

During 1992–1993, the College brought in teachers from several local schools for a workshop that focused on recent advances in molecular genetics and molecular biology and a demonstration of the use of micropipettes and agarose gel electrophoresis. In addition, with support from the HHMI grant, Dr. Jann Primus from the Biology Department acted as a mentor for a science fair program at the Sammye E. Coan Middle School, and the College also lent equipment and other supplies to help the 35 students who participated (Figure 65).

During the summer of 1992, Spelman offered its first Howard Hughes Summer Science Program for 20 high school students. The program covered not only science, but also mathematics, reading, and problem-solving skills. Other components of the summer program included library visits, a mini-seminar series, and a field trip. Arlene Hankinson's talk focused on research she has done for three years on beta-galactoside lectin

Figure 65. Dr. Jann Primus (*third from left*) of Spelman College discusses techniques for photographing a gel with (*from left*) Victor Tate, Archer High School student; Larve Bailey, Crim High School teacher; Ruth Odum, Crim High School teacher; Sharon Gay, Archer High School Science Chair; Benzia Sapp, Coan Middle School student; and Jessie Jackson, Crim High School teacher (*right foreground*).

levels in fibroid tumor cells, in the lab of Associate Professor of Biology, Dr. Shelia McClure. Dr. Theresa Edwards, chair of the College's mathematics department, spoke on parallel computing.

Dr. Jones is beginning to keep track of the students who participated in the summer program and subsequently enrolled at Spelman and other colleges and universities. Of those first summer students, seven who graduated are now in full-time college courses, with four in the sciences. One of the students, Michelle Thompson, entered Spelman in the fall of 1993 as a biology major. According to Dr. Jones, Michelle Thompson's decision to enroll at Spelman was based primarily on her experiences as a participant in one of Dr. Victor Ibeanusi's DNA workshops for high school teachers and students, and also as a participant in the HHMI-supported 1992 summer science program.

Institutional Profile	
Total Enrollment	2,025
Undergraduate Enrollment	2,025
Number of Faculty Members	126
Endowment (in millions)	$108
Annual Budget (in millions)	$35

University of California–Berkeley

Program Director
Corey S. Goodman, Ph.D.
Professor, Division of Neurobiology
Department of Molecular and Cellular Biology
Investigator
Howard Hughes Medical Institute
University of California–Berkeley
Berkeley, CA 94270
(510) 643-9949 or
(510) 642-9084
(510) 643-5548 (fax)

The University of California–Berkeley is a public research institution. In 1992 the Howard Hughes Medical Institute awarded the University $2,000,000 to support activities to attract and retain students in the sciences. The activities are (1) a program of seminars, tutoring, and mentoring for students at the introductory levels, including those from underrepresented minority groups; (2) enhancements in upper-division laboratory courses in cell biology, immunology, molecular genetics, neurobiology, and structural biology, with the involvement of senior faculty scientists; and (3) new opportunities for undergraduates to conduct independent research in faculty laboratories during the summer and into the academic year, supplemented by seminars, symposia, and other opportunities to present their research.

Student Research and Broadening Access

By investing in its diverse student body, the goal of the University of California–Berkeley is to attract and retain more underrepresented minority students as biology majors. This commitment stems from the recognition that while almost 30 percent of entering freshmen are black or Hispanic, they constitute only 7 percent of graduates with a major in biology. With HHMI support, UC–Berkeley has created a new program, the Biology Scholars Program, to ensure that more underrepresented minorities are among the approximately 400 biology majors who graduate each year.

The program, with support from the HHMI grant, provides academic and social assistance for talented freshmen and sophomores, especially underrepresented minority students, who are interested in majoring in biology. The program offers tutoring, instruction, mentoring, counseling, and research and career opportunities. Through a required introductory course, organized workshops, study groups, and one-on-one contact, students interact with faculty, upper-division undergraduates, and graduate students in the Department of Molecular and Cell Biology.

There were 54 students in the first class of the Biology Scholars Program beginning in the 1992–1993 academic year. Of this group, 38 were women, 18 were black, and 13 were Hispanic. A major emphasis of the program is to prepare students for careers in the life sciences. One career-oriented workshop consisted of a panel of former UC–Berkeley biology majors, who spoke candidly about navigating through the University to attain their career goals. Duane Dyson, a minority

sophomore in the program, whose aspirations include medical school, said that this panel was one of the highlights of the program because it "opened up my eyes about what medicine and research were like. The panelists spoke about how they cope, their trials and tribulations, and even how they failed courses and still succeeded."

Another activity for the students was a workshop entitled "Finding an Undergraduate Research Position." According to workshop organizer Dr. Caroline Kane, Adjunct Assistant Professor of Biochemistry and Molecular Biology, "Most students considering laboratory work had not put together a résumé in order to contact a faculty member for a position. After the workshop, two or three students found work in laboratories, and one feels she succeeded because she knew how to present her positive qualities."

Based on his personal interviews with students after the first academic year of the program, Dr. John Matsui, Director of the Biology Scholars Program, felt that it was "an overwhelming success because it keeps students in the life science pipeline by providing a forum for them to ask their questions, access resources, and develop a sense of their place in the scientific community."

UC–Berkeley has also established a program that relies on Institute support to provide research opportunities for undergraduates. The program enables students to work in a campus laboratory, in the Lawrence Berkeley Laboratories, or at Children's Hospital Oakland Research Institute. Students participate during the academic year or summer and receive a stipend and a research supply allowance. Awards during the academic semester are targeted to students who would otherwise need to work part time. Students also can receive academic credit for their research. Eleven academic year stipends and 25 summer stipends have been awarded since the program began in September 1992.

One participant in the program is Matthew Falk, a senior who plans to pursue an M.D. and a Ph.D. in biochemistry. Working in the laboratory of Dr. Stuart Linn, a professor in the Department of Molecular and Cell Biology, Mr. Falk is investigating the impact of exposing DNA sequences to oxidized iron to determine what type of damage occurs and whether the damage is restricted to purine-rich regions. Prior to his research experience, Mr. Falk said, he "had no clue as to what a biochemist does. Now I have been exposed to a biochemistry lab, and this experience has definitely made my choice of a career more exciting."

Curriculum and Laboratories

Institute support is also being used to enhance and expand the biology curriculum through the development of a new introductory biology course and through the purchase of laboratory equipment needed for other courses. The new course, Current Topics in the Biological Sciences, is designed primarily for the students interested in majoring in a biological science, and its enrollment includes the members of the Biology Scholars Program. As the first exposure to biology at the undergraduate level, its purpose is to encourage students to major in biology.

Unlike some introductory courses that may unintentionally discourage students with excessive scientific detail, this course presents biology in a social and career context. Discussion sections are guided by the course instructor and teaching assistants. One of the beginning lectures is On Being a Scientist: What Do Scientists Do? The course covers such topics as cancer, human reproduction, and biotechnology. As this year's course drew to a close, students learned about becoming entrepreneurs during the lecture on Forming a Biotech Company.

New equipment purchased with HHMI funds has been added to four undergraduate laboratory courses. For example, 15 Macintosh computers with graphics software were bought for the laboratory course General Biochemistry and Molecular Biology. After purifying the enzyme lactate dehydrogenase, which catalyzes reactions in the glycolysis pathway, students in this class are able to visualize the enzyme's three-dimensional structure, using the Macintosh software. The software also allows them to manipulate the enzyme structure and to compare it with other proteins. Dr. Kane commented that the additional resources "improve our undergraduate laboratories and sustain the optimism and morale of many persons in our department."

Institutional Profile	
Total Enrollment	30,638
Undergraduate Enrollment	21,590
Number of Faculty Members	1,650
Endowment (in millions)	$17
Annual Budget (in millions)	$579

University of Georgia

Program Director
Alan J. Jaworski, Ph.D.
Professor and Director of Undergraduate Biology Degree Programs
Division of Biological Science
Room 400, Biological Sciences Building
University of Georgia
Athens, GA 30602
(706) 542-1868 or
(706) 542-1688
(706) 542-1805 (fax)
AlanJ@dogwood.botany.UGA.edu (Bitnet)

The University of Georgia is a public research institution in Athens, Georgia. In 1992 the Howard Hughes Medical Institute awarded the University $1,400,000 in support of the following: (1) outreach initiatives for teachers and students from junior and senior high schools in rural and urban schools in Georgia, particularly those serving underrepresented minority students, to include summer workshops in mathematics and science for students, activities to encourage participation by students and teachers in science fairs, and a "footlocker" program to lend equipment and supplies to teachers to carry out experiments in the classroom; (2) development of new introductory and upper-division laboratory courses in biochemistry, cell biology, general biology, genetics, and other areas, with equipment for the new laboratories; and (3) undergraduate research experiences, faculty mentoring, and study workshops to encourage students in the sciences.

Student Research and Broadening Access

Initial efforts have focused on recruitment of students and on creating awareness and interest in the program. HHMI funds supplemented the budget provided by the University and other funding sources to create an office where students who are interested in biology can congregate and find out about research opportunities in biology at the University. "This center has a lot of fringe benefits to it, and its effect is better than we anticipated," said Dr. Alan J. Jaworski, Professor and Director of Undergraduate Biology Degree Programs and program director.

For example, Chris Pung, an undergraduate student who frequented the center, came up with the idea of publishing a biology newsletter as a way of building student awareness of research opportunities and encouraging better interactions between students and faculty on the campus, according to Dr. Jaworski. "We'd planned on mentoring programs, and decided the newsletter fits in," he said about the project. Soon after the first newsletter was distributed in the spring of 1993 with HHMI support, other departments indicated that they wanted to become active participants in the undergraduate research program.

The center also helped to create additional opportunities for students to conduct research in various laboratories on the campus, particularly students from underrepresented minority groups. In addition to the HHMI support of highly qualified minority students, special funds allotted to the Dean of the Graduate School supported three black students in the 1993 summer research program.

Curriculum and Laboratories

HHMI funds were combined with other support from the University of Georgia to purchase new equipment for several biology courses, including a new molecular genetics course, a course in laboratory techniques in biochemistry, and a course in basic laboratory skills.

The new equipment included centrifuges, gel electrophoresis equipment, incubators, and computers for data analysis. "This course was offered for the first time last winter [1993], and it offered state-of-the-art equipment—what you see in research labs—so that students could go right into research and not skip a beat," pointed out Dr. Jaworski.

The new Institute-supported course in basic laboratory skills represents another "kind of success, reflecting more the time than the money spent on it," Dr. Jaworski commented. First offered during the winter quarter of 1993 on a trial basis to two undergraduate students and in the spring quarter to an additional five students, the course is designed to teach basic laboratory skills and to instill confidence in the students. Thus the exercises incorporated in this course build sequentially on one another but are not tied into any particular discipline within biology. "We want to use this course as a springboard for undergraduate research, giving these students an edge," Dr. Jaworski said. The course should also be helpful for training transfer students who come into the Biology Department and other undergraduates who need to become adept at basic laboratory procedures.

Institute funds are also being used to conduct study workshops to help students improve their performance in science courses. In addition, Dr. Jaworski noted, the workshops are monitoring students, particularly those from minority backgrounds, who tend to drop out early as science majors—typically, soon after taking first-year introductory courses. The workshops were designed with a grade-point "bonus" to entice students into attending on a regular weekly basis. In the process, participants learned time management and other study skills, he said. "We now know who the students are and will track their performance in science courses." The initial evaluation indicates that the workshops were "sufficiently successful to have caught my eye," he said.

Precollege and Outreach

The results of a pilot program to sponsor high school science fairs, particularly in disadvantaged school districts or where minority populations are high, are "very encouraging," Dr. Jaworski noted. The initial pro-

gram involved 43 participants in regional science fairs. It generated increased activity among high school students and also aided their teachers in building interest in science for their entire classes. "This is a program to enrich schools that aren't being reached in mathematics and the sciences," he said, "but it is at a very early stage of development."

Thirty 9th- and 10th-graders attended a special science institute on the campus in the summer of 1993. The program, for talented underachievers, is managed by Dr. Mary Atwater, Associate Professor of Science Education at the University. The underlying idea is to raise the self-esteem of these students and to encourage them to do well in the intensive three-week science course and to absorb all that they can from the laboratories they visit during their brief stay on the campus. Recruitment of participants was enhanced by setting up a toll-free telephone system, making it easier for teachers and students from a wider area to obtain information about the program (Figure 66).

Institutional Profile

Total Enrollment	27,118
Undergraduate Enrollment	21,530
Number of Faculty Members	2,007
Endowment (in millions)	$111
Annual Budget (in millions)	$505

Figure 66. Corey Benton, a high school student, starts a DNA gel as part of the Science and Mathematics Summer Institute. (Photo by Rick O'Quinn)

University of Maryland College Park

Program Director
William J. Higgins, Ph.I
Associate Professor of Zoology and Associate Dean
College of Life Sciences
1222 Symons Hall
University of Maryland College Park
College Park, MD 20742
(301) 405-2078
(301) 314-9566 (fax)
whiggins@alfs.umd.edu (Bitnet)

The University of Maryland College Park is a public research institution. In 1992 the Howard Hughes Medical Institute awarded the University $1,300,000 to support (1) development and implementation of upper-division laboratory courses in biochemistry, cell biology, genetics, and neurophysiology, to emphasize hands-on experimentation and encourage student research; (2) acquisition of teaching equipment for the new laboratories; and (3) summer and academic-year research experiences for students, including those from groups underrepresented in the sciences, to follow students' participation in the research-oriented laboratory courses.

Student Research and Broadening Access

A program to provide research opportunities for undergraduates is sponsored by the Hughes grant and the College of Life Sciences. The departmental honors programs have always required students to do research. But many faculty members were unable to take more than a few students into their laboratories because of the cost.

In the first year of the HHMI-supported program, five to seven times more juniors and seniors are getting appointments in faculty laboratories, said Dr. William J. Higgins, who is Associate Professor of Zoology, Associate Dean in the College of Life Sciences, and program director. There are 30 slots for independent biomedical research by juniors and seniors under direct faculty supervision during the academic year and 20 slots during the summer.

Dr. William E. Walton, Research Scientist and Lecturer in Zoology, and program coordinator, says that a new direction has been set at the University of Maryland. "Emphasis has changed from doing procedures out of a cookbook to doing research aimed at answering questions," he said.

"We fully intend to continue this beyond the five years of the Institute's grant," said Dr. Higgins. "This is essentially a paid internship that keeps students from having to work part-time at jobs that have nothing to do with science. You're not going to get the students to stay in the biomedical field if you don't have these kinds of programs," Dr. Higgins said. "From the students' perspective, doing research is what turns them on, gives them an idea of what the biomedical field is like." And, Dr. Higgins points out, a research experience can give undergraduates a head start in graduate or medical school.

Two-thirds of the students are using HHMI funds to support their research for an Honors degree in chemistry and bio-

chemistry, zoology, or psychology. In addition to the three majors mentioned above, these students are majoring in botany, biological sciences, and microbiology. Nineteen faculty from the departments of botany, zoology, chemistry and biochemistry, microbiology, psychology, and entomology are mentors in the fellowship program. Nine students began their fellowships in January 1993 and 13 more started in June.

Jennifer Harris, a senior, is an honors student in zoology who is working with Dr. Avis Cohen, Associate Professor, Department of Zoology. Since January she has been studying the interactions between the brain and the spinal cord that produce swimming movement in the lamprey, a primitive vertebrate (Figure 67).

Ms. Harris is examining the central pattern generator (CPG) in the spinal cord of the lamprey. She is attempting to clarify the interaction between the spinal cord and the brain. She measures the spinal cord and breathing activity when the spinal cord and brain stem are allowed to interact freely. The spinal cord and brain stem are bathed with D-glutamate, an amino acid that acts as an excitatory neurotransmitter. The D-glutamate turns on the CPG, which is distributed throughout the spinal cord. When excited, the CPG produces a stereotypical pattern of electrical activity that stimulates muscles to produce swimming in the lamprey and walking in cats and other mammals.

Figure 67. Jennifer Harris studies how the interaction between brain and spinal cord is coordinated in the lamprey in a Department of Zoology laboratory.

Ms. Harris and Dr. Cohen presented the data from some of this work at the Society for Neuroscience conference in November 1993. "I think it's very important that we have these programs to support undergraduate research," Ms. Harris said, because "there's usually a shortage of support" for undergraduate experimental research. Through the program, students can find out whether they really want a career in research, she said, and for those who do, it often opens up graduate research opportunities.

Nwamara Dike, a senior honors student in chemistry and biochemistry, is working with Dr.

Figure 68. Nwamara Dike works in a laboratory in the Department of Chemistry and Biochemistry on a research project that involves the organic synthesis of prostaglandins.

James Herndon, Associate Professor in the Department of Chemistry and Biochemistry, on a project that seeks to synthesize prostaglandins of high optical purity. Her initial objective is to study the stereochemistry of a reaction that produces a substituted cyclopentenone ring when an alkyne reacts with a chromium carbene complex. This ring system is structurally similar to that found in prostaglandins. Dr. Herndon and Ms. Dike hope to develop a general synthetic route to prostaglandins and prostaglandin derivatives used in treating cardiovascular malfunctions. Without the support, "I wouldn't be able to work in a laboratory because I'd have to be looking for other work," said Ms. Dike, who has been doing research in Dr. Herndon's lab since January (Figure 68).

Curriculum and Laboratories

The HHMI grant enabled the University of Maryland at College Park to revise three advanced undergraduate courses in biochemistry, microbiology, and cell biology in 1992–1993 and equipped the laboratories with new technology that allows undergraduate students to conduct experimental research.

Before the reorganization, students were taught one set of exercises one week and another unrelated set the next week. "Students may have learned techniques, but they didn't learn much about doing biology as an experimental science," said Dr. Higgins. He wanted the courses to provide students with exercises that all addressed one problem or a set of related problems. "So from an initial set of observations, students in these labs, just as a scientist would do, would ask questions, formulate hypotheses, design experiments, gather data, analyze the data, draw conclusions, and see where those questions lead them," Dr. Higgins said.

HHMI support allowed the University to bring in new technology to student laboratories and allowed faculty the time to redesign courses that created

research opportunities for undergraduates. "You can't involve students in biology research in a course laboratory if you don't have the technology," said Dr. Higgins. The HHMI grant "has allowed the students to work with equipment and technology that you would find in leading research laboratories."

The laboratory course in biochemistry was completely redeveloped with the intent of designing the experimental protocols as simply as possible so that students could carry out most of the procedures themselves. Dr. Sarah Woodson, of the Department of Chemistry and Biochemistry and a Pew Scholar in the biomedical sciences, wrote a new laboratory manual and instructor's manual and replaced outmoded equipment, in addition to designing new protocols and testing them with two student assistants.

The course, which consists of an hour lecture and a five-hour laboratory weekly, is centered around a semester-long investigation of the bacterial enzyme alkaline phosphatase. Dr. Woodson developed a series of laboratory exercises that lead students through the purification of the wild-type enzyme, site-specific mutagenesis, and finally the isolation and characterization of the mutated protein.

Students learn a variety of techniques commonly used in biochemistry and molecular biology, including centrifugation, nucleic acid and protein gel electrophoresis, Western blotting, DNA isolation and sequencing, and kinetic analysis of enzyme activity. Each pair of students works on a different active site mutation, fostering a sense of authorship in the results.

The new course was taught for the first time to 25 students in the spring semester. Emphasis was placed on keeping an up-to-date notebook, developing skills in designing and executing experiments, and practicing s[illegible] laboratory procedures. Students were required to write a final report of their research results in the format of a scientific journal article.

The updated microbiology course was also offered for the first time in spring 1993. Dr. Daniel Stein of the Department of Microbiology could now bring students into a fully equipped recombinant DNA laboratory that is the focus of the revised microbiology course. Dr. Stein acquired a variety of restriction enzymes and doubled the number of samples of DNA that students can treat with the enzymes. Before, students worked in groups of four. Now there are enough samples to allow students to work in pairs or individually. Forty-four students work in 20 labs mapping plasmids with restriction digestions and doing site-directed mutagenesis using exonuclease III,

Southern blots, and DNA cloning experiments.

Other basic equipment includes micropipettes and electrophoresis apparatus so that students no longer have to wait in line to use equipment. A new student laboratory manual was written for the spring and will be revised again for the fall. Before, it contained only brief descriptions of experiments students would do. Now it has doubled in length, with the addition of several pages preceding each experiment that explain the theory behind the experiment and why it is important. For example, Dr. Stein explains how enzymes work and how to analyze data.

A revised cell biology course is now offered every semester. Before the course modifications, cell biology was available only every two to three semesters. In the new course, open to juniors and seniors, students rotate through four stations in the laboratory, learning a different technology at each station.

As the last segment of the course, students are allowed to choose from a variety of problems they can address, using technologies from two or more stations. The students work independently on these projects.

Institutional Profile	
Total Enrollment	34,623
Undergraduate Enrollment	25,361
Number of Faculty Members	2,504
Endowment (in millions)	$50
Annual Budget (in millions)	$574

University of Michigan–Ann Arbor

Program Director
Robert A. Bender, Ph.D.
Professor of Biology
3033 Natural Science Building
University of Michigan–Ann Arbor
Ann Arbor, MI 48109-1048
(313) 763-4681
(313) 747-0884 (fax)
Robert_Bender@um.cc.umich.edu (Bitnet)

The University of Michigan–Ann Arbor is a public research institution. In 1992 the Howard Hughes Medical Institute awarded the University $1,400,000 for support of a program to (1) attract and retain students early in their academic careers by providing summer and academic-year laboratory research experiences in the biomedical sciences to first- and second-year undergraduates as well as enhanced advising and tutoring; (2) provide upper-division biology students with in-depth research experience through a new "project laboratory" course offering open-ended investigations in genetics and molecular biology; (3) enhance the use of computer technology in science education for use in student tutorials and other purposes; and (4) upgrade equipment for instructional laboratories in such fields as microbiology, developmental biology, and physiology, and establish a new course in neuroscience for nonscientists.

Student Research and Broadening Access

Craig Johnson was one of 59 students whose research was supported by the HHMI grant in 1992–1993 at the University of Michigan–Ann Arbor. The program places freshmen and sophomores in paid student research partnerships with faculty. As a freshman, Mr. Johnson worked in the laboratory of Dr. Benedict Lucchesi in the medical school's Department of Pharmacology on a new drug to reintroduce oxygen to the heart after a heart attack. "It gave me a lot of experience with research," Mr. Johnson said. And the experience matched his career goal, to get a degree in pharmacy and do drug research (Figure 69).

"The object is to get students involved in a research university from their first semester until the day they leave," said Dr. Michael M. Martin, Associate Dean and HHMI program director. "Students come in overwhelmed by lectures and by the transition from high school to university. [Through the research program] they get placed in laboratories and become involved in the enterprise of a research university. They turn into college students very, very quickly."

Under the program, students receive a stipend for a lab internship during the academic year, and the host lab receives an allowance for supplies for the student. In the summer of 1993, 24 students were working in labs, with support from the HHMI grant.

"The goal of our program is to improve the retention and academic performance, particularly of minority students and women," said Sandra Gregerman, program director of the Undergraduate Research Opportunities Program.

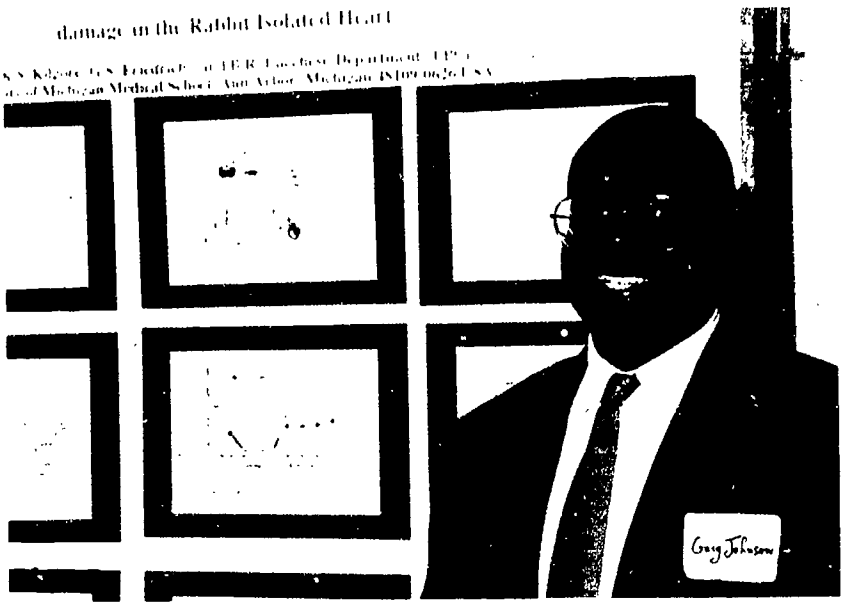

Figure 69. Craig Johnson, an undergraduate at the University of Michigan, presents the results of his research project in a poster session in spring 1993.

"Our goal is to keep them on a track in science and hopefully pursue advanced science degrees."

Initially, she said, some faculty hesitated to take freshmen and sophomores into their research laboratories. But after having the young students in their labs, there is "tremendous faculty support for the program," she said.

Several student participants explained why the program was important to them.

■ Jennifer Phan, a junior premed student, is working in the laboratory of Dr. Matt Kluger in the Department of Physiology, investigating interleukin-6 production in the central nervous system in response to injection of lipopolysaccharides in rats. "Through research, I have not only learned new techniques specific to my project, I've been able to apply my own knowledge and, most importantly, critical thinking to solve problems and hypothesize outcomes of experiments," Ms. Phan said. "I've gained a way of thinking that can't be taught in textbooks and have learned to deal with complications that randomly arise."

■ As a sophomore Kara Bucci, majoring in biomedical sciences, began working in the lab of Dr. Oveta Fuller in the Microbiology and Immunology Department last September and worked through summer 1993. She was trying to determine how HSV-1, a herpes simplex virus, gets into a cell. "I really wanted to do research, but I didn't know how to get into it" before entering the undergraduate research program, she said. "I couldn't have afforded to do volunteer research."

Students select a project that interests them from a book describing ongoing faculty research projects and are interviewed by the faculty member

in whose laboratory they are interested.

The students are also assigned a peer adviser and placed in peer groups of 20 student researchers. The peer advisers are juniors and seniors who have themselves experienced the undergraduate research program and who serve as leaders of the research peer groups. Last year the HHMI grant supported five biomedical groups, three women-in-science groups, and two physical science/engineering groups.

In addition to the 59 science students who received HHMI stipends, about 123 other freshman and sophomore science students benefited indirectly from the Institute grant, Ms. Gregerman said. They also worked in labs doing research in biology, biomedical research, physics, and chemistry. Some received a stipend from other sources, and some received three hours of academic credit per semester. All participated in the Institute-supported peer adviser and peer research group portions of the program.

The students worked on a research project, kept a weekly journal on their research experience, met monthly with their peer adviser, and attended a monthly peer research group meeting.

At the group meetings, students listened to a reading or watched a video on issues such as use and misuse of scientific data and use of animals in research, then held discussions on the topics. Students also heard presentations by graduate students and researchers. Some students made small presentations to the group on their research. In 1993–1994 the student groups will meet twice a month.

The program is advertised through a mailing to all incoming freshmen and sophomores. Underrepresented minority students are recruited through programs on campus and through counselors. There were 33 African Americans, 10 Hispanics, and 1 Native American among the 59 HHMI-supported students in the program in 1992.

The University also recruited eight students from nearby Washtenaw Community College who will participate in research projects 6 to 10 hours a week at the University campus while still taking classes at the Community College. Objectives of this initiative are to provide community college students with exposure to university researchers, students, and faculty, and to ease their transition to a four-year institution.

In April 1993 three students supported under the HHMI grant made formal presentations on their work at a spring research symposium reception for all undergraduate research program participants and invited guests, and six others made poster presentations. Two students, Terry Lie and Lynda Mankowiec, investigated whether mast cells, a connective tissue

cell whose functions are unclear, are involved in the development of fibroid tissue in the lungs when the anti-cancer agent bleomycin is administered. They found that mast cells appear not to play an important role in producing fibrosis, as previously thought. Cary Hsu studied the effects of halothane, an anesthetic that is inhaled, on the recovery of pulmonary artery rings from oxidant injury. His project was part of a larger investigation exploring how anesthetics affect the process of inflammation during surgery and patient recovery. A research project conducted by Alysia Green focused on the effectiveness of clofilium on inhibiting heart fibrillations. Few drugs are effective in preventing heart attacks in humans, but clofilium has been found to protect rabbit hearts.

Of 1,148 applicants, 327 were assigned to participate in the undergraduate research program in 1992–1993. Another 330 applicants who did not make the random selection into the program are being used as a control group in a study that will follow both sets of students for five years to see if the program really does improve student retention and academic performance in the sciences.

Institutional Profile

Total Enrollment	36,228
Undergraduate Enrollment	23,126
Number of Faculty Members	4,003
Endowment (in millions)	$486
Annual Budget (in millions)	$1,800

University of Nevada, Reno

Program Director
Robert W. Mead, Ph.D.
Associate Dean
College of Arts and Sciences
University of Nevada, Reno
Reno, NV 89557-0008
(702) 784-6155
(702) 784-1468 (fax)

The University of Nevada, Reno is a public doctorate-granting institution. In 1992 the Howard Hughes Medical Institute awarded the University $1,100,000 in support of a program to (1) provide undergraduates and high school students with collaborative research experiences during the summer in faculty laboratories, supplemented by seminars and academic and career counseling; (2) offer summer short courses for elementary and secondary teachers to update their knowledge of biology and related disciplines, and enhance the scientific content and laboratory activities in courses for prospective science teachers in the College of Education; (3) involve science and mathematics faculty members in undergraduate education and enrich their teaching skills; and (4) strengthen laboratory and classroom teaching in introductory, intermediate, and upper-division courses in biology and biochemistry.

Student Research and Broadening Access

Through the HHMI grant, the University of Nevada, Reno provides summer laboratory opportunities for undergraduates. This 10-week program, starting in the summer of 1993, enabled four students, all female or minorities, to undertake their own research project. In addition to research, the program offers orientation, weekly breakfast meetings, and scientific seminars.

Rhonda Monroe is an undergraduate at the University whose summer research project was undertaken in the laboratory of Dr. Gary Blomquist, Professor of Biochemistry. Ms. Monroe is studying insect nutrition and the role of linoleic acid in the diet. Studies have found that some—but not all—insects, unlike humans, synthesize this fatty acid. Because plants are an excellent dietary source of linoleic acid, her project examines whether insects whose diet is not rich in plant matter are more likely to synthesize linoleic acid. She is studying such insects as the Mormon cricket, the praying mantis, and the bark beetle, which have variable diets that are not exclusively reliant on plant material. To determine whether these insects synthesize linoleic acid, she is using injections of ^{14}C-acetic acid, a precursor in linoleic acid synthesis, along with high-performance liquid chromatography. Ms. Monroe said, "I have to figure out ways to perfect the procedure, which involves a lot of problem solving. It took me some time to perfect my extraction of lipids to see if they contained the isotope." She plans to incorporate

Figure 70. Claire Hettinger, a University of Nevada, Reno undergraduate, and Erica Westcott (*foreground*) a participant in the University's high school outreach program, examine samples for their research project.

her research into her senior thesis and embark on graduate training.

Another student, Claire Hettinger, was thinking about dropping biology as a major until she became an undergraduate trainee in the summer of 1993. "Tutoring mathematics has given me a tremendous amount of self confidence and I really like my summer lab experience," she said. "I know now that I am going to stay active in the lab for the next 3 years and that biology is what I want to do" (Figure 70).

The Undergraduate Trainees Program transforms undergraduates into mathematics tutors for nearby middle school children. Starting in the summer of 1993, seven freshmen and sophomores (all underrepresented minorities or females) who are interested in science, but who lack confidence in their mathematics abilities, receive seven weeks of training, with stipend and room and board provided by the HHMI grant. One half of each day's training takes place in a faculty laboratory where students engage in scientific research, and the other half of the day is devoted to either math instruction, tutor training, or other skills to improve their understanding of mathematical applications in science. After demonstrating proficiency in math and tutoring, these undergraduates are placed as tutors in a minority middle school in Reno.

This program is based on the premise that weakness in mathematics can be overcome and self-esteem can be nurtured by helping others who are at risk. Karen Alum, who coordinates the tutor training component of the program, views the experience for students as one of "understanding that they can be empowered to learn and that

they can empower other students." For the middle school student, the expectation is "for them to see that anyone can do math, especially people just a few years older," according to Dr. Robert Mead, Associate Dean of the College of Arts and Sciences and program director.

Curriculum and Laboratories

Curricular and laboratory changes have been a high priority at the University of Nevada, Reno since the inception of the Institute grant in 1992. Three advanced laboratory courses in molecular biology and biochemistry have been fundamentally revised or created as a result of laboratory equipment purchases. One of the transformations has occurred in an advanced laboratory course, Molecular Biology Techniques, given by Dr. Alice DeLisle, Assistant Professor of Biochemistry. The course has more workstations containing new electrophoresis equipment, micropipettes, and microcentrifuges, as well as more equipment serving the entire laboratory, such as spectrophotometers, gel dryers, and fluorometers.

The laboratory concentrates on hands-on molecular biology by training students in the growth and maintenance of bacteria and phage, preparation of DNA, subcloning of DNA fragments into plasmids, enzymatic analysis and manipulation of DNA, and sequencing of DNA using a computer program. Dr. DeLisle commented that "without the equipment, we simply could not have taught this course. The students became proficient at basic molecular biology techniques that they need to continue in a scientific career" (Figure 71).

Another new course, an introductory biology laboratory, was created after faculty members attended a conference on teaching introductory biology. With HHMI support, two biology faculty traveled to the Marine Biological Laboratory in February of 1993 to participate in the Coalition in Education for the Life Sciences conference. As a result of the conference, concepts such as hypothesis testing, experimental design, data analysis, and the use of scientific equipment have become an intrinsic part of the design of the new introductory biology course available to students in the 1993–1994 academic year.

Faculty Development

Integrating mathematics more thoroughly into the core curriculum, including the life sciences curriculum, was the driving force behind the hiring of a new Director of the University's

Figure 71. Students in the molecular biology laboratory (*from left*): William Thompson, John Bottorff, and Reiko Tomosugi.

Mathematics Center. With salary support from the HHMI grant, Dr. Jerry Johnson has the responsibility for implementing a new initiative, Mathematics Across the Curriculum. The program is patterned after the University's previous initiative, Writing Across the Curriculum, and is expected to lead to changes in at least 10 courses. With the goal of improving mathematics and problem-solving skills, Dr. Johnson plans to assist faculty in formal workshops and in informal settings to develop fresh approaches to, and new emphasis on, mathematics training. The first wave of changes is expected to come in the fall of 1993 when a physics and a calculus instructor are scheduled to take each other's classes and share their experiences in a faculty workshop organized by Dr. Johnson. Two biology courses—Biology for Non-Majors and Organismal Biology—are slated for curricular enhancements as well.

Precollege and Outreach

The HHMI grant has enabled the University of Nevada, Reno to create a summer research program designed to ease the transition from high school to college. High school students from far-off urban and rural areas within the state, especially underrepresented minority groups from the Las Vegas area and from remote Nevada counties, can join local Reno secondary students during this 10-week program in which they are placed in faculty laboratories.

One participant is Paul Park, who is working on the mechanism of action of captan, a fungicide. He is measuring the effects of captan on the activity of carboxylesterases, a group of intracellular enzymes involved in several cellular functions, using both *in vitro* and *in vivo* techniques. After working during the summer of 1993 in the laboratory of Dr. William Welsh, Mr. Park said, "I have been accepted to the University of Pennsylvania, where I plan to study biochemistry and eventually become a general practitioner."

Another participant in the program was Madeleine Cabrera, who said that her initial plans after graduating from high school were "to start out just taking a couple of courses in a community college and then see what happens." Ms. Cabrera noted, "The Howard Hughes trainee experience made me decide instead to enter the University as a biology major." Her research project concerned pattern formation during planarian regeneration (Figure 72).

High school minority students can also benefit from the High School Minority Scholars Program, a summer program providing prospective premedical students with background information on medical school. Lectures, tours, and interaction with medical students and faculty are designed to familiarize high school students with the medical school experience. The summer of 1993 marked the beginning of this program, in which student stipends, room, and board are funded by the Institute grant.

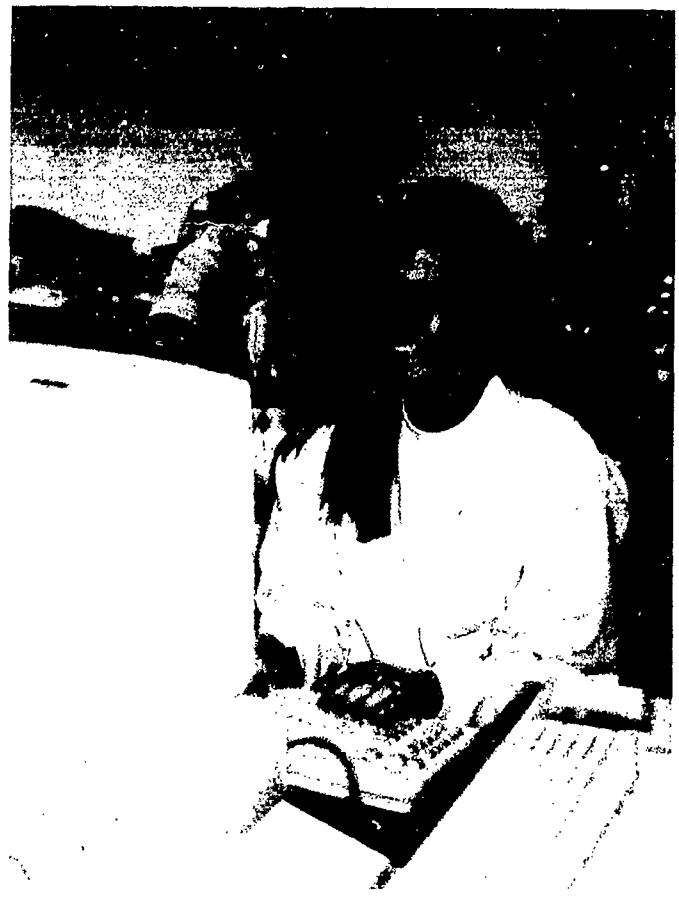

Figure 72. Madeleine Cabrera (*right*), a high school student, with Jenifer Reaves, an undergraduate, conducting research on pattern formation during planarian regeneration.

Other outreach efforts are directed to area high school teachers. Spring and summer workshops aid science teachers in designing new experiments for their classrooms and in using computers. The summer program is a formal three-week program for 15 teachers, whose stipends are supported by the HHMI grant. During the summer of 1993, the teachers gained

experience with a variety of approaches, including a software program that illustrates environmental transport and toxicology. With this program, their students can study the roles of such industrial metals as mercury and copper and their impact on environmental systems.

Institutional Profile	
Total Enrollment	8,665
Undergraduate Enrollment	6,995
Number of Faculty Members	729
Endowment (in millions)	$21
Annual Budget (in millions)	3138

University of Notre Dame

Program Director
John G. Duman, Ph.D.
Associate Dean
College of Science
Professor of
Biological Sciences
University of Notre Dame
Notre Dame, IN 46556
(219) 631-5495
(219) 631-7413 (fax)

The University of Notre Dame is a private doctorate-granting institution in Notre Dame, Indiana. In 1992 the Howard Hughes Medical Institute awarded the University $1,500,000 to support (1) integration of the fields of cell, molecular, and developmental biology, genetics, physiology, and other areas of biology with organic and physical chemistry and biochemistry, in a new interdisciplinary curriculum, with development of a laboratory for the new program; (2) expansion of undergraduate research opportunities, to emphasize interdisciplinary approaches; (3) new faculty appointments to implement the interdisciplinary curriculum; and (4) opportunities for biology teachers from urban high schools to earn academic credit and stipends by participating in laboratory research and developing experiments and demonstrations for classroom use.

Student Research and Broadening Access

The Hughes grant supports summer research opportunities for about 20 undergraduates, especially women and minorities, from the University and from four universities with predominantly minority populations: Xavier University of Louisiana in New Orleans and Clark Atlanta (Georgia), which are historically black, and St. Mary's of San Antonio and St. Edward's in Austin, which have large Hispanic populations. In 1993, its first year, 16 of the 22 participants were women.

The 10-week program provides a stipend and matches students and faculty with similar research interests. After two weeks of introductory training, students begin their own research projects, which in 1993 included such topics as the role of a novel gene in pattern formation in *Drosophila*, cloning of ovulation-specific cDNAs, and molecular characterization of the *retinal degeneration-B* gene of *Drosophila*.

Wendy Chan, a biology major entering her junior year at St. Mary's, worked on the project with the *rdgB* gene, which is involved with the degeneration of photoreceptors in *Drosophila*, during the summer at Notre Dame. The program gave her a chance to take "a step into the research field to see what it was like," an opportunity she would not otherwise have had.

Curriculum and Laboratories

Four new courses in the biological sciences comprise the heart of the HHMI-supported program at the University of Notre Dame to stimulate more student interest in biomedical research and careers in related fields.

The new courses are designed specifically for biology and biochemistry majors. Previously, these students had to take courses more oriented toward premed students.

"The [new] courses are geared toward the needs of somebody who is looking to go on to graduate school," said Dr. John Duman, Associate Dean of Biological Sciences and HHMI program director. "That's really the gist of the whole thing."

In 1992–1993 the University offered two of the new courses, Cell Biology and Genetics, for the first time. Although initially planned as pilot projects of 30 students, the courses were expanded to 45 students the first year when the Biological Sciences Department recommended that biology majors take these courses rather than the premed-oriented courses. In 1993–1994, enrollment in the new courses will be expanded to 60 students.

The third course, Bio-organic Chemistry, replaces organic chemistry for biology and biochemistry majors. The new two-semester course was also planned as a 30-student pilot project but will enroll about 100 students when it debuts in fall 1993. The fourth new course, Physiology, will be offered for the first time in 1994–1995.

The new cell biology and genetics courses contain much more molecular biology than did previous offerings. In addition, subject material has been coordinated between the two, and overlapping instruction has been minimized. Both are intended for sophomores. Cell Biology covers membrane structure and transport, cell adhesion, ATP formation, organelle biogenesis, cell signaling, and other topics. Genetics includes foundations of classical genetics, the molecular basis of classical genetics, recombination, chromosome theory, and other subjects.

The new course in bio-organic chemistry provides an alternative to traditional organic chemistry, which emphasizes benzene chemistry and similar material but "doesn't quite pique the fantasy of the average biology student," Dr. Duman said. The new sophomore-level course will teach the organic principles that biology majors need to know but will, where possible, include biologically important molecules. Most biology majors now take the new bio-organic course.

The new physiology course is aimed at juniors who have taken the other three new courses. It is being developed over 1993–1994 and will incorporate more molecular biology and biochemistry.

The HHMI grant is funding new equipment for laboratories to complement three of the new

courses. Laboratories were set up in summer 1993 for Cell Biology and Genetics, and another laboratory will be established later for Physiology. Instruction will be coordinated among the laboratories, and more useful laboratory techniques will be taught.

"Most undergraduate laboratories use antiquated kinds of techniques and procedures that illustrate interesting kinds of phenomena," Dr. Duman explained. The new laboratories will teach "the sort of thing a student who is going on to graduate school or somebody who would be looking for a job would be likely to use. Spurred by the power of molecular and biochemical techniques, biology is now more interdisciplinary than ever. Thus, traditional disciplines within biology (i.e., cell biology, genetics, physiology, developmental biology, etc.) have broken down to some extent as population biologists sequence genes and physiologists use molecular and biochemical techniques to investigate cell surface hormone receptors or ion channels in membranes. In addition, a solid background in chemistry is now more important than ever. These new courses attempt to impress upon the students the relevance of chemistry to biology and the integrative nature of modern biology."

Faculty Development

The new courses and laboratories developed under the HHMI grant are being augmented by two full professors (funded partially by the grant) and a laboratory coordinator (funded totally). During 1992–1993 the University hired Dr. Alan Johnson, a specialist in avian reproductive biology and endocrinology, to fill the physiologist position. He will begin in fall 1993 and help design the new physiology course.

Laboratory coordinator Dr. Michelle Murphy, a *Drosophila* molecular biologist, was hired in May 1993 to set up the laboratories for the new cell biology and genetics courses. She will operate those laboratories during 1993–1994 and assist in developing a laboratory for the new physiology course.

Precollege and Outreach

The outreach component of the HHMI-funded program is built on the idea that precollege teachers need to know how to do research if they are going to instill a love of research in their students.

"Here are people who are in a position to turn kids on or off at an age when they may be thinking about science as a career," Dr.

Duman said. "The typical high school teacher has ... never done research, and yet they're trying to give their students some sense of what a biologist does."

The project's summer research program brings high school teachers to the campus for 10 weeks of research with faculty in the chemistry or biology department. Dr. Duman said he was particularly pleased with the high quality of the eight teachers who came to Notre Dame for the 1993 summer session.

Institutional Profile	
Total Enrollment	9,828
Undergraduate Enrollment	7,607
Number of Faculty Members	561
Endowment (in millions)	$606
Annual Budget (in millions)	$259

University of Pittsburgh Main Campus

Program Director
David R. Burgess, Ph.D.
Professor and Chair
Department of
Biological Sciences
Room A234, Langley
Hall
University of Pittsburgh
Main Campus
Pittsburgh, PA 15260
(412) 624-4350
(412) 624-4759 (fax)

The University of Pittsburgh Main Campus is a public research institution in Pittsburgh, Pennsylvania. In 1992 the Howard Hughes Medical Institute awarded the University $1,700,000 to support a program with the following components: (1) undergraduate research training and experience, to provide students with workshops on research concepts and techniques in biology, summer research in faculty laboratories, activities to broaden access to biology and related disciplines through expanded summer research opportunities for underrepresented minority students, and development of small group sections and honors laboratories in introductory biology courses; (2) development of the laboratory curriculum through equipment acquisitions, computer enhancements, and new courses in such areas as cell biology, organic chemistry, developmental biology, and neurophysiology; and (3) summer research training for Pittsburgh-area high school students, including those from underrepresented minority groups, and ongoing summer workshops for teachers.

Student Research and Broadening Access

Twelve students were selected from 151 applicants throughout the United States to participate in the first paid summer research program for undergraduates at the University of Pittsburgh in the summer of 1993.

At the end of his first week in the program, junior Kevin Messner said he had spent about 70 hours in the laboratory. "But by the end of the summer, I'll have learned more molecular biology than I ever would in a classroom," he said.

"The summer undergraduate research program was designed to provide outstanding students the opportunity to experience firsthand the real culture of science," said program director, Dr. David R. Burgess, Professor and Chair of the Department of Biological Sciences. "We want students to learn about the excitement, frustrations, rigor, and collegiality of a research career."

Each student carries out research under the direction of a faculty member who is running a laboratory. The student receives a stipend plus free room and board under the HHMI-supported program, and the host laboratory receives an allowance for supplies.

The student researchers prepare a research prospectus within the first week of arrival, keep a laboratory notebook, attend lectures, participate in journal clubs and group research meetings, and gather for planned social activities. They are housed together in dormitories.

Participants attend workshops that explain major techniques used in modern biological research such as confocal

microscopy, polymerase chain reaction, electron microscopy to visualize proteins and protein complexes, and high-powered computers.

Near the end of the program, the students will give formal research talks about their work to their peers and faculty sponsors.

University of Pittsburgh officials sent over 300 packets of materials announcing the competition for the summer program to universities and colleges nationally. "We were extremely impressed by the quality" of the applicants, said Dr. Burgess. Pittsburgh has already decided to increase the size of next summer's program to 20 undergraduates.

The students selected as the 1993 summer research undergraduates had grade point averages ranging from 3.22 to 4.01. Four were underrepresented minority participants.

Mr. Messner, a zoology and chemistry major at Miami University of Ohio, worked with Dr. James Pipas of the Department of Biological Sciences, who studies the neoplastic transformation functions of the simian virus 40 (SV40) large T-antigen, a viral oncogene product. Mr. Messner planned to study a related large T antigen from hamster polyoma virus, using high level expression from a recombinant plasmid construct, in order to determine what contribution each of the several biochemical activities of the hamster polyoma T antigen makes to the unique transforming abilities of hamster polyoma virus. The students are all excited about their work, Mr. Messner said. "Back at the dormitory, everybody gives a three-minute synopsis of what they did in the lab that day" (Figure 73).

In addition to the University of Pittsburgh, students came from such institutions as Yale, Texas A&M University, University of Rochester, Barnard, Miami University of Ohio, Grambling State University, Georgetown University, Washington University, and Oberlin College. Their majors included biology, microbiology, biochemistry and genetics, neuroscience and chemical engineering, and biochemistry and biophysics.

Curriculum and Laboratories

During the past year, the University of Pittsburgh's Department of Biological Sciences has undergone a major curriculum revision. Several changes were supported by the HHMI grant:

New lecture and laboratory courses in developmental biology allow students to work with model organisms that biologists are using extensively in research, including *C. elegans*, *Drosophila*, and *Xenopus* embryos. The laboratory was equipped with new dissecting

Figure 73. Kevin Messner working with cell lines at a tissue culture hood.

and phase contrast microscopes, a fluorescence microscope, a microscope with differential interference optics, a demonstration microscope with video camera and monitor, centrifuges and rotors, power supplies and gel apparatus for both protein and nucleic acid analysis, and many smaller items. The laboratory will be used in the spring term for developmental biology and in the fall term for cell biology. The latter course will focus on principles of cell biology, with students performing a series of experiments in one area to gain an appreciation of how cell biology is done.

A computer-learning laboratory was designed to teach small groups of up to 12 students and to be used as a resource room for individual faculty and students. The laboratory was equipped with five Macintosh computers and a graphics work station with 24-bit color graphics, including a three-dimensional visualization system. Videodisc equipment, computer software, CD-ROM database access, and an instructional videotape library will allow users of the lab to view such things as nucleic acid sequences and molecular graphics of protein and DNA structure. Students will be able to look at three-dimensional models of how peptide bonds are formed.

A freshman honors laboratory in introductory biology is designed to be a more problem-based laboratory course for 18 students chosen from the 1,000 who take the regular introductory biology course. A time-lapse video showing sequences of mitosis and development was especially valued by the students, who wrote critiques of the course. "I had never seen mito-

sis before, and when I saw the video, I realized that I was wrong about some of its finer points," said Katherine Lestock. "For example, I had always pictured anaphase as a relatively clean split down the metaphase plate. I realize now that metaphase is not necessarily as ordered as textbooks would have you believe, and in anaphase, chromatids slide past each other."

A new sophomore-level, two-semester course in organic chemistry is designed to be as rigorous as traditional organic chemistry, but it will use biological examples rather than chemical examples. It will be about chemistry occurring in living systems and will explain such topics as biological molecules, design of drugs, pesticides and herbicides, and the chemical approach to synthetic enzymes.

In summer 1992 the University selected three of its own undergraduates from the Department of Biological Sciences to pave the way for the full summer program. The students participated in a limited, exploratory Institute-supported summer program that paid each student a stipend and provided each sponsoring laboratory with an allowance for supplies.

■ Christine Mueller was involved in a project to isolate and characterize genomic clones for a novel transcription factor called GATA-4 from *Xenopus*. But her work did not end when summer did. She stayed on in the laboratory of Dr. Todd Evans to complete her research project.

■ Joseph Molitierno spent summer 1992 in the laboratory of Dr. R. Jude Samulski, participating in several projects involving the development of the defective adeno-associated virus as a vector for human gene therapy. His principal project involves construction of a herpes simplex virus derivative that can "help" the defective virus once it enters the cell. Mr. Molitierno continued working in the laboratory in 1992–1993 for academic credit and remained through summer 1993 as a paid undergraduate researcher.

■ Matthew Fetters worked in the laboratory of Dr. Pipas, where he had been working since September 1991. Mr. Fetters helped isolate and characterize clones from a cDNA library generated from intestinal crypt mRNAs. The goal was to isolate and identify mRNAs that are more abundant in crypt cells than in the terminally differentiated zone of the villus. He has characterized 10 clones that detect unique, differentially expressed mRNAs. He graduated in December 1992 with a B.S. in biochemistry and biophysics and decided to remain in Dr. Pipas's laboratory for an additional year to see his project through to publication. He then plans to pursue a Ph.D. in molecular and cellular biology.

Dr. Burgess says the Institute's support "raised the expec-

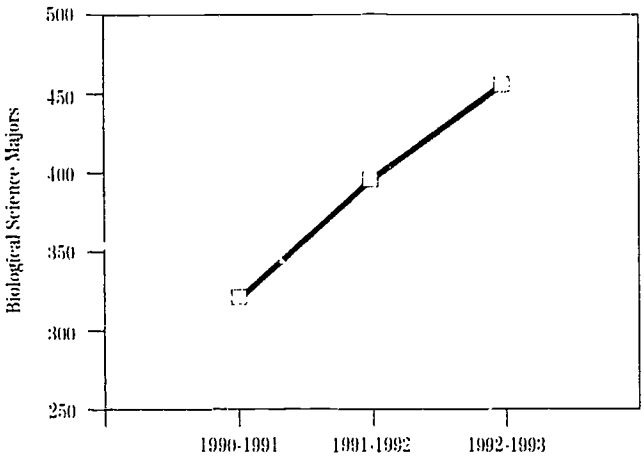

Figure 74. The number of biological science majors at the University of Pittsburgh has increased since 1990.

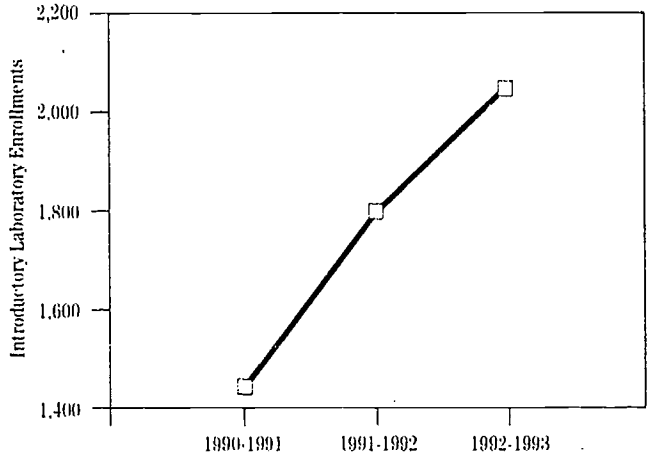

Figure 75. Enrollment in introductory biological sciences laboratories has grown by more than one-third.

tation of our students at a time when the curriculum in biological sciences underwent major revision. This change in expectation is reflected by the enthusiasm of our students for the sciences." In the past two years, the number of undergraduate majors in the Department of Biological Sciences has increased from 321 to 457, and introductory laboratory enrollment has increased from 1,450 to 2,050 (Figures 74 and 75).

Precollege and Outreach

INVESTING NOW, created in 1988, is a partnership between the University of Pittsburgh and the Pittsburgh Public Schools. Its objective is to stimulate, support, and reward high academic performance, particularly in mathematics and science, of middle school and high school students, especially those from minority groups underrepresented in the sciences. Four of its programs are supported by the Institute:

- Tutoring program: Up to 60 students who meet eligibility requirements and are interested in going on to college are tutored two to three times a week in mathematics, biology, chemistry, and physics. The Institute supports three of four tutors, including the coordinator, who work with 85 to 90 percent of the students in the program.
- Eighth grade program: From July 6 through July 31, 1992, 8th-grade students who were accepted into the INVESTING NOW program attended a special summer school at the Pittsburgh campus, designed to acquaint them with the laboratory, science, and math skills they would need in the academic/gifted programs in the Pittsburgh city schools. In 1992 Institute support provided the laboratory facility, equipment, and supplies for the program, and in 1993 it

also provided support for one of two instructors.

■ Summer fellowships for two high school students: Two incoming seniors, Erin Ford and Rasheed Clark, were selected from 14 applicants to work in laboratories in the Department of Biological Sciences for six weeks in summer 1993. The students received a stipend, and the sponsoring laboratory received an allowance for supplies. These students participated in the program activities of the undergraduate summer research fellows.

■ Workshop for teachers: In summer 1993, 30 high school science teachers attended workshops at the University. Fifteen participated in the workshop on DNA Techniques and the other 15 participated in an Environmental Science workshop held at the university's ecology field station. The workshops emphasized hands-on research and field experiences, and offered lectures by University faculty. Participating teachers received either a stipend or graduate credit in the biological sciences from the University.

Institutional Profile	
Total Enrollment	26,593
Undergraduate Enrollment	18,475
Number of Faculty Members	2,310
Endowment (in millions)	$296
Annual Budget (in millions)	$690

University of Texas at San Antonio

Program Director
Andrew O. Martinez, Ph.D.
Associate Professor of Life Sciences
University of Texas at San Antonio
6900 Loop 1604 N.W.
San Antonio, TX 78249
(210) 691-4184
(210) 691-5765 (fax)

The University of Texas at San Antonio is a public comprehensive institution. In 1991 the Howard Hughes Medical Institute awarded the University $650,000 for a program to (1) broaden access to the sciences for students, particularly Hispanics and other students underrepresented in the sciences, by providing laboratory training and research experiences, especially for freshmen and sophomores; (2) expand the biology curriculum to include laboratory courses in molecular biology and genetics and equip teaching laboratories for the new courses; (3) support the addition of new faculty members to assist in the implementation of the new curricula; and (4) establish linkages in the sciences with regional community colleges and increase student access to college-level science programs.

Student Research and Broadening Access

At the University of Texas at San Antonio, Hispanics make up 30 percent of the student population. In its student research and broadening access component, the HHMI-funded program focuses primarily on Hispanics as well as other underrepresented minorities and women through its undergraduate research training program in biology.

"The most significant aspect of the program so far has been... the success that we have had in recruiting the targeted students," said Dr. Andrew Martinez, Associate Professor of Life Sciences and HHMI program director. In 1991–1992 all five HHMI-funded participants were women, including one Hispanic and one black. In 1992–1993, six of seven students were women: five Hispanics and one black.

According to Dr. Martinez, the program's success among Hispanic women is particularly significant. "For Hispanics, the women are the most difficult group to attract to the sciences," Dr. Martinez explained. Traditional Hispanic culture encourages women to stay at home to care for the family, he said. As a result, many Hispanic parents may be reluctant to let their daughters attend college.

The research training program focuses on freshmen and sophomores in the life sciences. "It's during the first two years of the major that we lose many of the talented, promising minority students," Dr. Martinez said. "We are trying to make the first two years more exciting, more interesting to them by having them participate in research activities with the faculty."

Participants receive a stipend for two years and the opportunity to work part-time in a faculty laboratory during the academic

Figure 76. Cynthia DeLeon adjusts a digital oscilloscope in preparation for the intracellular labeling of hippocampal dentate granule cells with horseradish peroxidase. From these labeled cells, three-dimensional models of the labeled neurons are made and incorporated into computer models of the hippocampus.

year and full-time in the summer. The students are encouraged to enter one of the advanced research programs on campus, in particular the Minority Biomedical Research Support (MBRS) or the Minority Access to Research Careers (MARC) program funded by the National Institutes of Health.

Cynthia DeLeon, a Hispanic, entered the HHMI program as a sophomore in fall 1992 and the MARC program in summer 1993. In the HHMI program, she investigated changes in the homeostasis of calcium in brain cells in connection with research on aging and Alzheimer's disease being conducted in the laboratory of Dr. James Chambers, Professor of Life Sciences. Ms. DeLeon was involved in the partial characterization of a Ca^{2+}-independent, Mg^{2+}-dependent ATPase from PC12 cells grown in the presence of nerve growth factor. The specific activity of the enzyme was found to increase significantly following administration of the growth factor. Ms. DeLeon is a co-author on a forthcoming paper on the topic.

"We were guided by Dr. Chambers," she explained. "But we did the actual experiments and got the data." The work in Dr. Chambers's laboratory was interesting and exciting and pointed her toward biomedical research, Ms. DeLeon said. "It was probably the best thing that's happened to me. It's what really steered me into what I wanted to do" (Figure 76).

Chajuann Chambers, an African American participant in 1991–1992, perhaps best represents the type of student the program is trying to reach, Dr. Martinez said. Ms. Chambers was initially in danger of dropping out of the University. But she raised her grade point average during the academic year

and during the summer participated in research training with Dr. Brenda Claiborne, Associate Professor of Life Sciences, on a project involving the study of functional changes during the structural development of granule neurons in the hippocampal region of the brain.

Four 1992–1993 participants will continue for a second year, and three are expected to advance to other research programs. It is expected that six more students will be brought into the program in fall 1993.

Curriculum and Laboratories

The HHMI-funded program also seeks to attract and retain promising students in the biological sciences by supporting the development of more challenging and stimulating laboratory courses. The program calls for redesigning and reequipping two existing laboratory courses, Introductory Biology and General Genetics, to provide an exciting, hands-on laboratory experience.

Introductory Biology Laboratory is for freshmen interested in the life sciences, biotechnology, or allied health professions and enrolls about 400 students per year. During 1992–1993, the curriculum was totally rewritten. The new laboratory emphasizes practical biological experimentation—what biologists do—and provides students with a laboratory experience of biological principles. For example, students will run gels to solve forensic problems involving blood samples and develop an analogue of human digestion by investigating how factors such as pH affect the digestion of pork rind by pepsin. The new laboratory was offered in fall 1993.

The general genetics laboratory course for sophomores has also been restructured to incorporate more hands-on teaching, particularly in recombinant DNA technology. The course serves about 240 students each year. It is the entry to the advanced core curriculum and is required of all biology majors. In summer 1992 Dr. Martinez attended the week-long, HHMI-funded Workshop in Recombinant DNA Technology, operated since 1990 by the University of Chicago, to gather updated information for the new laboratory course. Laboratory sessions will involve, for example, experiments with plasmid DNA transformation, restriction digestion and gel electrophoresis, Southern blotting, and nick translation. The course will be offered in fall 1993.

The HHMI-funded program, though aimed at undergraduates, also contributed indirectly to the implementation of a biology Ph.D. program, the first at the San Antonio campus, in 1992–1993, Dr. Martinez said. The new program provides training in neurobiology, particularly for students from minori-

ty groups underrepresented in the sciences.

Faculty Development

The HHMI grant is helping to expand training in molecular biology and biotechnology at the University by partially supporting three new faculty in the Division of Life Sciences. Their addition to the faculty will give students a current, broader education in these areas and will provide more research training opportunities for undergraduates.

The new faculty were recruited during 1992–1993, and Institute funding will be used to help set up and equip their research laboratories. Dr. Aaron Cassill, a molecular geneticist, and Dr. Luis Haro, a Hispanic molecular endocrinologist, began in fall 1993. The third appointment is pending.

The new faculty will enhance and expand undergraduate education in emerging areas of biology and biotechnology. Dr. Cassill, who earned a bachelor's degree in biology at Harvard University and a Ph.D. in biology at the University of California–San Diego, was most recently a postdoctoral fellow in the laboratory of Dr. Charles Zuker at the latter institution. Dr. Haro earned a bachelor's degree in biology at the University of California–San Diego and a Ph.D. in biochemical endocrinology at the University of California–Santa Cruz; he was most recently an assistant member of the Lutcher Brown Department of Biochemistry at the Whittier Institute for Diabetes and Endocrinology in La Jolla.

Precollege and Outreach

The outreach component of the HHMI-funded program encourages students, particularly from underrepresented minorities, at San Antonio's three community colleges to transfer to the University for the last two years of their bachelor's degree. The program offers them 10 weeks of summer research and a stipend, as well as the opportunity to continue at the University on the HHMI undergraduate research program or another research training program.

In 1993 the outreach program recruited three Hispanic students from Palo Alto Community College in San Antonio. All three conducted research in neurobiology laboratories and plan to transfer to the University in fall 1993. Joel DeLeon and Rebecca Rizo worked with Dr. Clyde Phelix, Assistant Professor of Life Sciences, and Michael Gutierrez with Dr. David [illegible]enseman, Associate Professor of [illegible]e Sciences (Figure 77).

Joel DeLeon investigated a role of the transcription factor c-Fos associated with memory formation in the rat brain. "This transcription factor is believed to be associated with long-term

Figure 77. Michael Gutierrez analyzes high-speed neural activity recorded from 464 regions of the rat olfactory bulb, using an advanced 64-bit UNIX color graphics workstation. He is developing new programs to visualize how the vertebrate brain processes sensory information.

potentiation, which is equivalent to memory," he explained. "I'm trying to figure out what c-Fos does in the brain and whether it's found in certain portions of the brain with certain stimulations." During surgery, the rat brain is stimulated in various places by chemicals, electricity, or other means. The brain sections are microscopically examined for c-Fos revealed by the use of an anti–c-Fos antibody.

"It's interesting to study various kinds of chemicals and transcription factors and see what they do in different portions of the brain ... what they might cause," said Mr. DeLeon, who is contemplating medicine and research as possible career choices.

Information about the HHMI-funded program is passed along by Institute-funded students. Cynthia DeLeon, for example, explained the program to students at a predominantly Hispanic high school while presenting her research there. "Some people wanted to come into a lab and observe," she said. "They were really interested in it. So we made sure to stress that [the program] was an option when they go to college."

Institutional Profile

Total Enrollment	16,157
Undergraduate Enrollment	14,003
Number of Faculty Members	290
Endowment (in millions)	$5
Annual Budget (in millions)	$39

Washington State University

Program Director
John L. Paznokas, Ph.D.
Associate Professor and Chair, Program in Biology
Assistant Dean, Division of Sciences
Washington State University
Pullman, WA 99164-3140
(509) 335-8649
(509) 335-3517 (fax)

Washington State University is a public research institution in Pullman, Washington. In 1992 the Howard Hughes Medical Institute awarded the University $1,500,000 to support (1) summer and academic-year research experiences for undergraduates in faculty laboratories, with opportunities for students to present their research at University colloquia; (2) a program to provide middle and high school teachers with equipment and supplies to enable them to carry out experiments, demonstrations, and exercises in modern biology in their classrooms, supplementing training they receive at the University, and to provide an electronic "bulletin board" to communicate new teaching and scientific techniques and other information to the teachers; and (3) laboratory experiences, classroom training, demonstrations, and other activities to attract students in Washington middle and high schools to biology and related fields.

Student Research and Broadening Access

At the University level, the HHMI-supported program at Washington State University encourages students to remain in the biological sciences through an undergraduate research program. Students conduct research in faculty laboratories throughout the academic year and in the summer, presenting their work at a spring research colloquium. The program, which began in 1992–1993, provides stipends to 24 research students during the academic year and 10 over the summer. All students are provided an allowance for laboratory materials.

According to Dr. John Paznokas, Biology Department Chair and HHMI program director, the laboratory allotment has proved important because faculty sometimes cannot provide support for research materials for undergraduates. "The allotments allowed the students to step up a level in experimentation and this approach has started to pay off," he added.

Of 24 students supported in 1992–1993, 17 graduated, 6 will return to the University in the fall, and 1 transferred to another major. Of the 17 graduates, 10 will enroll in graduate programs, 2 will attend medical school, and 5 will work in science-related jobs, intending to go on to medicine or graduate work later. At least one publication is coming out of the 1992–1993 effort, "and that's only the tip of the iceberg," Dr. Paznokas said. "Things are starting to happen as these students work through the labs and build up some results."

Allen Campbell, a senior biology major, worked in the laboratory of Dr. Pam Soltis,

Associate Professor of Botany, attempting to sequence DNA from 20-million-year-old plant compression fossils, which contain material from ancient plants or animals. "Not only is this exciting from the standpoint of being involved in actual research," Mr. Campbell said, "but also it is an active area of research that has implications in the areas of molecular systematics and evolution."

Anja Stauber, a senior microbiology major, did her first independent research, on the toxicity of carbon tetrachloride in the drinking water of mice, under the mentorship of Dr. Richard Bull. "Results obtained so far are encouraging," Ms. Stauber said. "The data show a relationship between an increased dose of carbon tetrachloride and a higher rate of cell proliferation in the liver." In future studies they hope to relate the cell proliferation induced by carbon tetrachloride with the development of cancer.

The program sponsors a spring colloquium where the participants present their research in poster form and explain their work to visitors. The colloquium forces students to bring their work to closure and gives them an opportunity to present it formally. The first colloquium was held in April 1993 for HHMI-supported students. In 1994 the colloquium will be opened to other undergraduate researchers at the University and other institutions in the region (Figure 78).

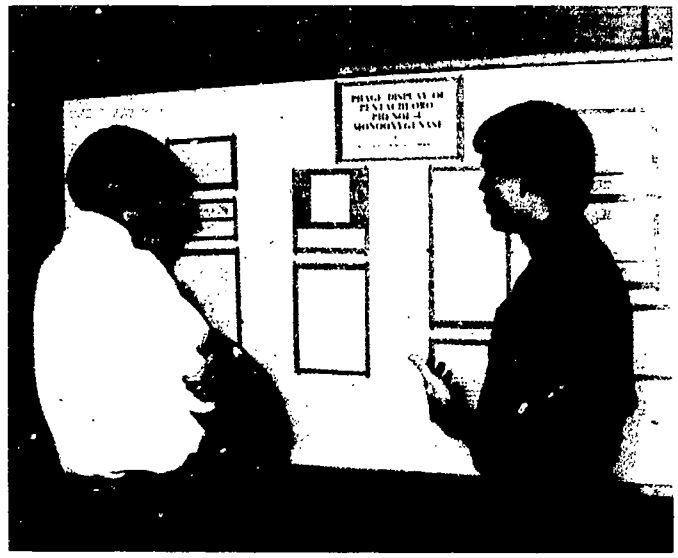

Figure 78. During the spring colloquium, Doug Davies (*right*), a biochemistry major, explains his research project to Dr. Ron Brosemer, Associate Dean, College of Sciences.

"These students will now have the incentive of presenting their work in a public forum," Dr. Paznokas said. "It's an opportunity for faculty to evaluate them as potential graduate students."

Besides its major student development programs, the HHMI-supported program is planning sponsorship in fall 1994 of a prefreshman summer camp for students from minorities underrepresented in the sciences. Students would arrive at the University before classes begin and attend a series of activities and workshops to introduce them to the campus, provide training on note-taking and studying, and help them

establish networks and support groups on campus.

Precollege and Outreach

Outreach to middle and high schools is the starting point for an array of HHMI-funded programs designed to attract students and nurture them through an undergraduate career in biological sciences at Washington State University. These programs aim to build enough scientific interest and excitement in students to propel them into the biological sciences at the University, where other HHMI-funded programs help them toward graduate studies or careers in the field.

"I'm attempting to reach the continuum, to keep the students interested in thinking about science, beginning certainly in middle school, through high school, through college," said Dr. Paznokas. "These programs tend to do that."

The major outreach efforts include an equipment loan program and an electronic bulletin board for teachers as well as three summer camps for high school students: one with a medical focus, and two with a science focus, one of these especially for Native Americans.

Equipment Loan Program. This program lends electrophoresis setups, spectrophotometers, video cameras, and other expensive equipment to schools that cannot afford to buy or maintain their own. The program began in late 1992. During 1992–1993 about a dozen schools borrowed equipment, which was used by an estimated 1,500 middle school, high school, and college students. The number of loans is expected to double in 1993–1994. Equipment is shipped to a school for about a month and returned to the University for maintenance and relending. A piece of equipment can be loaned to six or seven schools over an academic year.

Keith Olive, a middle school science teacher in Yakima, borrowed a digital stage micrometer so his students could measure growth bands in the submillimeter range on freshwater mussels. The measurements were part of a project to monitor water quality in the Yakima River, using growth patterns of the mussels. Howard Waterman, a high school biology teacher in Spokane, borrowed a complete DNA electrophoresis kit—gel boxes, power supplies, micropipettes, microfuge, light box, and consumables such as pipette tips and centrifuge

tubes—so that his 10th graders could do DNA fingerprints, digests, and examinations.

"When I brought that equipment in to my students, their level of excitement was [so high that] my problem then became to calm them down so they would listen more carefully," Mr. Waterman recalled. "But I would rather have that problem than trying to wake them up."

The sophistication of the technique plus the fact that the equipment came from Washington State University created a sense of importance among the students. "They really felt like university people," Mr. Waterman said. "The whole exercise took on an aura of considerably greater expertise than just the kinds of things they'd been doing all year in the regular sophomore biology class."

Probably fewer than 1 out of 10,000 high school students across the country have the opportunity to do electrophoresis experiments, said Mr. Waterman, a board member of the Washington State Science Teachers Association. Most students do not understand the workings of a modern technology that they read and hear about almost daily.

"Every state, every school knows that it needs to upgrade science education," he said. "What we're doing is not keeping up with what's happening worldwide." For many school districts, especially the smaller ones in predominantly rural states like Washington, buying equipment for a three-week DNA electrophoresis experiment is not cost-effective. Thus, an equipment loan program provides "a whole different technological buy-in to schools that otherwise just wouldn't be able to do that," he said.

The upgrading of science education faces another obstacle: Teachers are often reluctant to learn new laboratory techniques if their schools do not have the equipment. An incentive to get that training can be provided, however, by having the equipment available through a loan program. "That's a critical part of upgrading science instruction in this whole country, to have the equipment," Mr. Waterman said.

Electronic Bulletin Board. In another outreach effort, the HHMI-supported program has developed an electronic bulletin board for middle school and high school biology teachers throughout the Northwest to reduce the professional isolation they often experience, particularly in rural areas. Dr. Paznokas hopes eventually to enroll all

Washington state biology teachers, who number nearly 1,000.

Setting up the bulletin board and developing a user-friendly manual proved challenging. "I was a bit naive in terms of understanding just what it took to put a bulletin board together and make it effective and usable," Dr. Paznokas said. Nevertheless, the bulletin board opened to general use in June 1993.

The biology teachers bulletin board was modeled on another one set up earlier by the University for chemistry teachers. So Dr. Paznokas arranged to have chemistry teachers around the state instruct local biology teachers on how to get onto their new bulletin board. In addition, he demonstrates how to use the bulletin board at conferences attended by biology teachers.

Summer Camps. The outreach component of the program also targets high school students from rural areas and underrepresented minority groups through three science-related summer camps. One camp introduces students to science and engineering career possibilities with an emphasis on life sciences. More than half of the program involves biomedical science. Students are introduced to concepts of experimentation, observation, and data collection and analysis through exercises involving pH titration, enzyme kinetics, and other techniques. Engineering aspects include activities in bioprocess and environmental engineering. Electrical engineering experiments include, for example, recording electrical activity of the heart (electrocardiography). Thirty students attended the first week-long camp in 1993, and as many will be recruited in the future.

Another camp introduces students to opportunities in the health professions, including research, medicine, and nursing. Twenty-four students attended week-long sessions in 1992, and 24 again in 1993. The students spend time with working physicians and visit clinics and medical centers in Washington and Idaho. The program was started in 1990 and, since 1992, has been mostly funded by the HHMI grant.

A third summer camp, also focusing on science and engineering, is being designed especially for Native Americans. The program hopes to recruit 20 to 30 students for this camp in summer 1994.

In addition to its major outreach programs, the HHMI-funded program is planning sponsorship of the state-level competition in the 1995 Science Olympiad, which involves regional, state, and national competitions in science and engineering among teams of

middle and high school science students. Washington State University hosted the 1993 state competition, which involved some 600 students and about 200 parents and coaches.

Institutional Profile	
Total Enrollment	17,846
Undergraduate Enrollment	14,893
Number of Faculty Members	1,107
Endowment (in millions)	$35
Annual Budget (in millions)	$249

Washington University

Program Director
Sarah C. R. Elgin, Ph.D.
Professor of Biology and
of Biochemistry and
Molecular Biophysics
Washington University
St. Louis, MO 63130
(314) 935-5348
(314) 935-5125 (fax)

Washington University is a private research institution in St. Louis, Missouri. In 1992 the Howard Hughes Medical Institute awarded the University $1,700,000 to support (1) activities to increase student access and involvement in the sciences early in their college careers, including a mentoring program and tutoring for introductory-level students, coupled with summer research opportunities; (2) a summer institute in modern biology for teachers from St. Louis area high schools, particularly those with significant enrollments of underrepresented minority students, and a prefreshman program in biomedicine providing laboratory training in molecular biology for students from these and other schools; (3) creation of interdisciplinary laboratory courses, including a new general chemistry laboratory drawing on all of the natural sciences, an intermediate genetics course, and upper-division seminars in areas such as human genetics and structural biology; and (4) support for faculty involved in development and implementation of these programs.

Student Research and Broadening Access

The HHMI-funded program at Washington University seeks to attract and retain students in the life sciences by offering more undergraduate research opportunities, facilitating access to those opportunities, and providing support to students who show an interest in the life sciences.

The project offers a tutorial program to help underprepared students through second semester basic biology (Bio 297) and on to the next course for biology majors, Genetics (Bio 305).

"It's that transition from Bio 297 to Bio 305 that we thought was the...crucial point as to whether a student goes on or not," said Dr. Sarah Elgin, Professor of Biology and HHMI program director. "That's why we decided to focus our resources there."

Students earning a low grade in first semester biology (Bio 296) are brought into the tutorial program when they go on to the second semester. Of 51 students tutored in fall 1992, when the program was initiated, 20 improved their scores by a half grade or more and 45 went on to take Genetics. Some students, it turned out, had simply never developed systematic study habits, Dr. Elgin said. "The fact that the tutor was there telling them [to study] made a big difference in how well they did in the course."

Kevin Otipoby, a junior biology major, tutored three of the students and usually a couple of their friends. Although his tutees were intelligent and studied diligently, most had trouble with molecular biology and the speed with which professors covered material.

"They just needed to hear it in a different way and from someone who was definitely closer to their level," Mr. Otipoby explained. "When you are able to ask questions of someone one-on-one, who is closer to your level of understanding, closer to your age, in a small group, it's a lot easier to understand."

Besides helping students academically, the tutorial program lets them know that the Biology Department is concerned about them. "The fact that there is a tutorial program sends a message to students that the Biology Department is interested in helping them ... even if they're having difficulty," Dr. Elgin said.

In another support effort, Institute funding was used to organize a biology club late in the 1992–1993 academic year. The club will be further developed to expand interaction and information exchange among biology majors. A mentoring system, pairing older biology students with younger ones, is also being planned.

To attract more students into the life sciences, the HHMI-funded program offers a summer undergraduate research opportunity, which provides a stipend for 10 to 12 weeks of research with faculty mentors (Figure 79). The participants report their findings at a meeting in September. For 1993, 32 students were selected. In Dr. Elgin's laboratory, Andrea Holmes, an African American entering her senior year, investigated the effect of a factor binding to the sequence GAGA on DNA bending in the *hsp26* gene of *Drosophila*. "We're looking at nucleosome positioning in the *hsp26* promoter region," Ms. Holmes explained. "We want to find out, if binding the GAGA factor causes bending of the DNA, does that relate to the way the nucleosomes are positioned?" Her work contributes to a larger study of regulation at this locus.

Figure 79. Dr. David Kirk (*left*) and Kevin Otipoby examine a gel for their project on sequencing a gene that is expressed late in the life cycle of somatic cells and may be related to genes that control aging.

Kevin Beuttell, a biology major entering his senior year and

working in the laboratory of Dr. Jonathan Losos, Assistant Professor of Biology, studied morphology in the lizard genus *Anolis* to learn more about evolutionary diversification. About 300 species of the lizard are scattered among the Caribbean islands, where they have evolved independently on each. Mr. Beuttell used calipers and rulers, computers, and x-rays to perform extensive measurements of tails, toe-pad areas, bones, and other features of lizards from various islands. He looked for patterns among different ecomorphs, morphologically similar species that interact with the environment in similar ways.

"Right now I'm just looking at the similarities between different species of lizards," said Mr. Beuttell, who is planning to attend graduate school, possibly in conservation biology. "Hopefully, these different ecomorphs on the different islands will correlate well. Depending on what I get from that, we can go from there looking at the evolution patterns."

The Institute's grant brings coherence to undergraduate research opportunities at the University. "It [undergraduate research] has always been very piecemeal and very frustrating in terms of what we could do in a particular year, such as who can we place where, and how can we make this a coherent experience," Dr. Elgin said.

With five years of support from the Institute, a broad undergraduate research program is being developed. The Division of Biology and Biomedical Sciences is preparing a catalogue of undergraduate research opportunities available through Institute-funded and other programs with more than 250 faculty. The Division is also developing a faculty advising system to help students find the right research mentor.

"The really great thing is to be able to say with assurance to a prospective student, this is here, these are the opportunities, we know this is going to happen," Dr. Elgin said. "The Division now provides a real range of research opportunities both during the summer period and the academic year."

Curriculum and Laboratories

To stimulate more interest in research, the Biology Department added a laboratory to Genetics (Bio 305) in spring 1992 and upgraded the laboratory's optical equipment the following year with money from the Institute grant. The upgrade included high-quality compound microscopes, stereo microscopes, and a video system to use with them. The laboratory exposes biology majors to modern research techniques used in genetics, includ-

ing enzyme assays, spectrophotometry, and polyacrylamide and agarose gel electrophoresis.

In spring 1993, enrollment in Bio 305 jumped nearly 30 percent, the largest increase in recent years, Dr. Elgin said. The tutorial program apparently pushed more students out of Bio 297 and on to Genetics, and the new, upgraded laboratory undoubtedly pulled more into the course.

The increased genetics enrollment also appears to be part of a rising interest in biology generally, and in biological research particularly, over the past year, she said. Enrollment in Bio 296, the first basic biology course, reached 393 in spring 1993, over half of the University's approximately 700 Arts and Sciences freshmen. Enrollment in the biology research course jumped 50 percent, from 70 students in fall 1992 to 106 in fall 1993. And the increased enrollment in Genetics means that new laboratory space will probably be needed for spring 1994.

"I think we're seeing a confluence," Dr. Elgin said. "There's a rise in interest in biology.

And there's an increase in the quality of what the Biology Department's doing. It's more interesting to be a biology major now that the Institute grant is operating than it was before; [there are] more opportunities to do more things. You put all those together and you have steadily increasing enrollments."

In 1993–1994 the HHMI grant will support the introduction of biology-oriented experiments into general, organic, and physical chemistry laboratories. The new series of experiments will illustrate how concepts in physics, chemistry, and biology influence each other, giving students an ability to conduct interdisciplinary experiments.

Precollege and Outreach

To improve precollege science education, the HHMI-funded program offers a summer science institute for high school teachers and is developing a continuing education course in life sciences for kindergarten-through-5th-grade teachers.

The summer science institute provides a three-week intensive lecture/laboratory course to update the science backgrounds of high school teachers and enable them to incorporate hands-on learning activities into their classes. The 1993 session presented a course on molecular genetics to 18 teachers from urban and rural high schools in and around St. Louis. In 1994 a second course will be added, covering ecology and evolution. The latter course will subsequently be offered alternating with a course in environmental chemistry,

while the molecular genetics course will be offered every year.

The molecular genetics course includes work with techniques of gene cloning and analysis as well as lectures on genome organization, control of gene expression, oncogenes, and AIDS. Topical discussions explore the impact of biotechnology on treatment of infectious diseases, genetic engineering of plants, developmental biology, and the Human Genome Project.

During 1993–1994 the HHMI grant will support development of a course in the life sciences for kindergarten-through-5th-grade teachers. It will be an in-service course with 14 three-hour weekly sessions. "The course will essentially cover genetics for teachers who have had little or no chemistry," Dr. Elgin said. The course will involve some lecture but mostly hands-on laboratory work. It will revolve around a core of genetics, emphasizing basic rules of inheritance and the life cycles of plants and animals.

Institutional Profile	
Total Enrollment	11,572
Undergraduate Enrollment	6,074
Number of Faculty Members	3,284
Endowment (in millions)	$1,565
Annual Budget (in millions)	$709

Attendees, Program Directors Meeting, October 4–6, 1993

Joseph J. H. Ackerman
Washington University

Merrill Adams
University of Scranton

Jameel Ahmad
Cooper Union

Myra Alexander
Oklahoma State University
Main Campus

Richard H. April
Colgate University

William R. Bartlett
Fort Lewis College

Pamela J. Bjorkman
California Institute of Technology

Larry Blanton
Texas Tech University

David R. Burgess
University of Pittsburgh Main Campus

George D. Cain
University of Iowa

Robert S. Chase
Lafayette College

James P. Collins
Arizona State University

Eric Davies
University of Nebraska–Lincoln

John G. Duman
University of Notre Dame

Garry A. Duncan
Nebraska Wesleyan University

Frederick A. Eiserling
University of California–Los Angeles

Sharon R. Eisner
City University of New York
Brooklyn College

Sarah C. R. Elgin
Washington University

Morton S. Fuchs
University of Notre Dame

David A. Gapp
Hamilton College

Esther J. Gibbs
Goucher College

Norman L. Goldman
City University of New York
Queens College

Gerald Goldstein
Ohio Wesleyan University

Corey S. Goodman
University of California–Berkeley

Philip A. Gottlieb
University of Delaware

William C. Grant
North Carolina State University

Sandra Gregerman
University of Michigan–Ann Arbor

Pamela J. Gunter-Smith
Spelman College

Prudence J. Hall
Hiram College

Alan R. Harker
Oklahoma State University

Steven R. Heidemann
Michigan State University

William J. Higgins
University of Maryland College Park

Alan J. Jaworski
University of Georgia

Daniel Jay
Harvard University

Margaret Jefferson
California State Univer ty–Los Angeles

James Jensen
California State University–Long Beach

Terry C. Johnson
Kansas State University

Arthur Jones
Jackson State University

Larry Hudson Jones
University of the South

John R. Jungck
Beloit College

Caroline M. Kane
University of California–Berkeley

Loren W. Knapp
University of South Carolina–Columbia

Robert G. Kooser
Knox College

A. Krishna Kumaran
Marquette University

Jay B. Labov
Colby College

Philip C. Laris
University of California–Santa Barbara

John E. Lisman
Brandeis University

R. William Marks
Villanova University

Karen Martin
Fisk University

Andrew O. Martinez
University of Texas–San Antonio

Maryanne McClellan
Reed College

Mary E. McKelvey
Fisk University

Robert W. Mead
University of Nevada, Reno

John C. Mickus
Illinois Benedictine College

Preston Miles
Centre College

Donald J. Mitchell
Juniata College

Mary E. Morton
College of the Holy Cross

Alan Muchlinski
California State University–Los Angeles

Antony J. Mukkada
University of Cincinnati Main Campus

Rodney K. Murphey
University of Massachusetts–Amherst

Joseph H. Neale
Georgetown University

David Netzly
Hope College

Jerome L. Neuner
Canisius College

Kathy Nordeen
University of Rochester

Charles Allen Owens
King College

Paul J. Paolini
San Diego State University

Stephen M. Pasquale
Antioch University

John L. Paznokas
Washington State University

William J. Perreault
Lawrence University

Jerry Pine
California Institute of Technology

Jeanne S. Poindexter
Barnard College

John K. Pribram
Bates College

Jann P. Primus
Spelman College

William K. Purves
Harvey Mudd College

Dennis C. Quinlan
West Virginia University

Doris Ramirez
University of Puerto Rico
Mayaguez Campus

John M. Rawls
University of Kentucky

Ruth E. Reed
Juniata College

John E. Reynolds III
Eckerd College

Kenneth Schug
Illinois Institute of Technology

Peter F. Small
Ursinus College

Preston Somers
Fort Lewis College

Ralph A. Sorensen
Gettysburg College

James V. Staros
Vanderbilt University

Steven Stegink
Calvin College

Jennifer Swann
Rutgers The State University of
New Jersey Newark Campus

Robert H. Tamarin
Boston University

Anna Tan-Wilson
State University of New York–
Binghamton

William A. Tramontano
Manhattan College

Daniel Udovic
University of Oregon

Frank Vellaccio
College of the Holy Cross

Kathryn G. Vogel
University of New Mexico Main Campus

Bernard J. White
Iowa State University

Lawrence C. Wit
Auburn University

Christopher Z. Womersley
University of Hawaii–Manoa

Daniel Wulff
State University of New York–Albany

Steven Jaynes Zottoli
Williams College

Undergraduate Biological Sciences Education Program Awardee Institutions by Carnegie Classification, 1988–1993[1]

The Carnegie Foundation for the Advancement of Teaching classifies colleges and universities on the basis of such factors as the range of the baccalaureate program, number of Ph.D. degrees awarded annually, and amount of annual federal support for research and development, as appropriate. The Institute's assessments of institutions for the 1988–1993 competitions were based on the 1987 Carnegie Foundation classifications and included the following classifications and categorical definitions for public and private institutions:

Research Universities I: These institutions offer a full range of baccalaureate programs, are committed to graduate education through the doctorate degree, and give high priority to research. They receive annually at least $33.5 million in federal support and award at least 50 Ph.D. degrees each year.

Research Universities II: These institutions offer a full range of baccalaureate programs, are committed to graduate education through the doctorate degree, and give high priority to research. They receive annually between $12.5 million and $33.5 million in federal support for research and development and award at least 50 Ph.D. degrees each year.

Doctorate-Granting Universities I: In addition to offering a full range of baccalaureate programs, the mission of these institutions includes a commitment to graduate education through the doctorate degree. They award at least 40 Ph.D. degrees annually in five or more academic disciplines.

Doctorate-Granting Universities II: In addition to offering a full range of baccalaureate programs, the mission of these institutions includes a commitment to graduate education through the doctorate degree. They award annually 20 or more Ph.D. degrees in at least one discipline or 10 or more Ph.D. degrees in three or more disciplines.

Comprehensive Universities and Colleges I: These institutions offer baccalaureate programs and, with few exceptions, graduate education through the master's degree. More than half of their baccalaureate degrees are awarded in two or more occupational or professional disciplines such as engineering or business administration. All of the institutions in the group enroll at least 2,500 students.

Comprehensive Universities and Colleges II: These institutions award more than half of their baccalaureate degrees in two or more occupational or professional disciplines, such as engineering or business administration, and many also offer graduate education through the master's degree. All of the colleges and universities in this group enroll between 1,500 and 2,500 students.

Liberal Arts Colleges I: These highly selective institutions are primarily undergraduate colleges that award more than half of their baccalaureate degrees in arts and science fields.

Liberal Arts Colleges II: These institutions are primarily undergraduate colleges that are less selective and award more than half of their degrees in liberal arts fields. This category also includes a group of colleges that award less than half of their degrees in liberal arts fields but, with fewer than 1,500 students, are too small to be considered comprehensive.

Schools of Engineering and Technology: The institutions in this category award at least a bachelor's degree in programs limited almost exclusively to technical fields of study.

[1]Further information may be found in Carnegie Foundation for the Advancement of Teaching, *Classification of Institutions of Higher Education*, Princeton, N.J., 1987.

Research Universities I
Boston University
California Institute of Technology
Carnegie Mellon University
Case Western Reserve University
Colorado State University
Columbia University
Cornell University
Duke University
Harvard University
Howard University
Indiana University at Bloomington
Johns Hopkins University
Louisiana State University
and A&M College
Massachusetts Institute of Technology
Michigan State University
New York University
North Carolina State University
Ohio State University Main Campus
Pennsylvania State University Main Campus
Princeton University
Purdue University Main Campus
Stanford University
University of Arizona
University of California–Berkeley
University of California–Davis
University of California–Irvine
University of California–Los Angeles
University of California–San Diego
University of Chicago
University of Cincinnati Main Campus
University of Colorado at Boulder
University of Georgia
University of Hawaii at Manoa
University of Illinois at Chicago
University of Illinois at Urbana-Champaign
University of Iowa
University of Kentucky
University of Maryland College Park
University of Michigan–Ann Arbor
University of Minnesota–Twin Cities
University of Missouri–Columbia
University of New Mexico Main Campus
University of North Carolina at Chapel Hill
University of Pennsylvania
University of Pittsburgh Main Campus
University of Rochester
University of Southern California
University of Texas at Austin
University of Utah
University of Virginia
University of Washington
University of Wisconsin–Madison
Vanderbilt University
Washington University
Yale University

Research Universities II
Arizona State University
Auburn University
Brandeis University
Brown University
Emory University
Georgetown University
Iowa State University
Kansas State University
Oklahoma State University Main Campus
Rensselaer Polytechnic Institute
State University of New York at Albany
University of California–Santa Barbara
University of Delaware
University of Kansas Main Campus
University of Massachusetts at Amherst
University of Nebraska–Lincoln
University of Oregon
University of South Carolina–Columbia
Washington State University
Wayne State University
West Virginia University

Doctorate-Granting Universities I
College of William and Mary
Illinois Institute of Technology
Lehigh University
Marquette University
Miami University
Rice University
State University of New York at Binghamton
Texas Tech University
Tufts University
University of California–Santa Cruz
University of Notre Dame

Doctorate-Granting Universities II
Dartmouth College
Rutgers the State University of New Jersey
Newark Campus
Stevens Institute of Technology
University of Nevada
University of Vermont

Comprehensive Universities and Colleges I
California State University–Long Beach
California State University–Los Angeles
California State University–Northridge
Calvin College
Canisius College
City College of the City University of New York
City University of New York Brooklyn College
City University of New York
Herbert H. Lehman College
City University of New York Hunter College
City University of New York Queens College

Concordia College–Moorhead
Fort Lewis College
Hampton University
Humboldt State University
Jackson State University
Manhattan College
Morgan State University
San Diego State University
Saint Joseph's University
St. Mary's University
Southern University and A&M College at Baton Rouge
Tuskegee University
University of Puerto Rico Cayey University College
University of Puerto Rico Mayaguez Campus
University of Puerto Rico Rio Piedras Campus
University of Scranton
University of Texas at El Paso
University of Texas at San Antonio
Villanova University
Wake Forest Unive ..ty

Comprehensive Universities and Colleges II
Clark Atlanta University
Illinois Benedictine College
Xavier University of Louisiana

Liberal Arts Colleges I
Allegheny College
Amherst College
Antioch University
Barnard College
Bates College
Beloit College
Bowdoin College
Bryn Mawr College
Bucknell University
Carleton College
Centre College
Colby College
Colgate University
College of the Holy Cross
College of Wooster
Colorado College
Davidson College
DePauw University
Earlham College
Eckerd College
Franklin and Marshall College
Gettysburg College
Goucher College
Grinnell College
Hamilton College
Hampshire College
Haverford College
Hobart and William Smith Colleges
Hope College
Juniata College
Kenyon College
King College
Knox College
Lafayette College
Lawrence University
Macalester College
Marlboro College
Middlebury College
Millsaps College
Mount Holyoke College
Nebraska Wesleyan University
Oberlin College
Occidental College
Pomona College
Reed College
Rhodes College
Saint Olaf College
Smith College
Swarthmore College
Union College
University of the South
Ursinus College
Vassar College
Wabash College
Wellesley College
Wesleyan University
Western Maryland College
Wheaton College
Williams College
Whitman College

Liberal Arts Colleges II
Dillard University
Fisk University
Hiram College
Lincoln University
Morehouse College
Oakwood College
Ohio Wesleyan University
Spelman College
Tougaloo College
Wofford College

Schools of Engineering and Technology
Cooper Union
Harvey Mudd College

Undergraduate Biological Sciences Education Program Awardee Minority Institutions, 1988–1993

In the assessment of institutions for the 1988 and 1991 undergraduate grants competitions, the Institute has taken into account the institutions' records of graduating in the sciences students from minority groups underrepresented in scientific fields. Information for these assessments has been provided by the following sources:

The Minority Access to Research Careers Program of the National Institutes of Health. (This program was created in 1977 by the National Institute of General Medical Sciences to increase the number of biomedical scientists from minority groups.)

The Minority Biomedical Research Support Program of the National Institutes of Health. (This program was established in 1972 by the NIH Division of Research Resources to develop minority student, faculty, and institutional involvement in biomedical research.)

The National Association for Equal Opportunity in Higher Education. (This organization, founded in 1969, represents and serves some 117 historically and predominantly black colleges and universities.)

The Office of Civil Rights of the U.S. Department of Education. (This federal agency is responsible for analyzing and disseminating data on minority students at the nation's colleges and universities, including the number of degrees conferred, as submitted through the Integrated Post-Secondary Education System and required of all institutions.)

Historically Black Institutions
Clark Atlanta University
Dillard University
Fisk University
Hampton University
Howard University
Jackson State University
Lincoln University
Morehouse College
Morgan State University
Oakwood College
Southern University
and A&M College at Baton Rouge
Spelman College
Tougaloo College
Tuskegee University
Xavier University of Louisiana

Institutions with Significant Underrepresented Minority Student Presence in the Sciences
California State University–Long Beach
California State University–Los Angeles
City University of New York
Brooklyn College
City University of New York City College
City University of New York
Herbert H. Lehman College
City University of New York Hunter College
Fort Lewis College
St. Mary's University
University of Puerto Rico
Cayey University College
University of Puerto Rico Mayaguez Campus
University of Puerto Rico
Rio Piedras Campus
University of Texas at El Paso
University of Texas at San Antonio

Undergraduate Biological Sciences Education Program Awardee Institutions by State, 1988–1993

Alabama
Auburn University, Auburn University
Oakwood College, Huntsville
Tuskegee University, Tuskegee

Arizona
Arizona State University, Tempe
University of Arizona, Tucson

California
California Institute of Technology, Pasadena
California State University–Long Beach
California State University–Los Angeles
California State University–Northridge
Harvey Mudd College, Claremont
Humboldt State University, Arcata
Occidental College, Los Angeles
Pomona College, Claremont
San Diego State University, San Diego
Stanford University, Stanford
University of California–Berkeley
University of California–Davis
University of California–Irvine
University of California–Los Angeles
University of California–San Diego, La Jolla
University of California–Santa Barbara
University of California–Santa Cruz
University of Southern California, Los Angeles

Colorado
Colorado College, Colorado Springs
Colorado State University, Fort Collins
Fort Lewis College, Durango
University of Colorado at Boulder

Connecticut
Wesleyan University, Middletown
Yale University, New Haven

Delaware
University of Delaware, Newark

District of Columbia
Georgetown University
Howard University

Florida
Eckerd College, St. Petersburg

Georgia
Emory University, Atlanta
Clark Atlanta University, Atlanta
Morehouse College, Atlanta
Spelman College, Atlanta
University of Georgia, Athens

Hawaii
University of Hawaii at Manoa, Honolulu

Illinois
Illinois Benedictine College, Lisle
Illinois Institute of Technology, Chicago
Knox College, Galesburg
University of Chicago, Chicago
University of Illinois at Chicago
University of Illinois at Urbana–Champaign
Wheaton College, Wheaton

Indiana
DePauw University, Greencastle
Earlham College, Richmond
Indiana University at Bloomington
Purdue University Main Campus, West Lafayette
University of Notre Dame, Notre Dame
Wabash College, Crawfordsville

Iowa
Grinnell College, Grinnell
Iowa State University, Ames
University of Iowa, Iowa City

Kansas
Kansas State University, Manhattan
University of Kansas Main Campus, Lawrence

Kentucky
Centre College, Danville
University of Kentucky, Lexington

Louisiana
Dillard University, New Orleans
Louisiana State University and A&M College, Baton Rouge
Southern University and A&M College at Baton Rouge
Xavier University of Louisiana, New Orleans

Maine
Bates College, Lewiston
Bowdoin College, Brunswick
Colby College, Waterville

Maryland
Goucher College, Baltimore
Johns Hopkins University, Baltimore
Morgan State University, Baltimore
University of Maryland, College Park
Western Maryland College, Westminster

Massachusetts
Amherst College, Amherst
Boston University, Boston
Brandeis University, Waltham
College of the Holy Cross, Worcester
Hampshire College, Amherst
Harvard University, Cambridge
Massachusetts Institute of Technology, Cambridge
Mount Holyoke College, South Hadley
Smith College, Northampton
Tufts University, Medford
University of Massachusetts at Amherst
Wellesley College, Wellesley
Williams College, Williamstown

Michigan
Calvin College, Grand Rapids
Hope College, Holland
Michigan State University, East Lansing
University of Michigan–Ann Arbor
Wayne State University, Detroit

Minnesota
Carleton College, Northfield
Concordia College–Moorhead
Macalester College, St.Paul
Saint Olaf College, Northfield
University of Minnesota–Twin Cities, St. Paul

Mississippi
Jackson State University, Jackson
Millsaps College, Jackson
Tougaloo College, Tougaloo

Missouri
University of Missouri–Columbia
Washington University, St. Louis

Nebraska
Nebraska Wesleyan University, Lincoln
University of Nebraska–Lincoln

Nevada
University of Nevada, Reno

New Hampshire
Dartmouth College, Hanover

New Jersey
Princeton University, Princeton
Rutgers the State University of New Jersey Newark Campus
Stevens Institute of Technology, Hoboken

New Mexico
University of New Mexico Main Campus, Albuquerque

New York
Barnard College, New York City
Canisius College, Buffalo
City University of New York Brooklyn College
City University of New York City College
City University of New York Herbert H. Lehman College
City University of New York Hunter College
City University of New York Queens College
Colgate University, Hamilton
Columbia University, New York City
Cooper Union, New York City
Cornell University, Ithaca
Hamilton College, Clinton
Hobart and William Smith Colleges, Geneva
Manhattan College, Riverdale
New York University, New York City
Rensselaer Polytechnic Institute, Rensselaer
State University of New York at Albany
State University of New York at Binghamton
Union College, Schenectady
University of Rochester, Rochester
Vassar College, Poughkeepsie

North Carolina
Davidson College, Davidson
Duke University, Durham
North Carolina State University, Raleigh
University of North Carolina at Chapel Hill
Wake Forest University, Winston-Salem

Ohio
Antioch University, Yellow Springs
Case Western Reserve University, Cleveland
College of Wooster, Wooster
Hiram College, Hiram
Kenyon College, Gambier
Miami University, Oxford
Oberlin College, Oberlin
The Ohio State University Main Campus, Columbus
Ohio Wesleyan University, Delaware
University of Cincinnati Main Campus, Cincinnati

Oklahoma
Oklahoma State University Main Campus, Stillwater

Oregon
Reed College, Portland
University of Oregon, Eugene

Pennsylvania
Allegheny College, Meadville
Bryn Mawr College, Bryn Mawr
Bucknell University, Lewisburg
Carnegie Mellon University, Pittsburgh
Franklin and Marshall College, Lancaster
Gettysburg College, Gettysburg
Haverford College, Haverford
Juniata College, Huntington
Lafayette College, Easton
Lehigh University, Bethlehem
Lincoln University, Lincoln University
Pennsylvania State University Main Campus, University Park
Saint Joseph's University, Philadelphia
Swarthmore College, Swarthmore
University of Pennsylvania, Philadelphia
University of Pittsburgh Main Campus
University of Scranton, Scranton
Ursinus College, Collegeville
Villanova University, Villanova

Rhode Island
Brown University, Providence

South Carolina
University of South Carolina–Columbia
Wofford College, Spartanburg

Tennessee
Fisk University, Nashville
King College, Bristol
Rhodes College, Memphis
University of the South, Sewanee
Vanderbilt University, Nashville

Texas
Rice University, Houston
St. Mary's University, San Antonio
Texas Tech University, Lubbock
University of Texas at Austin
University of Texas at El Paso
University of Texas at San Antonio

Utah
University of Utah, Salt Lake City

Vermont
Marlboro College, Marlboro
Middlebury College, Middlebury
University of Vermont, Burlington

Virginia
College of William and Mary, Williamsburg
Hampton University, Hampton
University of Virginia, Charlottesville

Washington
University of Washington, Seattle
Washington State University, Pullman
Whitman College, Walla Walla

West Virginia
West Virginia University, Morgantown

Wisconsin
Beloit College, Beloit
Lawrence University, Appleton
Marquette University, Milwaukee
University of Wisconsin–Madison

Puerto Rico
University of Puerto Rico Cayey University College, Cayey
University of Puerto Rico Mayaguez Campus
University of Puerto Rico Rio Piedras Campus

Grants Publications

Comprehensive
Grants for Science Education (annual)

Meetings of Grantees
Graduate Science Education Program
Meeting of Medical Student Fellows (annual)
Meeting of Predoctoral and Physician Postdoctoral Fellows (annual)

Undergraduate Biological Sciences Education Program
Attracting Students to Science: Undergraduate and Precollege Programs, 1992
Enriching the Undergraduate Laboratory Experience, 1992
1993 Undergraduate Program Directory

Precollege and Public Science Education Program
Science Museums: Creating Partnerships in Science Education, 1993

Local Activities
Community Partnerships in Science Education: Washington, D.C., Metropolitan Area Precollege Science Education Initiatives, 1994

Program Announcements
Graduate Science Education Program
Predoctoral Fellowships in Biological Sciences (annual)
Research Training Fellowships for Medical Students (annual)
Postdoctoral Research Fellowships for Physicians (annual)

Undergraduate Biological Sciences Education Program
Undergraduate Biological Sciences Education Program (annual)

Precollege and Public Science Education Program
Precollege Science Education Initiative for Biomedical Research Institutions (annual)

International Program
International Program (annual)

Information Booklets
Graduate Science Education Program
Information for Medical Student Fellows and Fellowship Institutions (annual)
Information for Predoctoral Fellows and Fellowship Institutions (annual)
Information for Physician Postdoctoral Fellows and Fellowship Institutions (annual)

Undergraduate Biological Sciences Education Program
Information for Colleges and Universities Awarded Undergraduate Grants (annual)

Precollege and Public Science Education Program
Information for Science Museums, Aquaria, Botanical Gardens, and Zoos (annual)

International Program
Information for International Research Scholars and Grantee Institutions (biennial)

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Index

This index is intended to be a guide to educational and scientific topics mentioned in this report. The page numbers indicate the first reference to a topic in a particular write-up. There may be further discussion of that topic in that write-up.

Howard Hughes Medical Institute
Office of Grants and Special Programs
4000 Jones Bridge Road
Chevy Chase, MD 20815-6789