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ABSTRACT

This document presents the results of a meeting of undergraduate biology departments that receive funding from the Howard Hughes Medical Institute. The focus of this meeting was the assessment of science pathways. Discussion focused on assessment, predictors of student success in science, the importance of undergraduate research, career choices, women and underrepresented minorities, encouraging interdisciplinary collaborations, and teacher education and professional development programs for preservice, inservice, and precollege teachers. Sections include: (1) program descriptions of the biomedical research program and the grants and special programs at the Howard Hughes Medical Institute; (2) a preface and introduction; (3) program overview; (4) the keynote address; (5) summaries of panel and workshop discussions; (6) appendices with the agenda for the program directors meeting; and (7) a list of attendees and awards. (DDR)

Howard Hughes Medical Institute

Assessing Science Pathways

Undergraduate Program Directors Meeting

September 30–October 2, 1996

Undergraduate Biological Sciences Education Program

Office of Grants and Special Programs

Assessing Science Pathways

Tracking Science Education and Careers From Precollege Through Professional Levels

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About This Report

In the fall of each year, the Howard Hughes Medical Institute convenes directors of the programs supported by grants from the Institute's Undergraduate Biological Sciences Education Program for a review of the year's activities. These meetings provide a forum for the program directors, program participants, and other members of the science education community to discuss educational challenges facing undergraduate science departments, and to learn how the community at large is addressing those challenges. The Institute sought to broaden the outlook at the 1996 meeting by including students and teachers who have participated in Institute-supported programs and prominent funders of science education.

Each meeting is organized around a central theme, with plenary panel discussions and workshop demonstrations and discussions devoted to topics within that theme. The focus of the 1996 meeting was Assessing Science Pathways. The program directors examined issues related to assessing the impact of educational and professional experiences from the precollege years to the baccalaureate and beyond. Past meeting themes have included New Tools for Science Education (1995); Science Education: Expanding the Role of Science Departments (1994); Institutional Strategies for Enhancing Undergraduate Science Education (1993); Enriching the Undergraduate Laboratory Experience (1992); and Attracting Students to Science: Undergraduate and Precollege Programs (1991).

This report contains the proceedings of the 1996 meeting.

The contributions of Judith Dickson, Eleanor Mayfield, Jeff Porro, and Robert Taylor to this report are gratefully acknowledged. The photographs were taken by Barbara Ries.

The names of colleges and universities are listed as they appear in the 1997 *Higher Education Directory.*

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Howard Hughes Medical Institute Programs

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.

Biomedical Research Program

The Howard Hughes Medical Institute is a nonprofit 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, it employs over 270 independent investigators at its laboratories in more than 60 leading academic medical centers, universities, and hospitals throughout the United States. The Institute conducts research in five broad areas: cell biology, genetics, immunology, neuroscience, and structural biology.

To aid these research efforts, the Institute is involved in the training of graduate and postgraduate students in its investigators' laboratories, has given substantial support to the international genome mapping program, 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.

Grants and Special Programs

To complement its research activities, the Institute has a grants program dedicated to strengthening education in the biological and related sciences. Administered by the Office of Grants and Special Programs, the Institute grants are designed to enhance science education at the graduate, undergraduate, and precollege levels; to increase public understanding and appreciation of science; and to support fundamental biomedical research abroad and research resources in U.S. medical schools. In addition, a comprehensive assessment effort is under way. The grants reach a wide range of institutions involved in formal and informal science education, including colleges and universities, medical schools, research institutes, elementary and secondary schools, and museums.

Since 1988 the Institute's grants program has provided about $95 million in fellowship support to 1,400 students and physician scientists who have shown strong promise of becoming tomorrow's leading biomedical researchers.

The undergraduate program has awarded $335 million to strengthen life sciences education at 220 public and private colleges and universities. These awards are intended to enrich educational opportunities for science majors and enhance the general scientific literacy of students who major in nonscience subjects.

In addition to precollege activities in the undergraduate program, the Institute has awarded $11 million to 51 museums, aquaria, botanical gardens, and zoos to support innovative education programs and to interest youngsters in science. In 1994 the precollege program was extended by awards totaling $10 million to 42 biomedical research institutions.

The Institute's local science education initiatives provide opportunities in the Washington, D.C., area for precollege students at all levels to gain experience in the science classroom and laboratory. A holiday lecture series on science for high school students, held each December, is telecast via satellite throughout North America to more than 8,000 junior and senior high schools.

A research resources competition for U.S. medical schools was held in 1995. A total of $80 million was awarded to 30 U.S. medical schools. Annual payments of $550,000–$1 million will be made over four years for junior faculty start-up, core facilities, pilot projects, emergency funds, and other activities that will help the schools sustain their commitment to research. The research resources program also provides support to research organizations serving the biomedical community as unique resource laboratories and teaching facilities. Through a grants initiative launched in 1991, the Institute supports the research of outstanding biomedical scientists abroad. Altogether, more than $38 million in five-year grants has been awarded to 143 international research scholars.

The Institute has a home page on the World Wide Web, with direct links to the grant sites. The universal resource locator (URL) is <http://www.hhmi.org>.

Preface

Purnell W. Choppin, M.D. □ President

Undergraduate enrollments in biology are rising sharply at colleges and universities nationwide—and the increase includes those who have been traditionally represented in the sciences. This is an overlooked success story for a nation facing difficult choices about health care, the environment, and other issues involving biology.

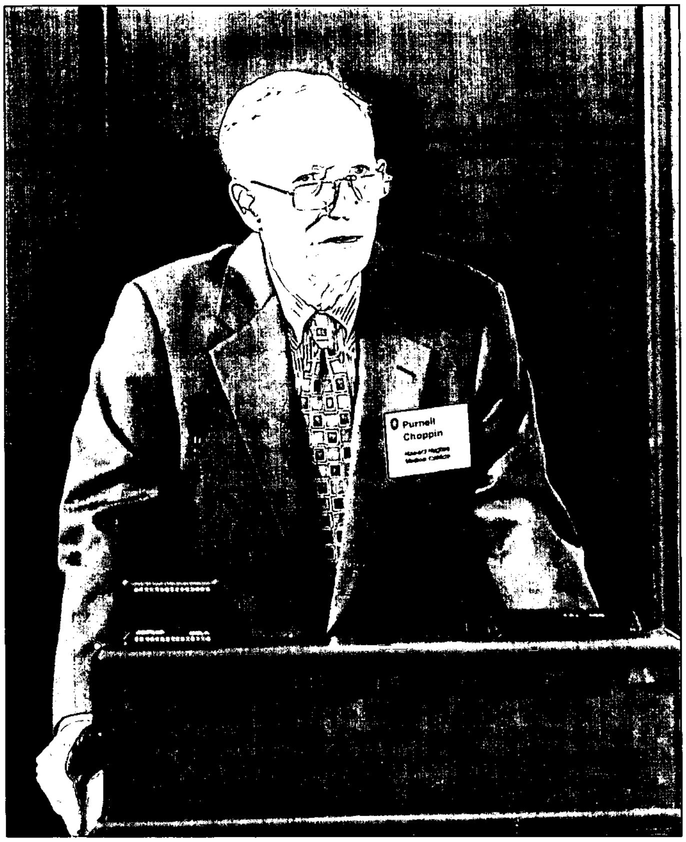
We are learning that it is possible to improve science education for large numbers of students. Undergraduate biology education has blossomed in part because of the discipline's own vitality, but another reason is the important changes that have occurred in the classroom. Students are getting involved in original research in addition to learning from lectures, textbooks, and the scientific literature. They are using powerful computers and state-of-the-art laboratory equipment and putting their new knowledge and skills to work in scientific settings and across society.

This trend in higher education is unfolding at all types of campuses—from big research universities to small women's colleges and historically black institutions. The revolution in undergraduate education is expanding the opportunities for students, whether they eventually pursue science as a career or just better understand how science is changing their lives.

Specifically, colleges and universities are changing the goals of teaching to include nurturing the interest of all students, especially women and underrepresented minorities. Departments are changing how science is taught—taking an interdisciplinary approach and restructuring freshman and sophomore courses in biology, chemistry, physics, and mathematics. Increasingly, college faculty are taking advantage of technological advances, especially in the revolution in communication technologies.

As significant as these changes are in the way college-level science is taught, they cannot be sustained if faculty are not recognized for the value of their science teaching, whether for the amount of time they dedicate to this noble goal or for the novelty of their methods or curriculum. We are learning that all of education is better served if students do research and researchers teach. In addition, as we integrate recognition of teaching and reward for innovation into the culture of higher education, new tools will be required to determine the value of our efforts.

Through the Howard Hughes Medical Institute's undergraduate program, we have seen that the *practice* of science can go hand in glove with the *teaching* of science. Institutions have developed impressive programs to involve research-active faculty in science education, from the introductory through upper-division levels. HHMI grants have also supported programs that provide opportunities for students to become engaged in research in faculty laboratories, to learn science by doing it, and interact with faculty scientists as colleagues and mentors. Through our assessment initiatives, we have seen an increasing number of these students competing successfully in HHMI's graduate fellowship programs and in programs supported by other organizations.



Institute President Purnell W. Choppin introduced Daniel Koshland, keynote speaker at the 1996 undergraduate program directors meeting.

The challenge remains for institutions to find the appropriate balance between teaching and research, and discern opportunities for faculty members to merge their research and teaching activities. This challenge was underscored by Janine Maddock, an assistant professor in the biology department at the University of Michigan, Ann Arbor, at the 1996 program directors meeting and in a recent Institute publication, *Beyond Bio 101*. Dr. Maddock eloquently described her efforts to develop her research program in cell biology while providing the undergraduates in her classes with excellent training in biology. Her efforts exemplify those of increasing numbers of science faculty members, who find they can be true to their science while remaining true to their students.

HHMI is a proud partner in the metamorphosis of biology education on our nation's campuses. More than 200 public and private colleges and universities have received several hundred million dollars in grants to expand research opportunities for students, update courses and facilities, attract talented women and underrepresented minorities to science, and reach out to science teachers and schools in their communities. Through their actions these institutions are changing attitudes, perceptions, and goals and, as a result, have begun to change how millions of young people learn about a science that is transforming their world.

Introduction: Making Enlightened Choices for Science Education

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

In December 1996, *Science* magazine cited advances in research regarding the human immunodeficiency virus (HIV) as the "Breakthroughs of the Year," in recognition of the potential power of accumulating knowledge about HIV infectivity and chemokine receptors in the fight against AIDS. In his opening editorial about the significance of these HIV studies, *Science* editor-in-chief Floyd Bloom quotes Sir Walter Scott, who said ". . . And hope is brightest when it dawns from fears." If, in fact, new knowledge about inhibitors of enzymes essential for viral replication provides hope for people infected with HIV, then science has served its public well. But it is important to remember that *Science* is a magazine for and by scientists, and the public still needs to understand the evolution of the science of HIV that has brought us this close to an effective treatment strategy.

Fortuitously, one week after the *Science* announcement, *Time* magazine named virologist David Da-I Ho, M.D., "Man of the Year" because of his leadership in the development of a therapeutic cocktail of protease inhibitors for patients infected with HIV. This choice is enormously gratifying for all supporters of science, because not only has a scientist been recognized for his contributions to society but there has been an all-too-rare convergence of the popular and scientific press in a matter of significant public health importance.

It is important to remember, however, that the accomplishments of science and scientists are not always as remarkable and ground breaking as AIDS therapeutics. In the *Time* article David Ho describes the essential and sometimes frustrating work done by scientists all over the world that preceded and provided the basis for his work, acknowledging that he could not have achieved his successes without them.

As a society we love the science success stories, but we sometimes forget that science most often moves incrementally toward these breakthroughs, relying on support from a scientifically literate public (or portion of the public), and on the work of many who may not receive the fanfare of our most notable scientists. This in no way diminishes their work, or their hope of making an important discovery. Winston Churchill once remarked that "success is nothing more than going from failure to failure with undiminished enthusiasm." Somehow we must promote this concept of science just as fervently as we do the headline-grabbing successes. It is an important, but essential lesson for the budding scientist. It is a challenging message for science educators in a world where celebrity is an increasingly important measure of achievement.

Fast-moving science, limited resources, and too many distractions pose additional challenges to our science education system, requiring that we plan ever more strategically how to design, implement, and evaluate our efforts.

Evaluating How Science Is Learned

For the past few decades all levels of education have been evaluating and re-evaluating the way science is

Joseph G. Perpich, Institute Vice President for Grants and Special Programs (left), with keynote speaker Daniel Koshland.

taught. Assessment has been a topic of discussion at every HHMI undergraduate program meeting since 1991, and it was the overarching theme of the 1996 meeting. At that meeting program directors expressed their desire for better evaluation tools, some reported on the progress of ongoing assessments, and others brought along evidence of their successes—enthusiastic students and teachers who have been newly invigorated or reinvigorated by their efforts.

Assessment has been a topic of discussion at every HHMI undergraduate program meeting since 1991, and it was the overarching theme of the 1996 meeting.

The 1993 program directors meeting focused on institutional strategies for effecting undergraduate science education reform and the need to assess the degree to which reform efforts have been successful. Assessment is crucial to science education reform, because it can provide the essential data to determine what works and what does not, and when program interventions can have the greatest impact in the science education continuum, from grade school through graduate school. Standards developed by the National Research Council for precollege science education could suggest useful assessment strategies to college-level science educators.

Mary Allen of Wellesley College summed up the fundamental issues surrounding assessment as what, how, and when to assess. Aaron Ellison, Mount Holyoke College, added a fourth: Why? Clearly, assessment can provide useful information to educators, students, and the communities in which they interact. However, assessment of science education initiatives must take into account a wide range of questions, such as How can the effects of a specific program be isolated from those of other programs at a college or university? What is the long-term impact of such programs on students' decisions to remain in the sciences? How can quantitative and qualitative data be used in conducting assessments?

Clearly defined objectives, well-planned methodologies, and measurable outcomes are minimum requirements for effective evaluation. Assessments can provide important answers in the aggregate. For example, can they indicate what types of interventions are received positively and when they can best be offered?

In 1996 representatives of foundations active in science and education attended the undergraduate program directors meeting for the first time and added an important dimension to the discussions about assessment. Martha Peck said that her organization, Burroughs Wellcome Fund, assesses its programs for a simple reason: to see the value of its investment. A major objective of the Fund's assessment is to determine the point in the education-career continuum (from elementary school through the postdoctoral and junior faculty levels) at which funding is most likely to contribute to an individual's successful career path.

The Institute's Undergraduate Biological Sciences Education Program aims to enrich educational opportunities for science majors and enhance the general scientific literacy of students who major in nonscience subjects. The program has awarded $335 million since 1988 to strengthen life sciences education at 220 public and private colleges and universities. The goals of the program are addressed through four broad areas: student research and broadening access to science; equipment and laboratories; science faculty and curriculum; and precollege outreach.

At recent undergraduate program directors meetings, participants have described evaluation activities under way at their institutions. These include tracking the test scores and course choices of students who have participated in science education programs and research experiences; evaluation of the career choices of women and underrepresented minorities; observational studies of classrooms using innovative curricula and educational technologies; surveys to assess changes in attitudes about science, and evaluations of content and curricular changes practiced by teachers who participate in professional development activities. Some examples of evaluation activities are described below.

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Supporting What Works: Student Research Experiences

Systematic research confirms what we know from anecdotal data, that the intense experience of student research is an effective way to learn science. The Third International Mathematics and Science Study, a project that evaluates science and mathematics aptitude in more than half a million students worldwide, found that American students still lag behind their peers in some parts of Asia and Europe but that the usual suspects, too much television and not enough studying, do not appear to be the cause of this deficit.

It is an understatement to say that we are not sure what works in science education. We suspect that many things help, like inquiry-based learning, direct exposure to research, the presence of mentors and supportive family, and plain old hard work. But what inspires one student may not ignite another. Human

Students who undergo the rigor of in-depth exploration of a subject . . . also provide an invaluable lesson in what keynote speaker Daniel Koshland calls "the sacredness of the fact."

[Kristin] Baldwin was an undergraduate economics major at Duke University [who] was so captivated by her first real brush with science that she changed majors.

Among the key points to emerge from Wellesley College's Pathways for Women in the Sciences project is that students who have mentors and who participate in undergraduate research are more likely to continue in science.

beings are inconstant learners: some learn in a linear fashion, others in fits and starts, some by experience, and others by study. This variability makes it difficult to design programs that will be broadly effective and then assess, measure, and predict what will make the difference in a student's educational experience.

More and more, research is showing that what makes a difference is how science and mathematics material is taught. Students exposed to too broad an array of content do not fare as well as students who undergo the rigor of in-depth exploration of a subject. This type of experience also provides an invaluable lesson in what keynote speaker Daniel Koshland calls "the sacredness of the fact."

The experience of Kristin Baldwin clearly makes the case for the value of student research opportunities. She also serves as an example of the danger of making science exclusive. Ms. Baldwin was an undergraduate economics major at Duke University when she participated in a research fellowship sponsored by HHMI. She was so captivated by her first real brush with science that she changed majors. She now has an HHMI predoctoral fellowship in molecular biology in the laboratory of Dr. Mark Davis, an HHMI investigator in immunology at Stanford University.

Because so many undergraduate institutions now offer laboratory-based investigation as the mainstay of their curricula, they struggle with how to evaluate student progress and how to strike a balance between the research experience and fundamental course work. Tara Gupta, a Colgate undergraduate who took part in an off-campus research semester at NIH, reported that she "spent an afternoon doing an experiment that was a failure because I forgot some fundamental cell biology." We are in the midst of a revolution in the way undergraduate biology is taught and it will take some time to sort out the proper balance. Assessment can help us in that process.

We also know from anecdotal evidence and some preliminary empirical studies that there is no substitute for the presence of a strong role model or mentor in a student's decision to stay in science. Among the key points to emerge from Wellesley College's Pathways for Women in the Sciences project is that students who have mentors and who participate in undergraduate research are more likely to continue in science. This confirms our commitment to supporting faculty and teacher enhancement programs as well as initiatives that seek to provide science education opportunities through community resources, such as churches, community centers, and local governments.

Keith Amos is an example of a "success story," an individual for whom we hope HHMI-funded programs made the difference in choosing a career in science. Under the tutelage of Xavier University program director Deidre Labat, Mr. Amos participated in a summer math and science academy as a 14-year-old high school student. Amos is now a graduate of Xavier and a student at Harvard Medical School. This past year as an HHMI-NIH scholar he conducted research at the National Cancer Institute on potential tumor rejection antigens in prostate cancer.

Making Science Education More Inclusive

There is something wonderfully democratic about the fact that we really don't know who among our children will rise to the highest ranks of scientific achievement. It means that it is in our best interest to ensure that *all* students and teachers are able to feel, in the words of Jerry Pine of Caltech, the "rigors and joys" of science.

Students, more than anyone else in our society, should be allowed the freedom to make real choices about where they wish to go. When receiving an honorary degree from Rutgers University last year, Yogi Berra opined, "In the years ahead, when you reach a fork in the road, take it!" New graduates are facing alternative pathways to a scientific career. The academic research laboratory might not be where they end up doing science in the near future. This change in the paradigm requires that we look differently at every aspect of science education, from how it is taught to whom we are targeting. Again, this requires new tools for assessment.

We often hear the argument that "the cream will rise to the top," that those students who truly love science and harbor an inner drive to pursue it will persist in science despite all odds. That might be true, but it is not an excuse for not providing better exposure to science for all comers. Science should not be a forbidding obstacle, in essence a boot-camp experience intended to weed out the weak from the strong. It is a way of thinking, a method of inquiry, that all should, at the very least, understand even if they choose not to practice it. The late Carl Sagan once said, "We make our world significant by the courage of our questions and by the depth of our answers.

Once we make the decision that we will try to reach those who have not already self-selected for science, then our strategies for education and evaluation must necessarily change. We must look more broadly at those who seek careers in research and science teaching, make special efforts to enroll women and underrepresented minorities, and find ways to determine the success of these efforts.

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A Continual Search for What Works

What is clear from the presentations described in this report is that all the program participants have a good sense of what does and does not work. Feedback from participants, whether students or teachers, is one way of knowing. For example, research experiences appear to have a palpable impact on a student's view of science and an energizing effect on teachers. Mary Colvard, a high school biology teacher in upstate New York who has participated in Cornell University's Institute of Biology Teachers, is a prime example. She describes the opportunity provided to teachers through this network as the basis of a "quiet revolution" in which teachers are updated scientifically and recognized as professional educators.

What we might never know is the value of a single program, course, or experience in a student's decision to pursue a research career. Such an approach is probably too simplistic

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when we consider the multiplicity of factors that influence learning and career choices.

Assessment, however, can provide important answers in the aggregate, that is, what types of interventions are received positively and when is the best time in the educational experience to offer them. Martha Peck, of the Burroughs Wellcome Fund, commented that, for funders, an important question is When is an intervention most productive? Tracking students who go on to careers in science may offer us an opportunity to do retrospective analysis about common experiences and perhaps draw inferences about their effects in career selection.

Even with the most successful and proven programs however, we must continue to be diligent in our efforts to provide lifelong safety nets for those who choose science. For example, Wellesley College has a remarkable track record of retaining its undergraduate women in the sciences: nearly one in four Wellesley graduates has a science degree. Discouragingly, however, these women run the greatest risk of leaving the field within the first six months of graduation. We need to better understand the forces beyond the baccalaureate that discourage women from sticking with science.

A Sustained Commitment to Science Learning at All Levels

At HHMI we believe that the undergraduate educational experience opens up a world of opportunities for not only exposing new minds to science but reinvigorating people who are already committed through teaching or course work. Our commitment of $335 million over the past decade has supported a diverse set of programs to improve science education, not just at colleges and universities, but also at the kindergarten through twelfth-grade levels. We are learning along with our grantee institutions about what works in reaching these goals, and we applaud their efforts to enhance the art and science of educational assessment.

A survey we conducted this year revealed that grants for undergraduate science education from a sample of 1,000 private foundations and corporations totaled $86 million in 1994. The Institute provided another $29 million for undergraduate education in the biological sciences alone.* In 1993, the federal government invested nearly $500 million to support undergraduate science and math education, not counting more than $12 billion expended for student financial assistance, student loans, and other support. Even with these relatively large sums, resources are increasingly constrained, and funders of science education must carefully target their support to the areas where it can have the greatest impact.

If we did not have so many exciting options to pursue or support, these decisions would not be so difficult. But the rapid growth of knowledge about biology, combined with innovative classroom and laboratory instruction, is creating a revolution in undergraduate science, a phenomenon that, despite its excitement, poses new challenges for funders, institutions, faculties, and

* Data compiled by the Foundation Center from *Foundation Giving*, 1966 edition.

students. The rules are changing for everyone, making this a time of high demands and great hope.

This past year Harold Varmus, M.D., Director of the National Institutes of Health, was nicknamed "Dr. Who" by the editors of the Harvard *Crimson* when they learned that he was to be the 1996 commencement speaker. In his address, Dr. Varmus said, "I speak for an element of our culture at least as important as politics or war—an element that has not been at this podium since Alexander Fleming, the discoverer of penicillin, addressed the graduating class of 1945. That element is science." Science must grab the bully pulpit, whenever possible, to remind its public that it is worth the investment, the time, and the patience, and that a scientifically literate public is a wiser one. Dr. Varmus reminded his audience that "science—like no empire, no sect, no star—can eventually change the whole face and state of things throughout the world." Good science is one end product of good science education. But given that we can never truly know who will create good science, the next best thing is to promote the learning of science, for its own value.

In *The Once and Future King* by Terence H. White, the court magician Merlin, who has been charged with educating King Arthur, urges the sad young man to study astronomy. "The best thing for being sad is to learn something . . . learn why the world wags and what wags it. That is the only thing which the mind can never exhaust, never alienate, never be tortured by, never fear or distrust, and never dream of regretting. Learning is the thing for you." Although we may all share the belief that learning is "the thing" for our children, we are not likely to agree on how best to achieve that goal, particularly with limited resources. Through careful planning and management of science education programs, we already know that we can make a difference in how students learn. As we integrate new strategies, curricula, and tools, we must continuously find ways to measure our accomplishments and make changes that will successfully carry our children into the next century of science.

"The best thing for being sad is to learn something . . . learn why the world wags and what wags it. That is the only thing which the mind can never exhaust, never alienate, never be tortured by, never fear or distrust, and never dream of regretting. Learning is the thing for you."
The Once and Future King,
T. H. White

Overview of the Undergraduate Biological Sciences Education Program

Since 1988 the Institute's Undergraduate Biological Sciences Education Program has awarded $335.4 million in grant support to 220 colleges and universities for undergraduate science education (Figure 1). The goal of this program is to support efforts to strengthen the national quality of college-level education in the biological sciences and other scientific disciplines as they relate to biology. Another important objective is to support outstanding programs that seek to attract and retain students in scientific fields, including women and members of minority groups.

Institutions have been invited to participate in the undergraduate competitions on the basis of their recent records of having graduated students who went on to medical school or to earn 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 (Figure 2).

To identify institutions eligible for assessment, the Institute referred to the classifications of higher-education institutions by the Carnegie Foundation for the Advancement of Teaching (1987 and 1994). 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. The Institute also took into account institutions' records of preparing students from minority groups underrepresented in the sciences to pursue scientific careers.

Proposals are reviewed by an external panel of distinguished scientists and educators. The panel's evaluations, in turn, are reviewed by an internal Institute committee that makes recommendations to the Institute's Trustees, who authorize funding. Through its ongoing assessment of the undergraduate program, the Institute has developed the program to respond to national needs in science education.

In its first phase of operation (1988–1992), the undergraduate program supported programs of student research and broadening access to science; science faculty development; curriculum, equipment, and laboratory development; and outreach programs linking science departments with community colleges, elementary and secondary schools, and other institutions. In its

Figure 1

Undergraduate Competitions (1988–1996)

1988: 44 public and private comprehensive and liberal arts colleges and universities were awarded $30.4 million in grant support for their science programs

1989: 51 public and private research and doctorate-granting universities received $61 million to enhance undergraduate science education

1991: 44 public and private comprehensive and liberal arts institutions were awarded $31.5 million in grant support

1992: 42 public and private research and doctorate-granting universities were awarded grants totaling $52.5 million

1993: 47 public and private comprehensive and liberal arts institutions received grants totaling $28.5 million

1994: 62 public and private research and doctorate-granting universities received grants totaling $86 million

1996: 52 public and private baccalaureate and master's institutions received grants totaling $45.4 million

Figure 2

Assessment Criteria

To identify institutions for participation in the undergraduate biological sciences education program competitions, the Institute conducted assessments covering the most recent 10-year period for which data were available. Based on data on total baccalaureate degree production collected by the U.S. Department of Education, institutions were assessed on the basis of the percentage 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

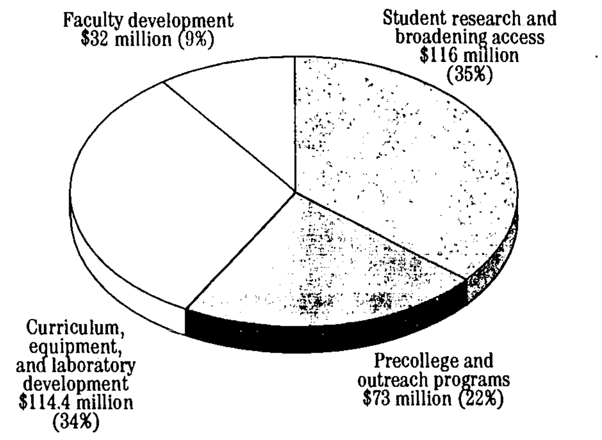
Data source: National Research Council of the National Academy of Sciences

Earned Doctorates in Chemistry, Physics, or Mathematics

Data source: National Research Council of the National Academy of Sciences

Figure 3

Awards to 220 Colleges and Universities ($335.4 million) by Program Component, Phases I–III, 1988–1996 Competitions



second phase (1993–1994), the program continued its support of student research and broadening access activities and precollege and outreach programs, and included an increased emphasis on laboratory development through equipment and renovation support.

The third program phase began in 1995, with invitations to 201 institutions classified as Baccalaureate Colleges I and II, Master's Colleges and Universities I and II, and Schools of Engineering and Technology to compete for grants. In 1996 grants totaling $45.4 million were awarded to 52 baccalaureate and master's colleges and universities. Invitations will be issued in 1997 to institutions classified as Research Universities I and II and Doctoral Universities I and II to compete for grants to be awarded in 1998. In this phase the Institute will continue its support for student research and broadening access to the sciences, equipment and laboratories, and precollege and other outreach programs. On the basis of information collected through assessment activities, the program includes support once again for faculty and curriculum development in the Phase III competitions.

Of the $335.4 million awarded, a total of $116 million supports students in summer and academic-year laboratory experiences on and off campus, as well as prefreshman bridging programs, laboratory training, opportunities for students to present their research at scientific meetings, and other activities that promote a culture of science at the undergraduate level. In the area of curriculum, equipment, and laboratory development, a total of $114.4 million supports the enhancement of undergraduate science education through the acquisition of modern teaching equipment, renovation of laboratories, and development of science curricula and educational technology. A total of $32 million supports the appointment of new science faculty members and opportunities for existing faculty members to broaden their knowledge base or update their teaching skills. A total of $73 million supports science outreach programs for faculty members, teachers, and students at two-year and four-year institutions and secondary and elementary schools (Figure 3).

Help for Scientists and Non-Scientists from the Howard Hughes Medical Institute

Daniel Koshland, Ph.D. ▣ **Professor, Department of Molecular and Cell Biology, University of California–Berkeley**

I am very impressed by all of the imaginative HHMI programs. Under Dr. Choppin's leadership, the Institute has progressed from being a classic funder of research (which by itself is enough) to supporting undergraduate education, museums, and the whole spectrum of science.

What we all really ought to do is sit back and say, "Gee, they're doing such a marvelous job." However, I know that the Institute is constantly trying to improve its programs, moving forward and thinking of new ideas.

Asking me here to discuss the assessment of scientific careers and the other things that all of you who are experts will be discussing in the next couple of days is like carrying coals to Newcastle. Since I am here and very involved in this area, I would like to present a couple of my own ideas, some of which might be valuable—and even if they are not valuable, they will infuriate you so much that you will go out and work twice as hard to get the right answer. I am going to discuss the training of graduate students in science and then veer off a bit to talk about the training of nonscientists.

Too Many Scientists?

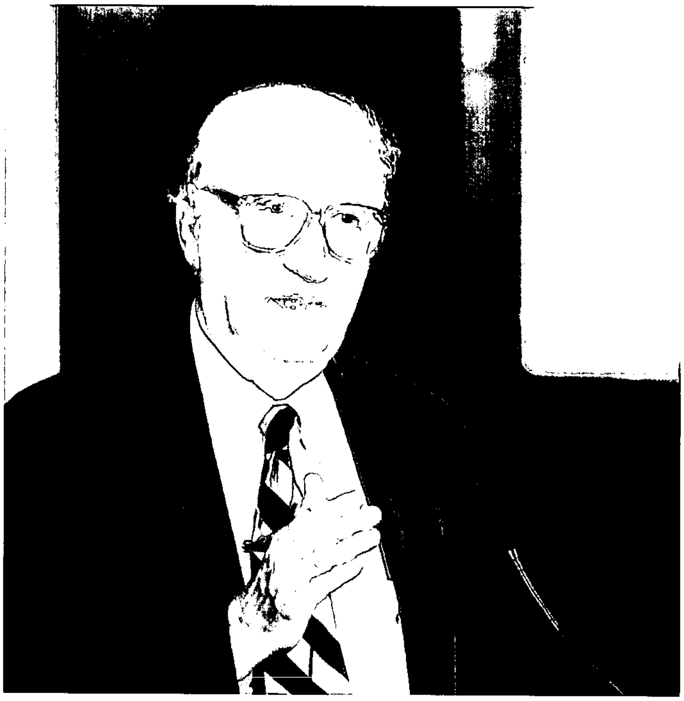
I think all of you know why this is particularly important and controversial at the moment—that is, the shortage of funds for science. It is a different era from that in which Dr. Choppin and I started our research careers. Today it is very difficult to get grants and there are hundreds of applicants for every assistant professor position.

Have we overproduced scientists? A lot of people are suggesting that we should not train any more scientists. "We have too many people and too little money," they say. In my opinion, however, that approach would turn a calamity into a disaster.

Benjamin Disraeli defined calamity and disaster by referring to his competitor for prime minister of England, William Gladstone. He said: "If Mr. Gladstone fell into the Thames, that would be a calamity. If somebody rescued him, it would be a disaster." The solution that some people are suggesting to the problem we have would actually be a disaster.

The fact is that none of us who is involved in training and assessing scientists can say to a young person, "You can't go into science." In the days before the National Institutes of Health and HHMI, people like Mendel, Pasteur, and Darwin went into science. They often depended on personal friends and wealthy donors. Nobody today could say, "We've got too many scientists. You can't go into it." I would like to see any of you (and I am an undergraduate adviser, too) say to a young man named Albert Einstein, "We've got too many physicists" or say to a chemist named Pasteur, "We can't use you."

We cannot turn off science or scientists. However, we also cannot expect either to receive a lot more money for science. I hope there are



Daniel Koshland

several more Howard Hugheses out there who are willing to give a lot of money to science. Both Democrats and Republicans in Congress have been very protective of science, and it may be that funding can go up an incremental amount, but we cannot expect it to increase in proportion to the number of people who want to be scientists.

Why is the number of scientists increasing exponentially? When you think about it, scientists are probably the luckiest people in the world. We like to fiddle around and solve important problems, and somebody is willing to put up capital to let us play these games. The secret has gotten out that science is a very attractive profession.

I wrote recently that I have spent my career having fun and getting paid for it. I thought I was being original until somebody told me a story about Babe Ruth. When he was a young man, just hired by the New York Yankees, the newspaper reporters rushed up to him and said, "Mr. Ruth, how much are you getting paid?" He said, "You mean you get paid for playing baseball?" This is probably true of science, too, and there is no way to stop the flow of people going into science.

Should we say that the whole thing is a fraud and that there are not enough problems to solve? Anybody who is familiar with biomedical research, which HHMI supports so well, knows that we have made a great deal of progress on infectious diseases, organic diseases, and inherited diseases. However, people are living longer, and we have not made as much progress on some of the mental diseases, such as Alzheimer's and Huntington's, or on chronic diseases like arthritis that make old age painful. There are plenty of biomedical problems that still need to be solved, to say nothing of the problems of the environment and the toxic waste problem that gets worse every year as our population increases. Clearly, there are plenty of problems.

Assessing Scientists

What can we do about the oversupply of scientists relative to the number of research positions and the availability of grant funding? In my opinion, one of the most important things we can do is to more accurately assess how good people are.

Even if we knew the exact number of jobs in science, which nobody can define, we could not train one scientist for each job. Universities will never admit this, but they love to have a lot of applicants for a position. Companies like it, too. Even professors like to have more than one applicant for a postdoctoral position in their laboratory. Professors also like to have more than one student working with them. Over the course of an active lifetime in research, a professor can produce a large number of duplicates of himself. This is one of many forces that are producing a lot of scientists.

As a professor at Berkeley, I sit on committees that select students for admission. We consider about 30 or 40 applicants for each student we admit. How do we decide whom to admit? We look at grades, quantitative and verbal SAT scores, and letters from professors the student has worked with. We add up all these things and we vote.

One professor says grades are the most important factor. Another says, "He got a B in this course, but his research professor said he did a great job in research." Somebody else says, "Her SAT was terrific." Another says, "The verbal SAT was great but the quantitative was terrible." By combining all of these things, we admit those who we think are the best students.

However, we rarely go back to try to correlate those assessments with how the students actually did. Now, if a company like General Motors or Goodyear Tire ran its business without assessing how good its initial selections were, it would be out of business. It is a minor scandal that scientists have been so careless about assessing how good a selection job they do. This suggestion will not be regarded as anything new by HHMI. It's something that they—and many of you—are already starting to do.

I would like to remind you of a study that caused quite a stir when it appeared in *Science* magazine during my editorship. Two professors of psychiatry became interested in how decisions were made about whom to release from prison on parole. With the cooperation of authorities, they obtained the records of prisoners who were about to be released on parole. They knew what crimes the inmates had committed, what their lives had been like before their arrest, whether they had a history of arrests, and so on. They got assessments from a variety of sources—the predictions of the parole officer, the prison chaplain, a nurse, a psychiatrist, and the arrest dossiers—as to what was likely to happen when the inmate was released.

The researchers put all of these data into a computer and correlated them. What they found, somewhat to their astonishment, was that the assessments by the psychiatrist, the parole officer, or any of the others were not very good. The one thing that correlated strongly with what happened to the prisoner after release was his previous record.

We published this paper in *Science*. I thought it was a great article. However, it caused an enormous stir, and a lot of psychiatrists were deeply offended. But it emphasized the fact that conditions of complex events may be between little understood factors and not just a compilation of general wisdom.

A similar type of assessment should be applied to science. I would like to see a program that kept records on individuals, starting with high school and continuing through college and graduate school: records of grades including such items as SAT scores, as well as assessments of how various people thought the person would do in science, for example, the committee that admitted her to graduate school and the professors who assessed her when she passed her first qualifying exam. You would also obtain a rough assessment of how good a researcher she is 5 or 10 years after she got her degree. Then, using a computer, you would try to correlate these data. If we could do this, we would be able to do a much better job of resolving the ratio of applicants to jobs. One could say, "Your SAT score is 'x.' We find that that score almost invariably leads to a meaningful career in science."

Steering Students to Alternative Careers

Some of the people who cry that there is a terrible crisis in science do not mention the fact that scientists' technological unemployment rate is less than one percent—one of the lowest in the world. Technological unemployment is defined as not doing work for which you are trained. It does not mean that if your ambition was to be a professor at Wisconsin and you did not achieve that ambition, you are technologically unemployed. If you ended up as a high school science teacher or took a position at an institution less distinguished than those represented at this meeting, that would not be considered technological unemployment.

My point is that we have to learn how to help students choose different careers. Let us say that I have an undergraduate student who has gotten a B– in elementary chemistry and a B in organic chemistry, and his grades continue at about that level. This student's ambition is to go to graduate school. In the current climate I would say to him, "I think that's probably not the best idea. There are a lot of other things that you can do with your life. Your training in science will be helpful to you. But for you to compete in the modern world of grant-funded research is going to be very tough."

Of course, there are also students who get much better grades than the student mentioned above as undergraduates and who get into graduate school but who are just not that good as researchers. We are now starting to advise these students to go into different careers.

If we had the basic data for this kind of assessment, we would be doing a good thing for science in general. We will get better teachers, better museum directors, and better people with scientific training in other careers. I would like to appeal to the Institute to consider funding a pilot project of this nature. Some graduate students in the social sciences could get their Ph.D.'s by collecting this information.

Some people have said to me that they are concerned that assessment might steer minorities away from science. To them I would say that you are doing a favor to a minority individual as much as to a majority individual if you are candid with him or her. The criteria for minorities should be exactly the same as for the majority. You want to help the student find the profession in which she will be the most useful and will enjoy herself the most.

I would guess that M.D.'s may have had higher average grades than researchers as undergraduates, but they have a different kind of mind. They will do a very good job as an M.D. and probably not such a good job as a researcher. That is the kind of issue I would like to have more information about.

Schools and Learning

The *New York Times* recently reviewed a book about some of the arguments regarding the relevance of school curricula. I read it and I thought, "You know, that's probably part of my problem, because I really enjoyed school and any kind of problem." For example, I always enjoyed math. I read an article about efforts to make math more meaningful to students by relating it to the budget of the United States or some other problem. I did not care about the budget of the United States when I was an undergraduate, but I loved the problem in which you had to figure out how fast you were moving in a canoe, rowing at three miles an hour, when the stream was moving at five miles an hour. That was a great problem, and who cared about the budget of the United States?

I asked some of my graduate students about this, and almost every one of them had the same experience that I had: They were very good at math as K–12 students. Many of them are no longer interested in working on mathematical or computer problems, but they were very good at it in elementary school and high school. What happens is that when you are very good at math, you enjoy school and do not need to be told about relevance.

You in this audience who are in undergraduate education tend to feel that you must keep the good students and train them well. It is probable, however, that very few students who are not already inclined toward science come into science at that stage. It is important to maintain them and train them, but it is in kindergarten and primary school where the selection takes place.

I heard a story, which is probably relevant, about a father saying to his son, "Son, you've got to go to school. It's 10:00 in the morning. It's your duty to go to school." The son says, "Dad, I hate school. The students hate me, the professors hate me, the principal hates me. Why do I have to go to school?" The father says, "Well, in the first place, you're 35 years old—and you're going to have to go to school. In the second place you are headmaster and it's your duty."

Schools are like football teams these days. Everybody knows how to make them better. Everyone is second-guessing headmasters, so probably a lot of headmasters hate to go to school. But they are the ones in the firing line, helping ordinary students, gifted students, and people of every race and from every walk of life. In a democracy we have to keep our schools doing well.

We must have new young people becoming scientists, and we cannot create a situation in which the public's image is that science is a terrible field to go into. We cannot go to the legislators and say, "We're training these students. You've got to give them jobs."

Nobody guarantees an architecture student that there is going to be a building boom when he gets his degree. Nobody guarantees members of other professions that they are going to have a job or that they are going to have all the support they need to do the job. The justification for scientists is that we are solving problems that are of great relevance to society. It is our job to send a message to which Congress is really sympathetic.

Training Nonscientists

Another subject that is of concern to me is the training of nonscientists. This subject is important for three reasons. First, some people who do not think that they are scientists may become interested in it and shift, which would be good. Second, we really ought to have people making budgets who understand the benefits of science and its impact on society. Third, scientific training is going to be very important in trying to resolve some of the terrible problems we face in our society.

Scientists are particularly good at solving problems. I have noticed that on the interdisciplinary departmental committees that we have at Berkeley, the chairman is usually a scientist. An English professor usually writes the minutes because the scientists are illiterate, but the scientists can keep things on track.

What we need to do is to try to convey some of the ways in which scientists have solved problems. One of the things that is very important is what scientists call the sacredness of a fact. I sometimes hear people who really do not understand science say, "The exception proves the rule." Well, of course, the exception does not prove the rule in science; it breaks it.

In science, if you obtain new data that do not fit your existing theory, you must get a new theory. That is how the Thompson atom became the Bohr atom and eventually the quantum mechanical atom, because when we were able to measure atomic spectra with a high degree of resolution, it became clear that the Bohr atom was a deficient model.

I heard a story that illustrates this issue. An admiral was commanding a battleship in the South Seas on a stormy night when the crew could barely see what was ahead of them. Suddenly the first mate said, "Admiral, sir, there's a light ahead, right on a collision course with us, and you've got to stop it! Something terrible is going to happen!" So the admiral got on the two-way radio and said, "Ship ahoy, ship ahoy, on collision course. Turn your vessel 40 south by southeast." The reply came back, "I'm sorry. You'd better change your direction 40 north by northwest." The admiral said, "I don't think you understand. This is Admiral Vanderbilt and I'm on a battleship. I think you'd better change your direction 40 south by southeast." A little voice came back saying, "I'm sorry. You don't understand. This is Midshipman Jones, and I'm on a lighthouse."

There are some facts that really do convince you to change your course.

Environment or Heredity

As editor of *Science*, I once wrote an editorial about spousal abuse in which I mentioned how effective the organization Mothers Against Drunk Driving had been and said that it was time to act more concertedly on spousal abuse. In the process of writing that editorial I learned some statistics: 50 percent of the women who are killed in the United States are killed by a husband, lover, or would-be lover. That is a staggering number. Of men who kill their wives, about 80 percent are the sons of men who were also involved in spousal abuse.

It struck me that a statistic of this magnitude might indicate that a hereditary factor was at work. As we know from experience with other hereditary factors, if we can find the gene, we may be able to develop a therapy. So I called some of the agencies involved in spousal abuse, some of which had written to tell me that they liked the editorial I had written, and I asked them whether they had considered the possibility of a hereditary factor.

Almost of them said, "Oh, no. This is a learning factor. These men think they can get away with battering their wives because they've seen their father battering their mother." I said that it did not seem to me that wife-battering was an instinctive thing that all of us would do if we learned that we could get away with it. Besides, there is something called the Oedipus complex—the notion that boys identify more with their mothers than with their fathers.

"Have you not investigated the hereditary factor?" I asked. They responded, "How would we do that?" I mentioned the very famous studies led by Seymour Kety and others that identified schizophrenia, manic depression, and other mental illnesses as hereditary. The social scientists were not familiar with these studies. I mentioned studies of adopted children, which correlated them with their adoptive family or their biological family.

Now, I do not know whether spousal abuse is caused by environment or heredity, but I certainly know what tests you would have to do to investigate that question. I was stunned to find that these social organizations had never thought to do this and did not know how to do it.

I am appalled when I read in the newspapers about welfare reform and policy makers saying that all we have to do is train these people and they are going to have jobs. Fifty percent of the homeless are mentally ill. You are not going to find a lot of new jobs for people with problems like that, no matter how you train them.

No doubt there are tough decisions to be made when setting budgets, but getting the basic facts on which you base a decision is important.

Value of the Scientific Approach

Another important thing that scientists can do is what I call the differentiation of a project. As scientists, we know that big, complicated problems are not solved by intellectualizing. A lot of people think that the beginning of modern science was the famous Buchner experiment, in which the Buchners broke up yeast, gradually isolated the enzymes, and were able to reconstruct the metabolism of sugars by breaking the problem up into small pieces.

We are not trying to cure cancer by constantly discussing cancer as a whole. We are facing the fact that cancer has many causes—inheritance in some cases, carcinogens in others, viruses in still others—and we tackle each of these causative mechanisms individually.

Too often when I discuss social science issues with some of my friends, they say, "It's no use having a deterrent for murder, because murder is a crime of passion and you can't stop it." Well, that is not true. Some murders are crimes of passion. Other murderers are people who want to eliminate witnesses or take revenge, or they are youngsters who hold up a mom-and-pop store and then panic. There are all sorts of murders, and you have to differentiate them in the same way that you differentiate cancers.

If scientists were still studying the population genetics problem by looking at the total population, we would not have gotten very far. Through being able to sequence DNA, however, the progress has been enormous. The ability of science to break problems into parts is very important.

I would like to advocate getting the really great talents in science to spend some time teaching nonscientists. Such teaching may be a more prodigious problem than evaluating scientists, because all the scientists I know were very good in elementary school mathematics. Logical procedure is something that appealed to them. Most of the people who are not scientists, however, hated math. So we may have to think differently when we teach nonscientists.

Many liberal arts courses in science at universities are what I would call tourist education: You're flying over a country at 30,000 feet and someone says, "Here's physics" or "Here's chemistry." The course becomes a very generalized comment instead of getting down and learning the standard scientific protocols as to how you distinguish between one decision and another. It is not going to be easy to change that. On the other hand, it is important that some of that knowledge be transmitted, not only to try to instill an appreciation of science but also because it helps people to understand the issues they are going to be faced with.

The O. J. Simpson trial is probably a perfect example of the misuse and misunderstanding of science. Psychological testing in which one is able to predict what a juror is going to decide before the trial even starts, regardless of the evidence, and using that information for wealthy clients is an example of the misuse of science to subvert the jury system. People talk about the misuse of genetic engineering, but they should start talking about the misuse of social science.

I heard a story about a young man who lived down the street from Charles Darwin. This young man, who may have been a lot like me, thought, "I'm going to fool this Darwin. He's supposed to know a lot." He got the body of a beetle and skillfully glued on the legs of a spider and the wings of a butterfly. He took this creature to Darwin and asked, "What kind of an animal is this?" Darwin looked at it and said to the young man, "By the way, does this bug hum?" The young man had not thought of that, but he recovered quickly. "Oh, yes, it hums." At which point Darwin said, "Then I think it's a humbug."

I do not know whether that is the conclusion of my talk. I know I am talking about areas in which the Institute is very involved, not only in training nonscientists but also in supporting museums and so forth. Much as I hate to see any money diverted from the support of basic research, I think that the Institute's broad view—focusing on the importance of science in society—is the right one. In addition to support for the assessment of science programs, there is a need to support programs for people who will not themselves become researchers but will go into other professions and help to improve the general understanding of science in society.

Discussion

Career Choices for Science Graduates. Many in the audience took issue with Dr. Koshland's suggestion that grades might be a basis for identifying those students most likely to succeed in science. Such a strategy risks diminishing the diversity of approaches that enriches science, said one listener. Dr. Koshland responded that although this was a concern, "a more rational selection process would produce a better situation than the present one, in which so many people are disappointed and the feedback to young people about a career in science is negative."

Another listener said that some ongoing studies suggest that grades are a poor predictor of career success and that involvement in research might be a much better one. Dr. Koshland said that it was important to establish whether or not grades are a predictor of success and that such information would be helpful to professors attempting to advise students on career choices. In response to those who said that they felt unqualified to advise students about alternative careers, he said that students will ultimately make their own career decisions, but it would be helpful if more objective data were available to guide those decisions.

A member of the audience contrasted attitudes toward career choices among students and professors in science with those in the fine arts, who "have no illusions about their chances of becoming Picasso. They take the competition for granted." By contrast, she said, scientists assume that there will be a job for every graduate.

Teaching Science to Nonscience Majors. Faculty who teach science to nonscience majors must demonstrate a lot of creativity and innovation, yet generally they are not rewarded for these efforts, one participant commented. Dr. Koshland noted that although much depends on the personality of the individual faculty member and on whether institutions consider the teaching of science to nonscience majors to be important, some great scientists have always enjoyed teaching freshmen and nonscience majors.

Nature and Nurture. A listener chided Dr. Koshland for jumping to the conclusion that domestic violence has a genetic basis. Dr. Koshland responded that scientists should not have preconceived ideas but should not be afraid to seek data on such controversial issues. He said that he sometimes feels that social scientists "don't want to hear that anything is genetic."

Biographical Sketch Daniel Koshland

Dr. Koshland was born in New York City on March 30, 1920. He earned his B.S. degree at the University of California–Berkeley in 1941 and his Ph.D. from the University of Chicago in 1949. After two postdoctoral years at Harvard, he joined the staff of Brookhaven National Laboratory and later had joint appointments at Rockefeller University and Brookhaven until 1965. At that time he joined the faculty of the University of California–Berkeley in the Department of Biochemistry.

Dr. Koshland is currently a professor in the graduate school in the Department of Molecular and Cell Biology at the University of California–Berkeley and was editor of *Science* magazine from 1985 to 1995. He is a member of the National Academy of Sciences, the American Academy of Arts and Sciences, the American Chemical Society, and the American Society of Biological Chemists. Among his honors are the National Medal of Science, the Edgar Fahs Smith Award of the American Chemical Society, the Pauling Award of the American Chemical Society, the Rosenstiel Award of Brandeis University, and the T. Duckett Jones Award of the Helen Hay Whitney Foundation. He was a Guggenheim Fellow and a Visiting Fellow of All Souls College at Oxford University. He has been elected an Honorary Foreign Member of the Japanese Biochemical Society and the Royal Swedish Academy of Sciences.

He was elected president of the American Society of Biological Chemists. He helped establish and was chairman of the Academy Forum, a committee of the National Academy of Sciences, which is charged with helping to develop policy on issues that pose dilemmas at the interface between science and societal problems. He has been elected to the council of the National Academy of Sciences.

Dr. Koshland has contributed more than 400 articles to the scientific literature. His early work focused on enzyme mechanisms and protein chemistry, leading to the concept of single and double displacement reactions, the development of reagents of carboxyl groups and tryptophan, and the analysis of factors that explain the high catalytic power of enzymes. This work led to his concept of the induced fit theory, the general work on cooperativity mechanisms, and the discovery of negative cooperativity. During this period the concept of reporter groups was developed and demonstrated experimentally.

His recent work has focused on mechanisms of behavior with bacterial chemotaxis as a model system. Bacteria were shown to have a memory that is essential for their survival. The receptors and many of the gene products of the processing system have been isolated, and the biochemistry of their sensory and adaptive properties has been delineated.

Dr. Koshland's research has produced major advances in our understanding of enzymes and protein chemistry. He is an international leader in research on short- and long-term memory. As editor of *Science*, the largest-circulation scientific journal publishing primary research across the entire spectrum of the sciences, he had an active role not only in selecting primary research on the frontiers of science but also in influencing and acting as a spokesman for science policy. He was instrumental in improving the reporting of scientific discoveries so that they are understandable to laymen and to scientists in different disciplines

Assessment

Assessment was the overarching theme of the 1996 undergraduate program directors meeting, and this topic was woven into almost all of the discussions that took place during the meeting. Although meeting participants had many questions and concerns about assessment, they had no doubt that it is an increasingly important issue in science education.

Mary Allen, Wellesley College, summed up the fundamental issues surrounding assessment as what, how, and when to assess. Aaron Ellison, Mount Holyoke College, suggested that a further important question for scientists is, What is the hypothesis?

Representatives of foundations making grants in science and education, attending the undergraduate program directors meeting for the first time, offered their perspectives on the importance of assessment. Martha Peck, Burroughs Wellcome Fund, said that her organization assesses its programs for a simple reason: to see the value of its investment. The fund would like to know, for example, at what point in the education-career continuum (from elementary school through the postdoctoral and junior faculty level) funding is most likely to contribute to an individual's successful career path.

Robert Lichter, Camille and Henry Dreyfus Foundation, defined assessment as a process or set of activities designed to answer the question, Does something matter? Although noting that the concept of assessment is ambiguous—there is disagreement, for example, on whether assessment is the same as evaluation—Lichter emphasized that the science and higher education communities must find ways to do assessment more effectively.

Raymond Bacchetti, William and Flora Hewlett Foundation, observed that as a result of changed public attitudes, higher education is now perceived as an interest group. Higher education needs to defend itself more effectively with regard to results, he said. Without assessment, there is no basis for making the case that higher education is important and effective.

Higher-education accrediting agencies are beginning to require institutions to have assessment mechanisms in place, said John Mickus, Benedictine University. When his institution went through a reaccreditation process recently, it was asked to demonstrate that measurable objectives had been set for new courses.

Determining what to assess involves setting clear goals and objectives for programs. Many speakers emphasized the importance of thinking about assessment criteria up front when designing a program. "Goals are more clearly defined if at the outset one takes into account how they might be assessed," said Frank Vellaccio, College of the Holy Cross.

Clearly defined objectives, well-planned methodologies, and measurable outcomes are necessary but not sufficient conditions for good assessment, according to Michael Gaines, University of Miami. Gaines added that he was dissatisfied with what he called the bean-counting approach to assessment, expressing a widespread view among meeting participants that many benefits of science education programs are

Several panelists conducted a plenary session on tracking science graduates' career pathways. From left to right: Martha Peck, Burroughs Wellcome Fund; Mary Allen and Christine Birchwood, Wellesley College; Keith Amos, Harvard University Medical School; and Kristin Baldwin, Stanford University.

intangible. Alan Gubanich, University of Nevada–Reno, spoke for many when he said, "We have to think about how to define success."

In a diverse student population, students may have very different starting lines. Deidre Labat, Xavier University of Louisiana, said that she measures success by the extent of systemic change or by seeing improvements in the performance of the best students trickle down to that of the average students.

Defining success by the classical criteria, which focus on numbers of students who pursue careers in scientific research, numbers of publications, numbers of research grants, and so on, may be both inadequate and inappropriate at a time when competition for research positions has never been more intense and students are being urged to consider alternative careers. Allen commented that it is as important to produce scientifically literate legislators as more researchers.

Discussions of how to assess frequently focused on the difficulty of establishing appropriate control groups. Lichter said that although scientists tend to favor controlled experiments, it is not clear from the evaluation literature that controlled experiments are always necessary. Helene Slessarev, Wheaton College, said that results similar to those of controlled experiments can be obtained by simpler methodologies such as the use of focus groups.

Slessarev echoed the comments of many other meeting attendees when she urged program directors to build linkages with their colleagues in the cognitive and social sciences who have experience in program assessment. Frederick Eiserling, University of California–Los Angeles, described the positive results of one such collaboration at his institution: After his colleague Orville Chapman worked with a faculty member in the psychology department, an expert in perception, to reorganize an organic chemistry course, test scores increased by about 50 percent.

However, test scores are just one way to measure a program's impact. Another equally important variable might be student attitudes toward science, the measurement of which would require a different kind of assessment tool. As for when to assess, participants generally felt that the most valuable data are likely to come from long-term studies. Allen noted that assessment of institutional change is also important.

Another important question is How much data is necessary to prove something? For example, must every institution assess the value of student participation in research, or are a few representative studies enough? Sarah Elgin, Washington University, suggested that a few large, sophisticated studies might be more valuable than many small, unsophisticated ones. This approach would also conserve resources.

Some attendees expressed concern that devoting resources to assessment means that fewer resources are available for other program activities. Others cautioned that assessment measures need to be appropriate to an institutional setting (one size does not fit all).

Several speakers drew a distinction between assessment and tracking. Tracking—long-term follow-up of program participants—is a necessary precursor for assessment. It was noted that institutions' alumni offices can be a useful resource in tracking graduates. For some attendees, however, tracking raises privacy concerns. Karen Olmstead, University of South Dakota, urged that institutions seek students' permission for tracking and allow them to choose not to be tracked.

Keith Amos, a graduate of Xavier University who is now a student at Harvard Medical School (and a former participant in the HHMI–National Institutes of Health [NIH] Research Scholars program), said that one of the benefits of tracking from the perspective of program participants is that it enables them to keep in touch and build valuable peer networks. It also provides a corps of program alumni who may be willing to serve as mentors to future participants. Thus, tracking has benefits unrelated to the provision of assessment data.

Predictors of Success in Science

Mary Allen presented an overview of the results to date of the Pathways for Women in the Sciences project, a longitudinal study of career choices and attitude changes among Wellesley College graduates, funded by the Alfred P. Sloan Foundation Among the key points to emerge from the study so far are that students who have mentors and who participate in undergraduate

Wellesley College: Pathways for Women in the Sciences

Women remain underrepresented in scientific careers, particularly at the senior levels of the science professions. In an effort to better understand the factors influencing women's choice of and persistence in a science career path, Wellesley College, with funding from the Alfred P. Sloan Foundation, initiated the Pathways for Women in the Sciences project in 1991.

The project's first phase comprised a longitudinal study of the Wellesley class of 1995 and a retrospective study of alumnae who graduated with majors in science or mathematics from 1983 to 1991. It is one of the few carefully controlled longitudinal analyses of postgraduation activities. Key findings of *The Wellesley Report, Part I*, published in 1993, include the following:

- Interest in pursuing science or mathematics as a career is probably developed before college.
- Science majors are more likely than nonscience majors to score highly on mathematics SATs.
- Science majors and premed students are more likely to have parents in science, mathematics, and health-related careers.
- Students in science are more likely than other students to have received encouragement from multiple sources to pursue science.
- Science majors are more likely than nonscience majors to see society at large as supportive of women in science.
- Students in the physical sciences are more likely than those in the life sciences to cite college teachers as a source of support, encouragement, and influence on their choice of major.

Part II of the report, currently in preparation, focuses on about 800 women from the classes of 1968–1991 who graduated from Wellesley in science, mathematics, or computer science and who did not go into medicine. (The 342 women—30 percent of science graduates—who went into medicine were studied separately.) The following data are excerpted from the prepublication report with the permission of Wellesley College.

- More than 40 percent of the study cohort (345 women) had left science by the time of data collection. The study found that about a quarter of science graduates leave the field at graduation, and a further 2–3 percent leave each year from year 1 to year 11 after graduation.
- Those who remain in science at year 11 after graduation represent just over half of those who graduated with a mathematics, computer science, or science degree. Few women leave after 11 years in the field.
- Having a mentor while an undergraduate is associated with retention in science. By the end of year 11, 62 percent of women who had a mentor are retained, compared with 52 percent who did not have a mentor. More than half of all women in science careers said that they would not be where they are today without their mentor. No differences were found between women who had a male mentor and women who had a female mentor.
- Participation in undergraduate research is also associated with retention in science. At the end of year 11, 60 percent of women who engaged in undergraduate research are retained, compared with 53 percent of women who did not engage in such research.

These data are significant for the Institute's undergraduate biological sciences education program, which is currently providing research experience with a mentor for 20,000 undergraduates.

Michael Gaines (left) and Beatriz Blanco, University of Miami, and Richard Storey, Colorado College, took part in a workshop discussion on bridging programs.

research are more likely to pursue graduate education and careers in science. A mentor's most important functions are providing support and encouragement; providing career advice is secondary. Parental encouragement is also crucial.

An anecdote related by Keith Amos illustrated the importance of a mentor's taking a personal interest in a student. He said that he became interested in science in junior high school and was determined to become a doctor. However, there were no laboratories at his high school in a small Louisiana town. When, at 14, he expressed interest in the summer science program at Xavier University of Louisiana, he was astonished to receive a personal letter from the program director, Deidre Labat. "I still have that letter today," said Amos.

Another student participant in the meeting, Beatriz Blanco, seemed to be living proof of the accuracy of the Wellesley study's findings. Blanco transferred to the University of

Miami from Miami-Dade Community College after participating in an HHMI-supported bridging program. She said parental encouragement had been the biggest factor in her success, followed by good high school teachers, a dedicated mentor (Michael Gaines), research experience, and financial support from HHMI.

Scott Santos, a graduate of the University of Hawaii at Manoa who is now a graduate student at the State University of New York at Buffalo, said that the opportunity to work at Waikiki Aquarium's bluewater marine lab during his senior year of high school had been the catalyst for his decision to pursue a career in science. Before that experience he had not even planned to go to college.

Santos participated in the HHMI program at the University of Hawaii at Manoa, where his mentor was Robert Kinzie of the Hawaii Institute of Marine Biology. "He taught me that research is fun. Someone is paying you to have fun."

Christine Birchwood, a recent graduate of Wellesley, said that the personal relationship between a mentor and a student may be the most important factor in determining whether the student goes on to a career in science.

High school teachers can be mentors, too. Tara Gupta, a student at Colgate University, told of becoming interested in biology because of a high school teacher who told her that there were still many unknowns in the field. "That was the most exciting part of biology for me—that there was so much empty space and room for me to fill it." Her mentor at Colgate was Nancy Pruitt, who advises students planning to conduct research in off-campus laboratories. Tara is doing research at NIH.

Importance of Undergraduate Research

All of the student participants at the meeting spoke emphatically of the importance of undergraduate research experience in motivating them to pursue careers in science. Kristin Baldwin, a graduate of Duke University and now a graduate student at Stanford University, changed her major from economics to biology as a result of her participation in an HHMI-supported undergraduate research fellowship program. She is now working in the laboratory of Dr. Mark Davis, an HHMI investigator, and is the recipient of an HHMI predoctoral fellowship.

Nancy Pruitt described Colgate University's off-campus study program that enables selected students to spend the fall semester of their senior year doing intensive research at NIH. Students spend at least 30 hours each week working on a laboratory research project under the direction of an NIH scientist and also take one to three courses required for the undergraduate science major. The students receive credit for two science courses.

One unresolved problem with off-campus research programs, several attendees observed, is how to enable students to follow through on their research experience after they return to campus. Pruitt said that as a result of feedback from students indicating that one semester at NIH was not enough, Colgate has decided to expand the program by allowing students to begin their laboratory experience the summer before the fall

semester. In addition, in 1997 Colgate will open the program to a small number of students from other colleges.

Tara Gupta, who took part in the off-campus program, described the difference between classroom laboratories and actual research experience as being "like the difference between taking driver's education classes and actually driving a car."

Several of the students said that independence, although often the most challenging aspect of a research experience, was also the most valuable because it made them think and forced them to be self-reliant. In a classroom laboratory, Christine Birchwood said, "you are told what to think, what to do, and what to expect." Doing research had given her confidence in her own ideas and abilities, she said. Students also enjoyed the professionalism and the sense of community evident in the laboratories where they worked.

Both students and program directors noted that research experience can also be counted a success if students learn that they do not like laboratory work and therefore decide to pursue other career options.

Research experience, however valuable, does not give students a broad background in fundamental scientific knowledge. A number of speakers stressed the need for a balance between research experience and fundamental course work. Tara Gupta confessed that by concentrating on research as an undergraduate she had not learned some of the basics. "I spent an afternoon doing an experiment that was a failure because I forgot some fundamental cell biology."

A workshop discussion on preparing students for research careers featured (left to right) Nancy Pruitt and Tara Gupta, Colgate University; Christopher Womersley, University of Hawaii at Manoa; Scott Santos, State University of New York at Buffalo; and Ted Greenwood, Alfred P. Sloan Foundation.

Another student participant, Kathryn Goettge, a graduate of Lehigh University who is now a graduate student at the University of North Carolina–Chapel Hill, pointed out a possibly unintentional consequence of the spread of programs to provide undergraduates with research experience: Such experience, she said, is now virtually a prerequisite for admission to graduate school.

Attendees expressed a range of views on the value of publishing the results of undergraduate research projects. Robert Lichter said that presenting results for peer review and publication is a critical aspect of research. Christopher Womersley, University of Hawaii at Manoa, said that it is unrealistic to expect all undergraduates to get papers published and expressed concern that emphasizing the publication of results would put too much pressure on students. Aaron Ellison noted that new journals have sprung up that are dedicated to publishing undergraduate research, but he was skeptical of the value of such journals.

Several attendees described their institutions' programs to train undergraduates in laboratory safety. Many institutions require students to attend a seminar on safety before they enter a laboratory. At Carnegie Mellon, students spend the first week of their summer program learning about all aspects of laboratory safety and must pass an examination on safety issues before beginning laboratory work. At the University of Hawaii at Manoa, students receive a two-week orientation that covers safety, laboratory techniques, stress management, and other topics.

Career Choices for Science Graduates

As competition for academic and research positions has stiffened, the traditional view of a successful science career path—graduate school, postdoctoral fellowship, tenure-track academic appointment, and finally the attainment of independent investigator status—has been increasingly called into question. Many meeting participants said that the time has come to adopt a broader view of a successful science pathway.

Too many graduate departments are continuing to ignore the realities of the job market for Ph.D.'s, said Ted Greenwood, Alfred P. Sloan Foundation. In many research fields, the supply of Ph.D.'s vastly exceeds the demand. "We must stop producing research-oriented clones of faculty who are unprepared for the kinds of jobs in which many, if not most, of them will end up," he said.

Student participants made it clear that they are not naive about their prospects for pursuing careers in academic research. "None of us is expecting to come out of a postdoc and have a tenure-track position at a major research university waiting for us," said Kathryn Goettge. She added that pharmaceutical and biotechnology companies will likely be the major employers of her generation of biological sciences graduates.

Kristin Baldwin said that her colleagues at Stanford are considering many career options, such as working in industry or investment banking. According to Keith Amos, Harvard medical students are considering working for regulatory agencies or managed-care companies, starting their own biotechnol-

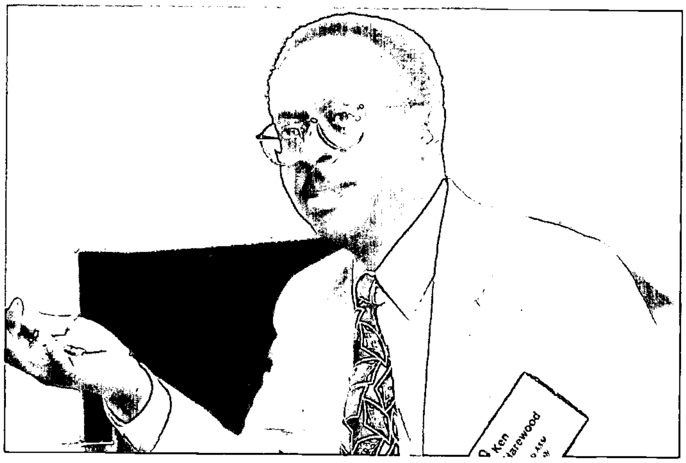
Careers in biotechnology research were discussed by (left to right) Shuang Ruy Huang, Merck Company Foundation; Lucybeth Nieves and Lillian Bird, University of Puerto Rico Rio Piedras Campus; Kathryn Goettge, University of North Carolina at Chapel Hill; and Jeffrey Sands, Lehigh University.

ogy businesses, or going into rural primary care.

Several attendees said that colleges and universities need to develop more extensive links with industry and opportunities for students to obtain research experience in an industrial setting. Jeffrey Sands said that Lehigh University has capitalized on its location in east central Pennsylvania—close to many pharmaceutical and biotechnology companies—to create a variety of interactions with industry.

As a result of these interactions, HHMI-supported undergraduates can obtain summer research experiences in pharmaceutical company laboratories, scientists working for pharmaceutical and biotechnology companies can work toward advanced degrees with mentoring from professors at Lehigh, and professors (including Sands himself) have developed research collaborations with industry scientists. Lehigh has initiated a master of science program in biotechnology that brings together science and engineering education.

Shuang Ruy Huang, Merck Company Foundation, described some of the educational outreach programs established by Merck, which include an undergraduate internship program for juniors and seniors who spend the summer working in a Merck laboratory; an ambassador program in which Merck scientists maintain relationships with the universities where they received their education, visiting regularly to lecture and work with faculty members at those institutions; and a new mentor program in which Merck scientists serve as



Ken Harewood, Florida A&M University, moderated a resource group meeting for directors of HHMI-supported undergraduate programs at master's institutions.

career counselors to students at nearby universities.

Ken Harewood described Florida A & M University's program to place students in industry laboratories for internships lasting 8–10 weeks. Students, faculty, and industry representatives all benefit from the relationship, he said. Kathleen Parson, Macalester College, said that she had spent a one-year industrial sabbatical at 3M in Minneapolis and had maintained her relationship with the company since that time, sending students there on internships and bringing 3M scientists to her college as guest lecturers.

Goettge noted that in industry scientists tend to work in teams, whereas in academia they are more likely to work independently. Research experience in industry gives students valuable exposure to collaborative science, she said.

Several attendees commented that few biology graduates now enter precollege teaching and wondered how more students could be influenced to consider this career option. Thomas Settlemire, Bowdoin College, and Alice Grier Lee, Washington and Jefferson College, described programs at their institutions in which undergraduates work with students at local elementary and middle schools; it is hoped that some of these undergraduates will decide to pursue teaching careers.

Some institutions are devising programs to surmount students' need for financial support for a postgraduate year of teaching training. Donald Goldberg said that Occidental College participates in a National Science Foundation collaborative teacher preparation program that provides students with scholarships.

Several attendees told anecdotes to support their contention that a science education can be valuable in unpredictable ways for people who do not pursue careers in science. At one institution a survey of biology and biochemistry graduates' career choices found that many students commented favorably on the value of their science education even though they had not pursued careers in science. One graduate said, "My undergraduate degree taught me to think, to organize, and to set goals."

Norman Hackerman said that the Robert A. Welch Foundation considers the development of scientifically educated lay persons to be its most important goal. "Those who don't go into research become supporters of research," he said.

Focusing on Women and Minorities Underrepresented in the Sciences

Implicit in the notion that all students should have access to a science education is the recognition that strategies are needed to recruit and retain women and members of minority groups that have traditionally been underrepresented in the sciences.

Ted Greenwood described a program, funded by the Alfred P. Sloan Foundation for six years, that increased the recruitment and retention of women in science, mathematics, and engineering. The program supported model graduate and undergraduate programs at institutions committed to altering their culture, climate, and (where necessary) curriculum to enable women to succeed as readily as men.

Characteristics of funded programs included vigorous recruitment of women students, improved mentoring and advising, and efforts to eliminate sexism in the classroom (intentional or unintentional); undergraduate research opportunities; and curriculum changes that emphasized collaborative learning, hands-on approaches, and reliance on meaningful real-world examples.

Another Sloan program is intended to increase the number of minority students receiving Ph.D.'s in science and engineering. The foundation's approach is to seek out faculty members with a proven record of success in producing minority Ph.D.'s and offer them additional resources for each additional minority Ph.D. they produce.

Several program directors described HHMI-supported programs that focus on the recruitment and retention of minorities underrepresented in the sciences. Colorado College offers a residential summer bridging program for high school students that aims to increase participants' scientific knowledge, teach the principles of field study, and encourage participants to continue their education. Students take a writing and analytical skills inventory test before and after participating in the four-week program, and scores on the post-program test go up significantly, said program director Richard Storey. To date 95 percent of program participants have gone on to college.

Colorado College offers a second residential summer program for incoming minority freshmen who have indicated an intention to major in science. The program covers writing, mathematics, and computer skills; note-taking and study skills; and test-taking strategies. The earliest participants in this program are now in their junior year, said Storey; one measure of the program's success will be how many of them graduate.

Michael Gaines described a bridging program to encourage talented students from Miami-Dade Community College to transfer to the University of Miami. Features of the program include a high-school-to-college transition course that emphasizes basic skills in chemistry, mathematics, and writing; twice-weekly mathematics and chemistry workshops during the academic year; a summer course in biotechnology laboratory techniques; and a monthly research colloquium.

Quantitative assessment of the program's impact is difficult to do, said Gaines, because students enter the program from unequal starting points. "You can take the sure-fire people that you know are going to succeed, but to me that's not as challenging as taking the people who have not had an opportunity because of where they went to high school."

This point was reinforced by Charles Putman, who said that the most important lesson he had learned from Duke University's broad-spectrum program to attract

Shuang Ruy Huang, Merck Company Foundation, Velma Richardson, Tuskegee University, and Verna Case, Davidson College, chatted during a break.

women and minorities into science was "how critical it is for institutions to take risks." Students who would not normally have met Duke's admission requirements had thrived in the HHMI-supported summer research program, which had also served as a stimulus for reform of Duke's biology curriculum.

The University of Hawaii at Manoa's program includes two-year hands-on internships and travel awards that enable students to obtain research experience on the United States mainland and present their findings at scientific meetings. A key feature of the program, said program director Christopher Womersley, is that students choose their own research projects and select their own mentor by interviewing faculty members.

Karen Olmstead described the University of South Dakota's outreach program to American Indian tribal colleges, which focuses on developing research infrastructure for faculty and students at these often geographically remote institutions. HHMI support has provided a molecular biology facility at one tribal college; workshops, release time, and travel funds for faculty development; and laptop computers for faculty members who need to travel long distances between college campuses.

Several program directors commented on the fact that women greatly outnumber men in undergraduate research programs targeted at underrepresented minorities. It was suggested that the stipends offered by such programs may not be high enough to attract minority men and that minority men may be less likely to view biology as a viable career option. Ray Gavin, City University of New York Brooklyn College, proposed that programs be targeted at underrepresented minority men just as they are now targeted at women.

Changing How Undergraduate Science Is Taught

Burgeoning enrollments in undergraduate biology present colleges and universities with a dilemma: There are simply too many students for all to participate in resource-intensive undergraduate research programs. However, research is the characteristic activity of science and as such, attendees argued, is a pivotal component of any science curriculum. Christopher Womersley said that traditional lecture-based methods of undergraduate science education have been comparable with training carpenters in only the theory and not the practice of their trade.

Julio de Paula, Haverford College, advocated creating undergraduate research methods courses and discovery-based laboratory courses that provide a research-like environment while offering more guidance than an independent research experience. Distinguishing features of discovery-based (or inquiry-based) courses are that students originate the research questions to be answered, work collaboratively, and present their results to their peers for critical comment.

Program directors presented examples of how the principles of discovery-based science teaching are being introduced on their campuses. At the University of California–Los Angeles, an inquiry-based approach is being incorporated into introductory organic chemistry, and students are encouraged to publish their research on the Internet. Guy Bradley said that Eckerd College offers a special one-month course in hands-on genetic engineering. The students who learn the most in this course "are those whose experiments don't work the first time."

The University of Maryland College Park has developed three upper-level undergraduate science courses in which students work in teams. Teams are selected so that they include students of both sexes, of different races, and with a range of grade point averages. Each team writes a research proposal and each student makes an oral presentation. Students also critique other teams' research proposals. The performance of average students in these courses has improved, and bright students have learned that they can help others to perform well.

City University of New York City College has introduced an undergraduate course in the techniques of molecular biology. Working in groups, students learn how to run concurrent experiments, budget their time, and troubleshoot problems that arise. This course also provides valuable experience for students who go on to jobs as laboratory technicians in industry, said program director Sharon Cosloy.

At the University of Chicago, HHMI support for undergraduate programs provided the impetus for reinvigoration of the institution's undergraduate biological sciences program, said program director José Quintans. The university has the new Biological Sciences Learning Center in which all biology education (for undergraduates, graduate students, and medical students) now takes place. Quintans characterized the new center as a one-room schoolhouse where undergraduates mingle not only with graduate students and medical students but also with faculty researchers whose laboratories are housed in the research wing of the building.

At some institutions, the impetus for curriculum reform came from outside in the form of criticism by external evaluators. Ray Gavin, City University of New York Brooklyn College, said that such criticism had been a catalyst for wholesale curriculum redevelopment, including the introduction of inquiry-based approaches in biology laboratories.

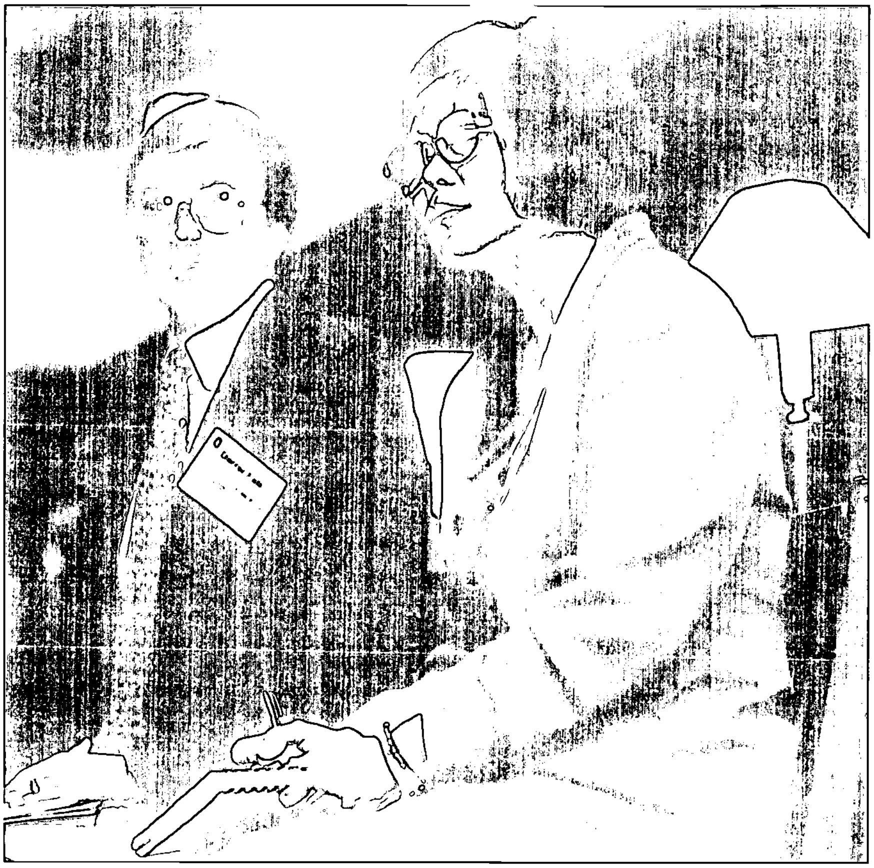
Science faculty often fear that, because inquiry-based teaching approaches are time-intensive, students will lack the content knowledge necessary to do well on standardized tests such as the Graduate Record Examination and the Medical College Admission Test. Kathleen Blits, St. John's College, said that such fears may be misplaced; her institution's entire science program is predicated on the principle that less is more, and students do very well on standardized tests. Some program directors, however, were skeptical that students retain information any better in inquiry-based courses than in traditional lecture-based courses.

Nancy Devino said that the National Research Council's national science education standards may, by changing the way precollege science is taught, provide an impetus for the adoption of the same kinds of approaches at the undergraduate level. Students who have learned science through hands-on, discovery-based approaches in elementary and secondary school will not tolerate didactic lectures when they get to college, she said.

Devino and Greenwood recommended a report titled *Talking About Leaving*,* an inquiry into the reasons for high attrition rates among undergraduate science, mathematics, and engineering majors. Among the report's findings, said Greenwood, are that students who drop out of science are no less capable than those who remain and that many students (both those who leave and those who persist) are unhappy with the quality of teaching and advising they receive as undergraduates.

Several program directors described their institutions' experiences with peer-tutoring programs. At Washington and Jefferson College, freshmen and upper-class students work together to design and conduct experiments in a biotechnology workshop. At California State University-Northridge, student tutors provide supplemental instruction in the more difficult science courses. Student participation is booming, said program director Joyce Maxwell. The tutors benefit as much

* Seymour, E. and N.M. Hewitt. 1994. *Talking About Leaving: Factors Contributing to High Attrition Rates Among Science, Mathematics, and Engineering Undergraduate Majors.* Final Report to the Alfred P. Sloan Foundation on an Ethnographic Inquiry at Seven Institutions. Boulder, CO: University of Colorado.



Darrel Falk, Point Loma Nazarene College (left), and Anna Tan-Wilson, State University of New York at Binghamton, moderated a program directors' forum.

as the tutees because "there is no better way to learn than to teach."

At the State University of New York at Binghamton, upper-level undergraduates participate in an on-campus summer program to create undergraduate laboratory courses. During the following semester, these students work as mentors one on one with other undergraduates. Program director Anna Tan-Wilson said that although the goal of the summer program was to provide upper-level undergraduates with teaching experience, an unexpected additional benefit was that the experience of preparing laboratories got students excited about research.

The University of Nevada-Reno developed a program in which students who have difficulty with mathematics are trained to be math tutors. Program director Alan Gubanich said that this approach is very successful, although the definition of success is different for each student. For example, a student who obtains a C in mathematics, meeting her personal goal and enabling her to graduate, is considered a success as much as the student who discovers new self-confidence in math and goes on to medical school.

At many institutions information technology is a catalyst for classroom innovation.* Electronic com-

* The role of electronic communication and other computer technologies in the classroom was examined at the 1995 HHMI undergraduate program directors meeting. (*New Tools for Science Education*, 1996, Howard Hughes Medical Institute, Office of Grants and Special Programs.) Also see the HHMI World Wide Web site at http://www.hhmi.org.

Scott Santos, University of Buffalo; Robert Cluss, Middlebury College; William Marks, Villanova University; and Kristin Baldwin, Stanford University, examined the offerings at a materials exchange that ran concurrently with the meeting.

munication can help to foster a sense of community in a class, said Earl Fleck, Whitman College. He has used listservs for two years to provide course material to students, and he also encourages students to post questions. "Other students will often answer the questions before I do. Sometimes a student who doesn't say a word in class will participate in the electronic network."

Gavin, however, worried that the widespread integration of information technology into the classroom will put students who cannot afford computers at a disadvantage. He noted that many Brooklyn College students live in households without telephones. Other program directors said that their institutions were responding to this concern by developing on-campus computer laboratories. Unless such laboratories are open 24 hours each day, however, many students who have full-time jobs may still lack adequate access to computers.

Interdisciplinary collaborations were the topic at a workshop session featuring (left to right) Robert Lichter, Camille and Henry Dreyfus Foundation; Frederick Eiserling, University of California–Los Angeles; and Dale Benham, Nebraska Wesleyan University.

The responsibility of colleges and universities to prepare students for the workplace by equipping them with skills in writing and data analysis, as well as in the use of computers, was an issue that concerned both program directors and student participants. Keith Amos said that it is crucial for students to learn good writing skills as well as science. Some institutions have implemented workshops in writing and statistics and increased their report-writing requirements to ensure that students develop adequate skills in these areas.

Encouraging Interdisciplinary Collaborations

Several program directors noted that the availability of funds for the development of interdisciplinary courses can be an important incentive to faculty to overcome traditional disciplinary barriers and begin to work together. Julio de Paula said that an HHMI-funded effort to develop new introductory courses in biology, chemistry, math, and physics at Haverford College had facilitated the development of relationships among faculty in those departments.

Dale Benham reported that Nebraska Wesleyan University is investing some of its HHMI funding in the development of an interdisciplinary, laboratory-based environmental science course for freshman nonscience majors. The course will be team-taught by faculty from the geology, chemistry, mathematics, and physics departments.

Environmental science was selected because it involves issues—

University of California–Los Angeles: What to Assess?

UCLA's introductory chemistry and biology courses have been redesigned using interactive video learning and student teamwork. Assessment strategies that have been used include

- strategies for developing and validating assessments: model-based versus ideographic assessment approaches and their trade-offs;
- mapping assessment to key characteristics of laboratory science: content understanding, problem solving, collaboration or teamwork, and metacognition (learning to learn);
- development of quality criteria to judge performance; and
- successful faculty collaboration processes.

some controversial—that are not only relevant to Nebraska but also important globally. One of the measures of its impact will be a longitudinal comparison of the career outcomes of course alumni with a control group of students who do not take the course.

The University of California–Los Angeles has developed a four-course, self-paced interdisciplinary life sciences curriculum and a battery of measures to assess student performance in the new curriculum, said program director Frederick Eiserling. Assessment tools include a diagnostic test on course entry to measure how much students already know, an electronic portfolio that students maintain as they progress through the sequence of courses, and a self-assessment test that students complete when they decide they are ready to evaluate their mas-

Mary Lynn Grayeski, Research Corporation (left); Mark Jacobs, Swarthmore College; José Quintans, University of Chicago; and Karen Olmstead, University of South Dakota, discussed fostering faculty development at a workshop session.

tery of both theoretical and practical course material.

Karen Olmstead noted that interdisciplinary collaborations may be easier to initiate at small institutions because faculty members are more likely to be acquainted with their counterparts in other departments.

Collaborative initiatives may extend beyond other science departments and may have unexpected spinoffs, noted James Collins, Arizona State University. His institution's invitation to its school of architecture to design new science laboratories led architecture faculty and graduate students to investigate how to create space that helps science teaching. As a result, Collins said, the school of architecture has made the design of science laboratories a major initiative.

Research and Teaching: Finding a Balance

As competition stiffens for both available research dollars and tenured faculty positions, junior faculty members feel the pressure most directly. With the tenure clock ticking, they must balance the often competing demands of research and teaching while contributing their share of service, the third traditional element of an academic career.

At research-intensive institutions, research accomplishments are perceived as paramount, creating a dilemma for young faculty members who wish to excel at teaching as well as in research. Janine Maddock, University of Michigan-Ann Arbor, told of being advised by her merit review committee to focus on her research and put less effort into her teaching.

At predominantly undergraduate institutions, expectations are somewhat different. Teaching is a primary criterion for tenure, and junior faculty members who want to do research often struggle to find the time and resources to do so, according to Julio de Paula.

How to achieve a better balance between teaching and research—on the one hand, increasing the value placed on teaching at research-focused institutions and, on the other hand, providing improved opportunities to pursue research at predominantly undergraduate institutions—was a recurring theme at the meeting.

The institutional culture of research universities needs to change so that teaching excellence is valued as highly as research in the tenure and promotion process, many attendees said. Equally, faculty at predominantly undergraduate institutions need a better research infrastructure, including not only laboratory space and equipment but also sabbatical leaves, travel funds, and release time to attend scientific meetings so that they remain current in their fields.

Julio de Paula and Mark Jacobs, Swarthmore College, emphasized the importance of frequent sabbatical leaves as a faculty development tool. At Haverford College, tenure-track faculty can take a sabbatical after three years and another after tenure is obtained. Swarthmore offers its faculty a sabbatical every fourth year.

Many participants expressed concern that, although the teacher-scholar who is actively involved in both teaching and research remains an academic ideal, in reality the highest status is frequently awarded to

Janine Maddock, University of Michigan–Ann Arbor—Excited About Education

As a tenure-track faculty member at a major research university, Janine Maddock is under enormous pressure to win—in a highly competitive environment—research grant support for her genetics laboratory and to publish research results that will strengthen her case for tenure.

Maddock, an assistant professor of biology at the University of Michigan–Ann Arbor, is also deeply committed to undergraduate education. She encourages undergraduates to work in her laboratory, welcoming the opportunity to demonstrate the fun as well as the challenge of science.

Her classroom presentations to undergraduates are laced with references to cutting-edge research discoveries. With deadlines looming on two crucial grant applications, she takes two hours out of her crowded schedule to talk about her scientific career to members of the university's undergraduate biology club.

Maddock exemplifies the dilemma faced by university science faculty members who are committed to teaching well but whose professional survival depends on obtaining research support. Balancing the demands of teaching and research—not to mention administrative responsibilities and family commitments—is a constant challenge.

The focus of Maddock's research is cell fate and the mechanisms of cell cycle control, using the bacterium *Caulobacter crescentus* as a model. She arrived at the University of Michigan after completing a postdoctoral fellowship with developmental biologist Lucille Shapiro at Stanford University School of Medicine.

Like most faculty members who work with undergraduates, Maddock finds that teaching extends beyond the lecture hall. "A lot more goes into the job of teaching than most people ever know," she says. "We counsel. We mentor. We advise. It's a lot more than just delivering a lecture." Then there are departmental commitments, which for Maddock have included serving on the graduate admissions committee and on the microbiology and cell and molecular biology curriculum committees.

The mother of a 10-year-old girl and a 5-year-old boy, Maddock believes that excitement about science is instilled in childhood. She regularly visits a local elementary school to give science presentations to fourth graders.

Her contributions to teaching should be weighed equally with her research productivity when she is evaluated for tenure, says Maddock. "I'm excited about education. I want to keep that level of excitement and get tenure."

(Adapted from *Beyond Bio 101,* Howard Hughes Medical Institute, Office of Communications, 1996.)

those who do not teach, and the status of those who focus solely on teaching is devalued. Some research-intensive institutions, including the University of Chicago and Carnegie Mellon University, have introduced a nontenured lecturer career track for faculty who focus on teaching and are not involved in research.

In the biological sciences, lecturers generally work full-time on labor-intensive biology laboratory courses.

Swarthmore College: What to Assess?

To track science faculty members as they advance in their careers and to assess the effect of external funding on faculty development, the following categories of each faculty member's teaching and research are periodically examined:

- new laboratories teaching new techniques within already existing science courses;
- new courses offered on previously unexamined topics at the frontier of a field of science;
- number and area of publications, to assess the importance of the support both for general productivity and for easing access to a new field;
- publications with student coauthors—research articles and abstracts—to assess fruitful interaction with college and high school students; and
- research and educational grants obtained after faculty-development support.

Susan Henry, noting that the proportion of women in lecturer positions at Carnegie Mellon is higher than the proportion in tenured or tenure-track positions, wondered whether the lecturer track would become a de facto academic ghetto for women. Other attendees worried that the institutionalization of a nontenured lecturer track exacerbates the separation between research and teaching.

Several attendees suggested that funding agencies could encourage institutions to value teaching more by supporting postdoctoral fellowships that include a teaching component. At present, it was noted, the best graduate students and postdocs usually have research fellowships that exempt them from teaching.

The need to develop better criteria to define good teaching was another recurring theme. It was suggested that surveys of alumni several years after graduation might produce more thoughtful, and as a result more valuable, assessment data than the typical end-of-course student evaluations. Henry said that Carnegie Mellon is experimenting with peer evaluation of teaching. Several speakers observed that although the elements of good teaching may be difficult to define precisely, most faculty members know who the good teachers are in their own departments.

Broadening the definition of scholarship to include contributions to teaching, including developing innovative courses and bringing educational technology into the classroom, is another way to increase the value of teaching. Journals published by a number of educational professional associations publish articles about innovations in teaching. However, at some institutions, publication in such journals may be valued less highly than publication in research journals.

Elizabeth Duffy described a program that the Andrew W. Mellon Foundation is funding at selected liberal arts colleges to support the use of educational technology in teaching. She said that the foundation is using its funding to encourage institutions to recognize the efforts of faculty, especially junior faculty, who devote time to this kind of curriculum development. "We have been very explicit about telling institutions that we don't want to fund a project that is going to jeopardize the assistant professors who work on it."

Several attendees commented that faculty members become more excited about teaching when they are also engaged in research. However, many participants felt that better incentives are needed for junior faculty to become involved in undergraduate research. Junior faculty who are under pressure to produce publishable results may fear that having undergraduates in the laboratory will impede their progress. Although research grants often include funds for faculty salaries and overhead expenses, agencies that support undergraduate education programs usually do not pay for these costs.

Some institutions are finding ways to provide incentives. Henry said that Carnegie Mellon is allocating part of its HHMI grant to provide financial support to junior faculty who work with undergraduates in their laboratories. Bradley McPherson said that Centenary College of Louisiana offers summer research support to faculty members who apply for but do not receive external research grants.

Abolition of the mandatory retirement age for faculty means that institutions must reconsider the role of tenure, said Henry. She warned that this issue will be decided by

Tracking faculty careers was the topic of a plenary session featuring (from left to right) Susan Henry, Carnegie Mellon University; Janine Maddock, University of Michigan–Ann Arbor; Julio de Paula, Haverford College; and Elizabeth Duffy, Andrew W. Mellon Foundation.

society and politicians unless academia takes some action.

Henry, who is dean of sciences at Carnegie Mellon University, and Frank Vellaccio, who is vice provost of the College of the Holy Cross, stressed that faculty—not administrators—make the rules that govern the tenure and promotion process. "If the faculty decide that they want to change the reward structure, it's as good as done," said Henry.

Outreach to Precollege Teachers

Another finding of the Pathways for Women in the Sciences study of Wellesley graduates is that interest in pursuing science or mathematics as a career is probably developed before college. Precollege science education lays the foundation that enables a student to succeed in science as an undergraduate. Meeting participants heard from several HHMI grantees who have developed innovative collaborative programs to enhance the preparation and professional development of precollege science teachers.

Programs for Inservice Teachers

Teaching is often a lonely career, said Raymond Bacchetti, William and Flora Hewlett Foundation. He quoted Judith Warren-Little of the University of California–Berkeley: "Schools are collections of small businesses called classrooms." In a multimedia presentation by Frank Vellaccio, a public school teacher in Worcester, Massachusetts, Dermot Shea, described a typical school day as consisting of "cells and bells—the bell rings and you go into your cell."

Mary Colvard, a high school biology teacher in upstate New York and a participant in the Cornell Institute of Biology Teachers (CIBT) network, said that professional isolation is a primary cause of teacher attrition. Bacchetti said there is evidence that attrition diminishes significantly when school districts make a commitment to in-service education. The Hewlett Foundation supports programs that encourage good candidates to enter and remain in teaching as well as programs that improve teacher training and promote systemic change in the education system.

CIBT overcomes teachers' isolation by linking them to a network of colleagues and Cornell University faculty, said Colvard. She and Peter Bruns, Cornell program director, said that the program is effective for two reasons: ongoing assessment and a strong partnership between the teachers and the faculty participants. For example, new classroom laboratory materials are developed jointly by teachers and faculty working in teams. The materials are then tested in classrooms for a year. Components that do not prove useful are eliminated.

Other forms of ongoing assessment include extensive use of questionnaires and teacher interviews as well as having teachers serve as instructors at the annual summer institutes that provide an opportunity for teachers to familiarize themselves with recent research advances. Bruns advised other program directors involved in teacher development programs to form partnerships with their institutions' schools of education to develop effective assessment strategies.

During a plenary session on assessing science partnerships (from left), Norman Hackerman, Welch Foundation; Sandra Mims, Pasadena Unified School District; Jerome Pine, California Institute of Technology; Mary Colvard, Cobleskill-Richmondville High School; and Peter Bruns, Cornell University, discuss science outreach for teachers.

Outreach activities in the Cornell program include return-to-campus lectures and regional meetings at which Cornell faculty members are invited to lecture. Program extension associates travel around the state to conduct workshops for teachers; each workshop participant is charged with presenting the workshop twice to other groups of teachers, thus disseminating the materials and information more widely.

The CIBTnet communications network facilitates ongoing contact among teachers and between teachers and Cornell faculty. Such ongoing contact is essential for achieving systemic, sustainable change, said Colvard. Tangible results are already evident: New York teachers have developed a new hands-on, constructivist, and inquiry-based science curriculum and have designed an examination blueprint that incorporates essay questions, performance assessment, and use of student portfolios.

Another program benefit that is greatly appreciated by teachers, said Colvard, is the opportunity to obtain second-hand equipment when university laboratories upgrade their facilities. "Your trash is our treasure," she said.

Vellaccio and Barbara Swidler, an elementary school mathematics teacher in Worcester, Massachusetts, described the partnership program developed by the College of the Holy Cross and the Worcester public schools. The key program elements are a summer institute for teachers and one-year sabbaticals for selected teachers.

The Holy Cross and Cornell programs are both based on the assumption that teachers can best judge the kind of professional development training they need. The ultimate goals of both are to increase students' science literacy and enthusiasm for science and to encourage more students to seek further education or careers in science. However, these outcomes are extremely difficult to measure at the local level, said Vellaccio, for reasons that include student mobility, the need for a long time frame, and the influence of other uncontrolled variables on student learning.

Teacher outcomes—such as subject matter knowledge, self confidence, and the ability to use hands-on approaches, collaborative learning techniques, and educational technology—are measured by a variety of means, including interviews and monitoring of participants' classroom teaching to observe the degree to which they have integrated the newly learned approaches into their instructional style. Classroom time spent teaching science can also be measured. "We are confident that if we get the desired teacher outcomes, they will lead to the desired student outcomes," said Vellaccio.

Teachers on sabbatical were replaced in the classroom by recent Holy Cross science graduates who were not certified teachers. This approach would not have been permitted in many other states, which require a certified teacher to be in the classroom at all times. One unexpected benefit of the program, said Vellaccio, was that some of the uncertified student teachers were inspired to obtain their certification and pursue teaching careers.

Sarah Elgin commented that introducing teachers to a hands-on, inquiry-based approach to science teaching can conflict with the imperative to cover a large amount of material. "Is it better to teach one scientific concept well, or is it necessary to cover everything?" she asked. Other speakers noted that precollege teachers need a broad, but not necessarily deep, understanding of scientific concepts and that college-level science courses geared to their needs are difficult to find.

Mark Jacobs, Swarthmore College, pointed out a need to provide financial incentives for faculty to become involved in summer institutes for precollege teachers. High school teachers are paid to attend a summer institute at Swarthmore, he said, because the college successfully argued that teachers need to earn money during the summer to support their families. However, the Swarthmore professors who work with the teachers are unpaid.

Programs for Preservice Teachers

Studies have shown that elementary school teachers tend to avoid science, spending little classroom time on the subject, and that students begin to lose interest in science by the fourth grade. Such findings prompted the University of Nebraska-Lincoln to focus its precollege outreach efforts on revising science instruction for preservice elementary education majors.

George Veomett, program director, and Cindy Mahler, a student majoring in elementary education at the University of Nebraska–Lincoln, described the characteristics of the four hands-on science courses (in biology, chemistry, physics, and earth science) developed so far: an emphasis on both process and content; a classroom environment that emphasizes success; use of cooperative learning groups; and multiple bases for student assessment, including test scores, self-assess-

Frank Vellaccio (left), and Barbara Swidler, College of the Holy Cross; Raymond Bacchetti, William and Flora Hewlett Foundation; and Cindy Mahler and George Veomett, University of Nebraska–Lincoln, participated in a workshop discussion on assessing science teacher training.

ments, and reports from student-teacher supervisors.

Assessment data are available for the hands-on biology course, which was developed first and has been taken by the greatest number of students. In addition to assessing content knowledge, the program has also endeavored to assess student-teachers' comfort level and enthusiasm about teaching science. The data suggest that the course has positively affected preservice teachers' attitudes toward science and confidence in their ability to teach science, said Veomett.

Jerome Pine, California Institute of Technology (Caltech), and Sandra Mims, an elementary school teacher in the Pasadena Unified School District, described a preservice teacher-training program in biology and physics that was developed collaboratively by teachers, Caltech scientists, and faculty of the Claremont Graduate School in Los Angeles.

The course, which was based on cooperative learning techniques and class discussion and included no lectures, was team-taught by a master elementary school teacher and a member of Caltech's science faculty. Students were graded on the basis of projects, homework, science notebooks, and class participation. Two trial runs of the course at Caltech enabled refinements to be made before the course was more widely disseminated.

Caltech employed Inverness Research Associates, a firm of professional evaluators, to assess the course. The evaluators conducted precourse interviews with course developers and students, organized classroom observations and focus groups, interviewed students during the course, and conducted follow-up interviews with both students and

California Institute of Technology: What to Assess?

The two topics in the preservice science course—in physics (sound) and biology (plants)—are taught in a laboratory through experimentation and discussion. Among the issues assessed are

- the effectiveness of the broad-based collaborative effort,
- the response of preservice elementary teachers to the course,
- the subject matter knowledge gained by students,
- the acceptance of the course for trials by other universities,
- the success of transfer to other faculty members, and
- the effect of the course on teachers after graduation.

faculty. A simple, inexpensive question to ask in program assessment, said Pine, is What did I want to achieve with this program that I didn't? Caltech is planning to do a follow-up study of 12 students who took the preservice course and 12 who did not.

The hands-on, collaborative-learning approaches being used in these programs, both in-service and preservice, are in line with the recommendations of the National Research Council's national science education standards, noted Nancy Devino. Charles Lytle, North Carolina State University, said that the adoption of such approaches leads to profound changes in student attitudes and class participation. He said that the most dramatic improvements are often seen in students who previously seemed the least interested in science.

Where responsibility lies for the education of precollege science teachers was a recurring topic of discussion. Some attendees contended that university science departments have abdicated responsibility by turning over science teacher education to the schools of education. That connection needs to be re-established, said Lytle.

Norman Hackerman noted that Texas had abolished the bachelor's

Norman Hackerman, Robert A. Welch Foundation, spoke at a workshop session on bridging programs.

Joseph Perpich (left) moderated a plenary review session featuring Susan Henry, Carnegie Mellon University; Mary Allen, Wellesley College; and Peter Bruns, Cornell University.

degree in education in 1989 in an effort to reassert the primacy of subject-matter degrees. As a result, the University of Texas at Austin has recently reintroduced teaching degrees in chemistry, physics, biology, and geology.

Summary

Assessment is an important management tool, not only to document success but also to enable ongoing program adjustment and improvement. The strongest programs are those that continually assess and adjust. To be most effective, assessment must be built in when programs are designed. In this way program managers are required to clearly define their goals and objectives and think about how they might measure the achievement of those intentions.

Science educators are still struggling to devise appropriate assessment tools to measure their programs' achievements. The most valuable information may come from long-term assessment, but such assessment is a challenge because of the resources it requires. Program managers can benefit from collaborations with cognitive and social scientists, statisticians, and education specialists who have expertise in assessment methodologies.

A consequence of science education reform is the recognition that traditional methods of evaluating the performance of students, teachers, and faculty members are no longer adequate. Because the goals, objectives, and target audiences of science education programs are extremely diverse, no one-size-fits-all technique exists for definitively answering the question How do you know that what you are doing makes a difference? The program directors meeting spotlighted the many creative ways in which HHMI-supported institutions are responding to change and endeavoring to assess the results of their efforts.

Appendices

Appendices

Agenda, Program Directors Meeting, September 30–October 2, 1996

Monday, September 30, 1996

Welcoming Remarks
HHMI Overview and Introduction of Keynote Speaker
Purnell Choppin
Keynote Address
Daniel Koshland

Tuesday, October 1, 1996

Session I

Plenary Panel Discussion: Baccalaureate and Beyond: Tracking the Science Pathway
Burroughs Wellcome Fund—Martha Peck
Duke University/Stanford University—Kristin Baldwin
Wellesley College—Mary Allen, Moderator, and Christine Birchwood
Xavier University of Louisiana/Harvard University School of Medicine—Keith Amos

Workshop Demonstrations and Discussions
Group 1—Taking a Different Route: Careers in Biotechnology Research
Lehigh University—Jeffrey Sands and Kathryn Goettge
Merck Company Foundation—Shuang Ruy Huang
University of Puerto Rico Rio Piedras Campus—Lillian Bird, Moderator, and Lucybeth Nieves
Group 2—Preparing Students for Research Careers
Colgate University—Nancy Pruitt and Tara Gupta
Alfred P. Sloan Foundation—Ted Greenwood
University of Hawaii—Christopher Womersley, Moderator, and Scott Santos
Group 3—Bridging Programs
Colorado College—Richard Storey
University of Miami—Michael Gaines, Moderator, and Beatriz Blanco
Robert A. Welch Foundation—Norman Hackerman

Session II

Plenary Panel Discussion: Assessing Science Partnerships
California Institute of Technology—Jerome Pine and Sandra Mims
Cornell University—Peter Bruns, Moderator, and Mary Colvard
Robert A. Welch Foundation—Norman Hackerman

Resource Group Meetings
Master's Colleges and Universities
Florida A&M University—Ken Harewood, Moderator
California State University–Northridge—Joyce Maxwell, Co-Moderator
Baccalaureate Colleges
Kenyon College—Joan Slonczewski, Moderator
Occidental College—Donald Goldberg, Co-Moderator
Research and Doctoral Universities
University of Texas at Austin—Mary Ann Rankin, Moderator
Tufts University—Ross Feldberg, Co-Moderator

Program Directors Forum
Point Loma Nazarene College—Darrel Falk, Moderator
SUNY at Binghamton—Anna Tan-Wilson, Co-Moderator

Wednesday, October 2, 1996

Session III

Plenary Panel Discussion: Tracking Faculty Careers
Carnegie Mellon University—Susan Henry, Moderator
Haverford College—Julio de Paula
Andrew W. Mellon Foundation—Elizabeth Duffy
University of Michigan–Ann Arbor—Janine Maddock
Workshop Demonstrations and Discussions
Group 1—Fostering Faculty Development
Research Corporation—Mary Grayeski
Swarthmore College—Mark Jacobs
University of Chicago—José Quintans, Moderator
University of South Dakota—Karen Olmstead
Group 2—Assessing Laboratory Development/Interdisciplinary Collaborations
Duke University—Charles Putman
Camille and Henry Dreyfus Foundation—Robert Lichter
Nebraska Wesleyan University—Dale Benham
University of California–Los Angeles—Frederick Eiserling, Moderator
Group 3—Assessing Science Teacher Training
College of the Holy Cross—Frank Vellaccio, Moderator, and Barbara Swidler
William and Flora Hewlett Foundation—Raymond Bacchetti
University of Nebraska–Lincoln—George Veomett and Cindy Mahler

Plenary Review
Summary of Key Issues
Mary Allen, Peter Bruns, Susan Henry, and Joseph G. Perpich

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Mary E. McKelvey Welch, Ph.D.
Professor and Chair
Department of Biology
Fisk University

Christopher Z. Womersley, Ph.D.
Professor of Zoology
Department of Zoology
University of Hawaii at Manoa

Terry Woodin, Ph.D.
Program Director
Division of Undergraduate Education
National Science Foundation

Robert J. Wyman, Ph.D.
Professor of Biology
Biology Department
Yale University

Jill Yager, Ph.D
Chair, Biology Department
Associate Professor of Environmental Science
Antioch University

Robert Yuan, Ph.D.
Professor
Department of Microbiology
University of Maryland

Undergraduate Biological Sciences Education Program—1988 Awards

Allegheny College, Meadville, Pennsylvania	$900,000
Amherst College, Amherst, Massachusetts	500,000
Bryn Mawr College, Bryn Mawr, Pennsylvania	800,000
Bucknell University, Lewisburg, Pennsylvania	700,000
Carleton College, Northfield, Minnesota	800,000
Clark Atlanta University, Atlanta, Georgia	700,000
College of Wooster, Wooster, Ohio	1,000,000
Colorado College, Colorado Springs, Colorado	800,000
Davidson College, Davidson, North Carolina	700,000
DePauw University, Greencastle, Indiana	600,000
Dillard University, New Orleans, Louisiana	400,000
Earlham College, Richmond, Indiana	750,000
Franklin & Marshall College, Lancaster, Pennsylvania	400,000
Grinnell College, Grinnell, Iowa	400,000
Hampshire College, Amherst, Massachusetts	400,000
Hampton University, Hampton, Virginia	600,000
Haverford College, Haverford, Pennsylvania	1,200,000
Howard University, Washington, D.C.	900,000
Kenyon College, Gambier, Ohio	500,000
Lincoln University, Lincoln University, Pennsylvania	700,000
Macalester College, Saint Paul, Minnesota	800,000
Marlboro College, Marlboro, Vermont	400,000
Middlebury College, Middlebury, Vermont	400,000
Millsaps College, Jackson, Mississippi	600,000
Morehouse College, Atlanta, Georgia	400,000
Morgan State University, Baltimore, Maryland	400,000
Mount Holyoke College, South Hadley, Massachusetts	400,000
Oakwood College, Huntsville, Alabama	400,000
Oberlin College, Oberlin, Ohio	900,000
Occidental College, Los Angeles, California	500,000
Pomona College, Claremont, California	500,000
Rhodes College, Memphis, Tennessee	700,000
Saint Olaf College, Northfield, Minnesota	600,000
Smith College, Northampton, Massachusetts	400,000
Swarthmore College, Swarthmore, Pennsylvania	900,000
Tuskegee University, Tuskegee, Alabama	900,000
Union College, Schenectady, New York	900,000
Vassar College, Poughkeepsie, New York	700,000
Wabash College, Crawfordsville, Indiana	900,000
Wake Forest University, Winston-Salem, North Carolina	800,000
Wellesley College, Wellesley, Massachusetts	750,000
Wesleyan University, Middletown, Connecticut	1,200,000
Whitman College, Walla Walla, Washington	400,000
Xavier University of Louisiana, New Orleans, Louisiana	1,800,000
Total	**$30,400,000**

Undergraduate Biological Sciences Education Program—1989 Awards

Brown University, Providence, Rhode Island	$1,000,000
Carnegie Mellon University, Pittsburgh, Pennsylvania	1,200,000
Case Western Reserve University, Cleveland, Ohio	1,200,000
City University of New York City College, New York, New York	1,400,000
College of William and Mary, Williamsburg, Virginia	1,000,000
Colorado State University, Fort Collins, Colorado	1,500,000
Columbia University, New York, New York	1,000,000
Cornell University, Ithaca, New York	2,000,000
Dartmouth College, Hanover, New Hampshire	1,000,000
Duke University, Durham, North Carolina	1,500,000
Emory University, Atlanta, Georgia	1,000,000
Indiana University at Bloomington, Bloomington, Indiana	2,000,000
Johns Hopkins University, Baltimore, Maryland	1,000,000
Lehigh University, Bethlehem, Pennsylvania	1,000,000
Louisiana State University and A&M College, Baton Rouge, Louisiana	1,000,000
Massachusetts Institute of Technology, Cambridge, Massachusetts	1,000,000
Miami University, Oxford, Ohio	1,000,000
New York University, New York, New York	1,200,000
Ohio State University, Columbus, Ohio	1,200,000
Pennsylvania State University Main Campus, University Park, Pennsylvania	1,200,000
Princeton University, Princeton, New Jersey	1,000,000
Purdue University Main Campus, West Lafayette, Indiana	1,000,000
Rensselaer Polytechnic Institute, Troy, New York	1,000,000
Rice University, Houston, Texas	1,000,000
Stanford University, Stanford, California	1,000,000
Stevens Institute of Technology, Hoboken, New Jersey	1,000,000
Tufts University, Medford, Massachusetts	1,500,000
University of Arizona, Tucson, Arizona	1,500,000
University of California–Davis, Davis, California	1,200,000
University of California–Irvine, Irvine, California	1,200,000
University of California–San Diego, San Diego, California	1,200,000
University of California–Santa Cruz, Santa Cruz, California	1,000,000
University of Chicago, Chicago, Illinois	2,000,000
University of Colorado, Colorado Springs, Colorado	2,000,000
University of Illinois at Chicago, Chicago, Illinois	1,000,000
University of Illinois at Urbana–Champaign, Urbana, Illinois	1,500,000
University of Kansas Main Campus, Lawrence, Kansas	1,000,000
University of Minnesota–Twin Cities, Minneapolis, Minnesota	1,000,000
University of Missouri–Columbia, Columbia, Missouri	1,000,000
University of North Carolina at Chapel Hill, Chapel Hill, North Carolina	1,500,000
University of Pennsylvania, Philadelphia, Pennsylvania	1,200,000
University of Puerto Rico Rio Piedras Campus, Rio Piedras, Puerto Rico	1,200,000
University of Southern California, Los Angeles, California	1,000,000
University of Texas at Austin, Austin, Texas	1,000,000

University of Utah
Salt Lake City, Utah 1,200,000

University of Vermont
Burlington, Vermont 1,000,000

University of Virginia
Charlottesville, Virginia 1,000,000

University of Washington
Seattle, Washington 1,000,000

University of Wisconsin–Madison
Madison, Wisconsin 1,200,000

Wayne State University
Detroit, Michigan 1,200,000

Yale University
New Haven, Connecticut 1,000,000

Total $61,000,000

Undergraduate Biological Sciences Education Program—1991 Awards

Antioch University, Yellow Springs, Ohio	$600,000
Barnard College, New York, New York	900,000
Bates College, Lewiston, Maine	900,000
Beloit College, Beloit, Wisconsin	650,000
California State University–Long Beach, Long Beach, California	750,000
California State University–Los Angeles, Los Angeles, California	800,000
Calvin College, Grand Rapids, Michigan	500,000
Canisius College, Buffalo, New York	700,000
Centre College, Danville, Kentucky	500,000
City University of New York Brooklyn College, Brooklyn, New York	1,200,000
City University of New York Queens College, Flushing, New York	1,100,000
Colby College, Waterville, Maine	1,000,000
Colgate University, Hamilton, New York	900,000
College of the Holy Cross, Worcester, Massachusetts	600,000
Cooper Union, New York, New York	750,000
Eckerd College, St. Petersburg, Florida	550,000
Fisk University, Nashville, Tennessee	700,000
Fort Lewis College, Durango, Colorado	800,000
Gettysburg College, Gettysburg, Pennsylvania	850,000
Goucher College, Towson, Maryland	500,000
Hamilton College, Clinton, New York	700,000
Harvey Mudd College, Claremont, California	500,000
Hiram College, Hiram, Ohio	700,000
Hope College, Holland, Michigan	750,000
Illinois Benedictine College, Lisle, Illinois	500,000
Jackson State University, Jackson, Mississippi	700,000
Juniata College, Huntingdon, Pennsylvania	900,000
King College, Bristol, Tennessee	500,000
Knox College, Galesburg, Illinois	500,000
Lafayette College, Easton, Pennsylvania	600,000
Lawrence University, Appleton, Wisconsin	700,000
Manhattan College, Riverdale, New York	500,000
Nebraska Wesleyan University, Lincoln, Nebraska	500,000
Ohio Wesleyan University, Delaware, Ohio	700,000
Reed College, Portland, Oregon	1,000,000
San Diego State University, San Diego, California	1,200,000
Spelman College, Atlanta, Georgia	900,000
University of Puerto Rico Mayaguez Campus, Mayaguez, Puerto Rico	500,000
University of Scranton, Scranton, Pennsylvania	700,000
University of Texas at San Antonio, San Antonio, Texas	650,000
University of the South, Sewanee, Tennessee	500,000
Ursinus College, Collegeville, Pennsylvania	500,000
Villanova University, Villanova, Pennsylvania	650,000
Williams College, Williamstown, Massachusetts	900,000
Total	**$31,500,000**

Undergraduate Biological Sciences Education Program—1992 Awards

Arizona State University Tempe, Arizona	$1,500,000
Auburn University Auburn University, Alabama	1,000,000
Boston University Boston, Massachusetts	1,000,000
Brandeis University Waltham, Massachusetts	1,400,000
California Institute of Technology Pasadena, California	2,000,000
Georgetown University Washington, D.C.	1,000,000
Harvard University Cambridge, Massachusetts	1,100,000
Illinois Institute of Technology Chicago, Illinois	1,000,000
Iowa State University Ames, Iowa	1,300,000
Kansas State University Manhattan, Kansas	1,200,000
Marquette University Milwaukee, Wisconsin	1,200,000
Michigan State University East Lansing, Michigan	1,200,000
North Carolina State University Raleigh, North Carolina	1,000,000
Oklahoma State University Stillwater, Oklahoma	2,000,000
Rutgers the State University of New Jersey Newark Campus, Newark, New Jersey	1,200,000
State University of New York at Albany Albany, New York	1,200,000
State University of New York at Binghamton Binghamton, New York	1,500,000
Texas Tech University Lubbock, Texas	1,300,000
University of California–Berkeley Berkeley, California	2,000,000
University of California–Los Angeles Los Angeles, California	1,300,000
University of California–Santa Barbara Santa Barbara, California	1,000,000
University of Cincinnati Cincinnati, Ohio	1,000,000
University of Delaware Newark, Delaware	1,000,000
University of Georgia Athens, Georgia	1,400,000
University of Hawaii at Manoa Manoa, Hawaii	1,000,000
University of Iowa Iowa City, Iowa	1,100,000
University of Kentucky Lexington, Kentucky	1,000,000
University of Maryland College Park College Park, Maryland	1,300,000
University of Massachusetts at Amherst Amherst, Massachusetts	1,200,000
University of Michigan–Ann Arbor Ann Arbor, Michigan	1,400,000
University of Nebraska–Lincoln Lincoln, Nebraska	1,000,000
University of Nevada, Reno Reno, Nevada	1,100,000
University of New Mexico Albuquerque, New Mexico	1,000,000
University of Notre Dame Notre Dame, Indiana	1,500,000
University of Oregon Eugene, Oregon	1,000,000
University of Pittsburgh, Pittsburgh Campus Pittsburgh, Pennsylvania	1,700,000
University of Rochester Rochester, New York	1,000,000
University of South Carolina–Columbia Columbia, South Carolina	1,000,000
Vanderbilt University Nashville, Tennessee	1,200,000
Washington State University Pullman, Washington	1,500,000
Washington University Saint Louis, Missouri	1,700,000
West Virginia University Morgantown, West Virginia	1,000,000
Total	**$52,500,000**

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 Herbert H. Lehman College
Bronx, New York 500,000

City University of New York Hunter College
New York, New York 650,000

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

Total $28,500,000

Undergraduate Biological Sciences Education Program—1994 Awards

Arizona State University, Tempe, Arizona	$1,000,000
Auburn University, Auburn University, Alabama	1,000,000
Boston University, Boston, Massachusetts	1,200,000
Brown University, Providence, Rhode Island	1,500,000
California Institute of Technology, Pasadena, California	1,200,000
Carnegie Mellon University, Pittsburgh, Pennsylvania	1,500,000
Case Western Reserve University, Cleveland, Ohio	2,000,000
Catholic University of America, Washington, D.C.	1,200,000
Cornell University, Ithaca, New York	2,000,000
Dartmouth College, Hanover, New Hampshire	1,800,000
Duke University, Durham, North Carolina	1,800,000
Emory University, Atlanta, Georgia	1,200,000
Georgia Institute of Technology, Atlanta, Georgia	1,000,000
Harvard University, Massachusetts	1,000,000
Howard University, Washington, D.C	1,800,000
Johns Hopkins University, Baltimore, Maryland	1,800,000
Lehigh University, Bethlehem, Pennsylvania	1,500,000
Louisiana State University and A&M College, Baton Rouge, Louisiana	1,200,000
Massachusetts Institute of Technology, Cambridge, Massachusetts	1,600,000
Miami University, Oxford, Ohio	1,000,000
Mississippi College, Clinton, Mississippi	1,000,000
New York University, New York, New York	1,300,000
Oklahoma State University Main Campus, Stillwater, Oklahoma	1,000,000
Oregon State University, Corvallis, Oregon	2,000,000
Pennsylvania State University Main Campus, University Park, Pennsylvania	1,000,000
Princeton University, Princeton, New Jersey	1,300,000
Rice University, Houston, Texas	1,600,000
Rutgers the State University of New Jersey, New Brunswick Campus, New Brunswick, New Jersey	1,400,000
Stanford University, Stanford, California	1,800,000
State University of New York at Binghamton, Binghamton, New York	1,000,000
State University of New York at Buffalo, Buffalo, New York	1,500,000
State University of New York at Stony Brook, Stony Brook, New York	1,000,000
Temple University, Philadelphia, Pennsylvania	1,200,000
Texas A&M University, College Station, Texas	1,700,000
Texas Tech University, Lubbock, Texas	1,000,000
Tufts University, Medford, Massachusetts	1,800,000
University of Arizona, Tucson, Arizona	2,000,000
University of Arkansas Main Campus, Fayetteville, Arkansas	1,000,000
University of California–Davis, Davis, California	2,000,000
University of California–San Diego, San Diego, California	1,100,000
University of Chicago, Chicago, Illinois	1,800,000
University of Colorado at Boulder, Boulder, Colorado	1,800,000
University of Georgia, Athens, Georgia	1,000,000
University of Illinois at Urbana–Champaign, Urbana, Illinois	1,200,000
University of Iowa, Iowa City, Iowa	1,000,000
University of Massachusetts at Amherst, Amherst, Massachusetts	1,000,000

University of Miami Coral Gables, Florida	2,000,000
University of Missouri–Columbia Columbia, Missouri	1,300,000
University of Nebraska–Lincoln Lincoln, Nebraska	1,000,000
University of New Orleans New Orleans, Louisiana	1,500,000
University of North Carolina at Chapel Hill Chapel Hill, North Carolina	2,000,000
University of North Dakota Main Campus Grand Forks, North Dakota	1,600,000
University of South Dakota Vermillion, South Dakota	1,100,000
University of Tennessee Knoxville, Tennessee	1,400,000
University of Texas at Austin Austin, Texas	1,000,000
University of Washington Seattle, Washington	1,800,000
University of Wisconsin–Madison Madison, Wisconsin	1,000,000
Utah State University Logan, Utah	1,400,000
Vanderbilt University Nashville, Tennessee	1,000,000
Washington University Saint Louis, Missouri	1,400,000
Wayne State University Detroit, Michigan	1,100,000
Yale University New Haven, Connecticut	1,600,000
Total	**$86,000,000**

Undergraduate Biological Sciences Education Program—1996 Awards

Allegheny College Meadville, Pennsylvania	$600,000
Bard College Annandale-on-Hudson, New York	600,000
Barnard College New York, New York	1,100,000
Bates College Lewiston, Maine	600,000
Beloit College Beloit, Wisconsin	1,200,000
Benedictine University Lisle, Illinois	600,000
Bryn Mawr College Bryn Mawr, Pennsylvania	1,000,000
Canisius College Buffalo, New York	650,000
Carleton College Northfield, Minnesota	650,000
Centenary College of Louisiana Shreveport, Louisiana	600,000
City University of New York Brooklyn College Brooklyn, New York	1,200,000
City University of New York Queens College Flushing, New York	600,000
Colby College Waterville, Maine	1,000,000
Colgate University Hamilton, New York	650,000
College of the Holy Cross Worcester, Massachusetts	1,100,000
Colorado College Colorado Springs, Colorado	750,000
Davidson College Davidson, North Carolina	650,000
Earlham College Richmond, Indiana	600,000
Florida A&M University Tallahassee, Florida	700,000
Hampshire College Amherst, Massachusetts	1,300,000
Haverford College Haverford, Pennsylvania	750,000
Hope College Holland, Michigan	700,000
Humboldt State University Arcata, California	650,000
Kenyon College Gambier, Ohio	1,500,000
Lawrence University Appleton, Wisconsin	800,000
Macalester College Saint Paul, Minnesota	1,000,000
Middlebury College Middlebury, Vermont	650,000
Mount Holyoke College South Hadley, Massachusetts	900,000
Nebraska Wesleyan University Lincoln, Nebraska	1,200,000
Oakland University Rochester, Michigan	600,000
Oberlin College Oberlin, Ohio	600,000
Occidental College Los Angeles, California	800,000
Ohio Wesleyan University Delaware, Ohio	650,000
Point Loma Nazarene College San Diego, California	750,000
Pomona College Claremont, California	900,000
Reed College Portland, Oregon	700,000
St. John's College Annapolis, Maryland	1,000,000
St. Mary's University San Antonio, Texas	600,000
Saint Olaf College Northfield, Minnesota	1,300,000
Smith College Northampton, Massachusetts	1,600,000
Spelman College Atlanta, Georgia	800,000
Swarthmore College Swarthmore, Pennsylvania	1,200,000
Tuskegee University Tuskegee, Alabama	600,000
University of Texas at San Antonio San Antonio, Texas	750,000
Villanova University Villanova, Pennsylvania	1,600,000
Washington and Jefferson College Washington, Pennsylvania	600,000
Wellesley College Wellesley, Massachusetts	1,500,000
Wesleyan University Middletown, Connecticut	750,000
Western Maryland College Westminster, Maryland	700,000
Whitman College Walla Walla, Washington	600,000
Williams College, Williamstown, Massachusetts	900,000
Xavier University of Louisiana New Orleans, Louisiana	1,600,000
Total	**$45,400,000**

Undergraduate Biological Sciences Education Program Awardee Institutions by Carnegie Classification, 1992–1996*

Carnegie Classifications

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 1992–1994 competitions were based on the 1987 Carnegie Foundation classifications and, for the 1996 competition, on the 1994 classifications.* The following classifications and categorical definitions were used for the 1992–1996 competitions, which included both public and private institutions:

Research Universities I (1992–1994 competitions): These institutions offer a full range of baccalaureate programs, are committed to graduate education through the doctorate, and give high priority to research. They award 50 or more doctoral degrees each year. In addition, they receive annually $40 million or more in federal support.

Research Universities II (1992–1994 competitions): These institutions offer a full range of baccalaureate programs, are committed to graduate education through the doctorate, and give high priority to research. They award 50 or more doctoral degrees each year. In addition, they receive annually between $15.5 million and $40 million in federal support.

Doctoral Universities I or Doctorate-Granting Universities I (1992–1994 competitions): These institutions offer a full range of baccalaureate programs and are committed to graduate education through the doctorate. They award at least 40 doctoral degrees annually in five or more disciplines.

Doctoral Universities II or Doctorate-Granting Universities II (1992–1994 competitions): These institutions offer a full range of baccalaureate programs and are committed to graduate education through the doctorate. They award annually at least 10 doctoral degrees—in three or more disciplines—or 20 or more doctoral degrees in one or more disciplines.

Master's Colleges and Universities I (1996 competition) or Comprehensive Universities and Colleges I (1993 competition): These institutions offer a full range of baccalaureate programs and are committed to graduate education through the master's degree. They award 40 or more master's degrees annually in three or more disciplines.

Master's Colleges and Universities II (1996 competition) or Comprehensive Universities and Colleges II (1993 competition): These institutions offer a full range of baccalaureate programs and are committed to graduate education through the master's degree. They award 20 or more master's degrees annually in one or more disciplines.

Baccalaureate Colleges I (1996 competition) or Liberal Arts Colleges I (1993 competition): These institutions are primarily undergraduate colleges with major emphasis on baccalaureate degree programs. They award 40 percent or more of their baccalaureate degrees in liberal arts fields and are restrictive in admissions.

Baccalaureate Colleges II (1996 competition) or Liberal Arts Colleges II (1993 competition): These institutions are primarily undergraduate colleges with major emphasis on baccalaureate degree programs. They award less than 40 percent of their baccalaureate degrees in liberal arts fields or are less restrictive in admissions.

*Further information may be found in *Classification of Institutions of Higher Education*, Carnegie Foundation for the Advancement of Teaching, Princeton, N.J., 1994

Research Universities I

Arizona State University
Boston University
Brown University
California Institute of Technology
Carnegie Mellon University
Case Western Reserve University
Cornell University
Duke University
Emory University
Georgia Institute of Technology
Georgetown University
Harvard University
Howard University
Iowa State University
Johns Hopkins University
Louisiana State University and A&M College
Massachusetts Institute of Technology
Michigan State University
New York University
North Carolina State University
Oregon State University
Pennsylvania State University Main Campus
Princeton University
Rutgers the State University of New Jersey New Brunswick Campus
Stanford University
State University of New York at Albany
State University of New York at Stony Brook
Temple University
Texas A&M University
Tufts University
University of Arizona
University of California–Berkeley
University of California–Davis
University of California–Los Angeles
University of California–San Diego
University of California–Santa Barbara
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 Urbana–Champaign
University of Iowa
University of Kansas Main Campus
University of Kentucky
University of Maryland College Park
University of Massachusetts at Amherst
University of Miami
University of Michigan–Ann Arbor
University of Missouri–Columbia
University of Nebraska–Lincoln
University of New Mexico Main Campus
University of North Carolina at Chapel Hill
University of Pittsburgh, Pittsburgh Campus
University of Rochester
University of Tennessee, Knoxville
University of Texas at Austin
University of Washington
University of Wisconsin–Madison
Utah State University
Vanderbilt University
Washington University
Wayne State University
West Virginia University
Yale University

Research Universities II

Auburn University
Brandeis University
Kansas State University
Lehigh University
Oklahoma State University Main Campus
Rice University
State University of New York at Albany
University of Arkansas Main Campus
University of Delaware
University of Notre Dame
University of Oregon
University of South Carolina–Columbia
Washington State University

Doctoral Universities I

Catholic University of America
Clark Atlanta University
Illinois Institute of Technology
Marquette University
Miami University
State University of New York at Binghamton

Doctoral Universities II

Dartmouth College
San Diego State University
Rutgers the State University of New Jersey Newark Campus

University of Nevada, Reno
University of New Orleans
University of North Dakota Main Campus
University of Puerto Rico Rio Piedras Campus
University of South Dakota

Master's Universities and Colleges I

Benedictine University
California State University–Los Angeles
California State University–Northridge
Canisius College
Centenary College of Louisiana
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
Concordia College–Moorhead
Florida A&M University
Hampton University
Humboldt State University
Mississippi College
Oakland University
Saint Joseph's University
St. Mary's University
Southern University and A&M College at Baton Rouge
Tuskegee University
University of Puerto Rico Mayaguez Campus
University of Texas at El Paso
University of Texas at San Antonio
Villanova University
Xavier University of Louisiana

Master's Universities and Colleges II

Point Loma Nazarene College

Baccalaureate Colleges I

Allegheny College
Amherst College
Bard College
Barnard College
Bates College
Beloit College
Bowdoin College
Bryn Mawr College
Carleton College
Colby College
Colgate University
College of the Holy Cross
Colorado College
Davidson College
Earlham College
Gettysburg College
Hampshire College
Haverford College
Hobart and William Smith Colleges
Hope College
Kenyon College
Knox College
Lawrence University
Macalester College
Middlebury College
Morehouse College
Mount Holyoke College
Nebraska Wesleyan University
Oberlin College
Occidental College
Ohio Wesleyan University
Pomona College
Reed College
St. John's College
Saint Olaf College
Smith College
Spelman College
Swarthmore College
Union College
University of Puerto Rico Cayey University College
Ursinus College
Washington and Jefferson College
Wellesley College
Wesleyan University
Western Maryland College
Wheaton College
Whitman College
Williams College
Wofford College

Baccalaureate Colleges II

Fisk University
Fort Lewis College
Tougaloo College

Undergraduate Biological Sciences Education Program Awardee Minority Institutions, 1993–1996

In the assessment of institutions for the 1993 and 1996 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
Fisk University
Florida A&M University
Hampton University
Howard University
Morehouse 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–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, 1992–1996

Alabama
Auburn University, Auburn University
Tuskegee University, Tuskegee

Arizona
Arizona State University, Tempe
University of Arizona, Tucson

Arkansas
University of Arkansas Main Campus, Fayetteville

California
California Institute of Technology, Pasadena
California State University–Los Angeles
California State University–Northridge
Humboldt State University, Arcata
Occidental College, Los Angeles
Point Loma Nazarene, San Diego
Pomona College, Claremont
San Diego State University, San Diego
Stanford University, Stanford
University of California–Berkeley
University of California–Davis
University of California–Los Angeles
University of California–San Diego, La Jolla
University of California–Santa Barbara

Colorado
Colorado College, Colorado Springs
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
Catholic University of America, Washington, D.C.
Georgetown University, Washington, D.C.
Howard University, Washington, D.C.

Florida
Florida A&M University, Tallahassee
University of Miami, Coral Gables

Georgia
Clark Atlanta University, Atlanta
Emory University, Atlanta
Georgia Institute of Technology, Athens
Morehouse College, Atlanta
Spelman College, Atlanta
University of Georgia, Athens

Hawaii
University of Hawaii at Manoa, Honolulu

Illinois
Benedictine University, Lisle
Illinois Institute of Technology, Chicago
Knox College, Galesburg
University of Chicago, Chicago
University of Illinois at Urbana-Champaign, Urbana
Wheaton College, Wheaton

Indiana
Earlham College
University of Notre Dame, Notre Dame

Iowa
Iowa State University, Ames
University of Iowa, Iowa City

Kansas
Kansas State University, Manhattan

Kentucky
University of Kentucky, Lexington

Louisiana
Centenary College of Louisiana, Shreveport
Louisiana State University and A&M College, Baton Rouge
Southern University and A&M College at Baton Rouge

University of New Orleans
Xavier University of Louisiana, New Orleans

Maine
Bates College, Lewiston
Bowdoin College, Brunswick
Colby College, Waterville

Maryland
Johns Hopkins University, Baltimore
St. John's College, Annapolis
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
Hope College, Holland
Michigan State University, East Lansing
Oakland University, Rochester
University of Michigan–Ann Arbor
Wayne State University, Detroit

Minnesota
Carleton College, Northfield
Concordia College–Moorhead
Macalester College, St. Paul
Saint Olaf College, Northfield

Mississippi
Mississippi College, Clinton
Tougaloo College, Tougaloo

Missouri
University of Missouri–Columbia
Washington University, Saint 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
Rutgers the State University of New Jersey New Brunswick Campus

New Mexico
University of New Mexico Main Campus, Albuquerque

New York
Bard College, Annandale-on-Hudson
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
Cornell University, Ithaca
Hobart and William Smith Colleges, Geneva
New York University, New York City
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
Union College, Schenectady
University of Rochester, Rochester

North Carolina
Davidson College, Davidson
Duke University, Durham
North Carolina State University, Raleigh
University of North Carolina at Chapel Hill

North Dakota
University of North Dakota, Grand Forks

Ohio
Case Western Reserve University, Cleveland
Kenyon College, Gambier
Miami University, Oxford
Oberlin College, Oberlin
Ohio Wesleyan University, Delaware
University of Cincinnati Main Campus, Cincinnati

Oklahoma
Oklahoma State University Main Campus, Stillwater

Oregon
Oregon State University, Corvallis
Reed College, Portland
University of Oregon, Eugene

Pennsylvania
Allegheny College, Meadville
Bryn Mawr College, Bryn Mawr
Carnegie Mellon University, Pittsburgh
Gettysburg College, Gettysburg
Haverford College, Haverford
Lehigh University, Bethlehem
Pennsylvania State University Main Campus, University Park
Saint Joseph's University, Philadelphia
Swarthmore College, Swarthmore
Temple University, Philadelphia
University of Pittsburgh, Pittsburgh Campus
Ursinus College, Collegeville
Villanova University, Villanova
Washington and Jefferson College, Washington

Rhode Island
Brown University, Providence

South Carolina
University of South Carolina–Columbia
Wofford College, Spartanburg

South Dakota
University of South Dakota, Vermillion

Tennessee
Fisk University, Nashville
University of Tennessee, Knoxville
Vanderbilt University, Nashville

Texas
Rice University, Houston
St. Mary's University, San Antonio
Texas A&M University, College Station
Texas Tech University, Lubbock
University of Texas at Austin
University of Texas at El Paso
University of Texas at San Antonio

Utah
Utah State University, Logan

Vermont
Middlebury College, Middlebury

Virginia
Hampton University, Hampton

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

General Publications

Grants for Science Education (annual)
Community Partnerships in Science Education, Washington, D.C., Metropolitan Area Precollege Science Education Initiatives (annual)
Fact Sheet on HHMI Grants Programs (program and technological orientations) (annual)
Holiday Lectures Brochures (annual)
Da Vinci and Darwin in the Molecules of Life, Stephen K. Burley, M.D., D.Phil., and John Kuriyan, Ph.D., 1993
Genes, Gender, and Genetic Disorders, Shirley M. Tilghman, Ph.D., and Robert L. Nussbaum, M.D., 1994
The Double Life of RNA, Thomas R. Cech, Ph.D., 1995
The Immune System–Friend and Foe, John W. Kappler, Ph.D., and Philippa Marrack, Ph.D., 1996

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 (biennial)
Precollege and Public Science Education Program
Precollege Science Education Program (biennial)
Research Resources for Medical Schools Program
Research Resources for Medical Schools Program
International Program
International Program (biennial)

Information Booklets (available only to grantees)

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 and Biomedical Research Institutions Awarded Precollege Grants (biennial)
Research Resources for Medical Schools Program
Research Resources for Medical Schools Program (biennial)
International Program
Information for International Research Scholars and Grantee Institutions (biennial)

Meetings of Grantees

Graduate Education Fellows Meetings
Meeting of Medical Student Fellows, Program and Abstracts (annual)
Meeting of Predoctoral and Physician Postdoctoral Fellows, Program and Abstracts (annual)
Undergraduate Program Directors Meetings
Attracting Students to Science: Undergraduate and Precollege Programs, 1992
Enriching the Undergraduate Laboratory Experience, 1993
Institutional Strategies for Enhancing Undergraduate Science Education, 1993
Science Education: Expanding the Role of Science Departments, 1994
New Tools for Science Education, 1995
Precollege Science Education Program
Precollege Program Directors Meetings
Science Museums: Creating Partnerships in Science Education, 1994
Science Museums: Enlisting Communities in Science Education Partnerships, 1995
Meeting the Challenges of Science Education Reform, 1996
International Program
Scientific Meeting of International Research Scholars from the Baltics, Central Europe, and the Former Soviet Union, Program, Abstracts, and Directory, 1996
Local
Student and Teacher Internship Program
Meeting of the Montgomery County Public Schools Student and Teacher Interns at the National Institutes of Health (brochure, annual)

Program Directories

Graduate Science Education Program
Directory of Predoctoral Fellows (pending)
Directory of Medical Student Fellows (pending)
Directory of Physician Postdoctoral Fellows (pending)
Undergraduate Biological Sciences Education Program
Undergraduate Program Directory (periodic)
Precollege Science Education Program
Precollege Science Education Program Directory (periodic)
Research Resources for Medical Schools Program
Research Resources Program Directory (periodic)
International Program
International Research Scholars Program Directory (periodic) (See Meetings of Grantees, International Program)
Many of these publications have been redesigned and edited for use on the Grants Web pages. The Institute's home page can be accessed at http://www.hhmi.org

Publications on the HHMI Grants Program may be requested from

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