DOCUMENT RESUME

ED 426 848 SE 060 883

TITLE	Grants for Science Education 1997. Including Grants for Research Resources in the United States and for Biomedical Scientists Abroad.
INSTITUTION	Howard Hughes Medical Inst., Chevy Chase, MD. Office of Grants and Special Programs.
PUB DATE	1997-00-00
NOTE	171p.
AVAILABLE FROM	Howard Hughes Medical Institute, Office of Grants and Special Programs, 4000 Jones Bridge Road, Chevy Chase, MD 20815-6789.
PUB TYPE	Reports - Descriptive (141)
EDRS PRICE	MF01/PC07 Plus Postage.
DESCRIPTORS	Biology; Biomedicine; Elementary Secondary Education; *Financial Support; Higher Education; Minority Groups; Program Evaluation; Science Curriculum; *Science Education; *Scientific Research; *Student Research; *Undergraduate Study
IDENTIFIERS	Howard Hughes Medical Institute MD

ABSTRACT

The data presented in this document provide information about those individuals and organizations that received funding from the Howard Hughes Medical Institute in 1997. Following a description of the Howard Hughes Medical Institute programs, details on the funding of graduate science education, undergraduate biological sciences education, precollege and public science education, holiday lectures on science, research resources, international programs, and program assessment are provided. Also included are descriptions of the policies and procedures for grant applications. (DDR)

Howard Hughes Medical Institute

Grants for Science Education

1997

Office of Grants and Special Programs

Howard Hughes Medical Institute World Wide Web Site Index

The contributions of Bill Carrigan, Judy Dickson, Kathi Hanna, Eleanor Mayfield, and Robert Taylor to this report are gratefully acknowledged.

Grants for Science Education

1997

Including grants for research resources in the United States and for biomedical scientists abroad

Howard Hughes Medical Institute
4000 Jones Bridge Road
Chevy Chase, MD 20815-6789

Contents

Figures

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, it employs more than 330 independent investigators based at 72 medical schools, universities, and research institutes located throughout the country. 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 1,600 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 a total of $21 million to 51 science museums, aquaria, botanical gardens, and zoos, and to 42 biomedical research institutions to support innovative education programs and to interest youngsters in science.

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 are being 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 $53 million in five-year grants has been awarded to 190 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, President, Howard Hughes Medical Institute

Vast changes in the health care environment and the infrastructure for biomedical research and training are occurring at a time when we have never been so invigorated by the scientific opportunities before us. Society's past investment in the biomedical research enterprise increasingly has been rewarded with extraordinary progress in the capacity to prevent, diagnose, and treat human disease and with new insights into disease processes and the functioning of the human body. These advances have been achieved by ever-growing numbers of highly trained biomedical scientists and physicians. Computer-based learning and the Internet have changed in fundamental ways the resources available to undergraduates and younger students and how they learn.

The opportunities resulting from these changes promise a new generation with deep interest in science careers. In addition, public interest in science remains high and there have been modest but steady gains in the performance of American schoolchildren in science and mathematics. Yet public and private policies that once consistently supported the growth of academic medical centers and the advancement of biomedical science are weakening.

In the midst of this increasingly uncertain and somewhat contradictory environment, the Howard Hughes Medical Institute for the past decade has contributed to science and education through both its grants program and its medical research organization (MRO) program. Through these programs it is our goal to provide measures of innovation, stability, and optimism about the future of science and scientific literacy.

Specifically, through its Office of Grants and Special Programs, the Institute is dedicated to meeting two primary goals: production of the finest scientists for the 21st century and raising the scientific and technological literacy of all Americans. Through this program the Institute has awarded more than $600 million to the enhancement of science education programs across the breadth of the education continuum, from prekindergarten to the postgraduate level.

The Institute supports programs in precollege and public science education as well as programs to strengthen the quality of undergraduate education in the biological sciences. Institute programs support efforts to enhance precollege and public science education and strengthen the quality of undergraduate education in the biological sciences and other disciplines as they relate to biology. Among the objectives of these programs are to enhance science teaching and learning through student research experiences, enriched laboratory curricula and faculty development, and opportunities for precollege teachers and students.

At the graduate level, the Institute supports the training of predoctoral and postdoctoral fellows at biomedical research institutions around the country. To help bolster the ranks of physician-scientists, HHMI in 1990 began a program of postdoctoral research fellowships for physicians. After supporting an outstanding cadre of physician postdoctoral fellows, the Institute is most anxious to see them utilize their extensive clinical and basic research training to push back the frontiers of biomedical research and, in so doing, to advance the public health. The future success of physician-scientists depends on their obtaining the necessary research funds to set up and maintain for many years their cutting-edge programs in biomedical research.

Through the Research Resources Program, the Institute provides core support to academic health centers and research institutions for basic infrastructure, pilot programs, new faculty, research resources, and new programs. Through the International Program, HHMI resources are distributed around the globe in support of scientists in 19 countries.

As the HHMI Grants program approaches the end of its first decade, the Institute has sought to review and assess the impact of its efforts. This extensive review is an attempt to quantify and evaluate the contribution that the Institute's grants program has made to education and training over the past decade. Several problems have made assessment studies difficult. One problem is managing and tracking the very large amounts of assessment data on the Institute's programs that have already been collected. The Institute has responded by developing programs and methods by which data on science education can be placed into a computer database. The need to have uniform fields by which data from different programs can be compared has led the Institute to resolve a second problem—uniformity. The Institute has developed standardized formats for archiving information from grants competitions, outcome information from grantees, and selected national education data. A third problem, the sheer quantity of program applicants and participants, has led the Institute to use the World Wide Web as a link that enables grantees to submit program activity data directly to the Institute's databank.

As the Institute assesses its programs, it will continue to commit resources to science education at all levels. In addition, we have begun working to develop collaborations with other public and private agencies and organizations that share our goals. Clearly, the Institute—or all other private and public sources of support—cannot expect to singlehandedly advance science and the way it is taught. Rather, the Institute seeks to help catalyze science and the improvement of science education by creating opportunities and models of effective science education. We look forward to reporting in future years on the extent to which we have succeeded in these goals.

A Decade of Change and Growth

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

In 1997 the HHMI Office of Grants and Special Programs enters its 10th year. Over the past decade the program has grown to create a broad system of support for science education and research at all levels, from pre-kindergarten to postgraduate school and internationally, through its research scholars program. All told, since 1987, 721 predoctoral fellows, 595 medical students, 267 postdoctoral fellows, 30 medical schools, 220 colleges and universities, 93 biomedical research institutions, science museums and related institutions, and 190 international scholars have received some measure of support for efforts in science education and research.

Special grants have been made to organizations such as the National Research Council, the Woodrow Wilson Fellowship Foundation, Cold Spring Harbor Laboratories, and the Marine Biological Laboratory at Woods Hole for the unique contributions they make to advancing the teaching and conduct of science. In 1996 the Institute committed $67 million to sustain these and other programs, amounting to a total of $608 million since the program began.

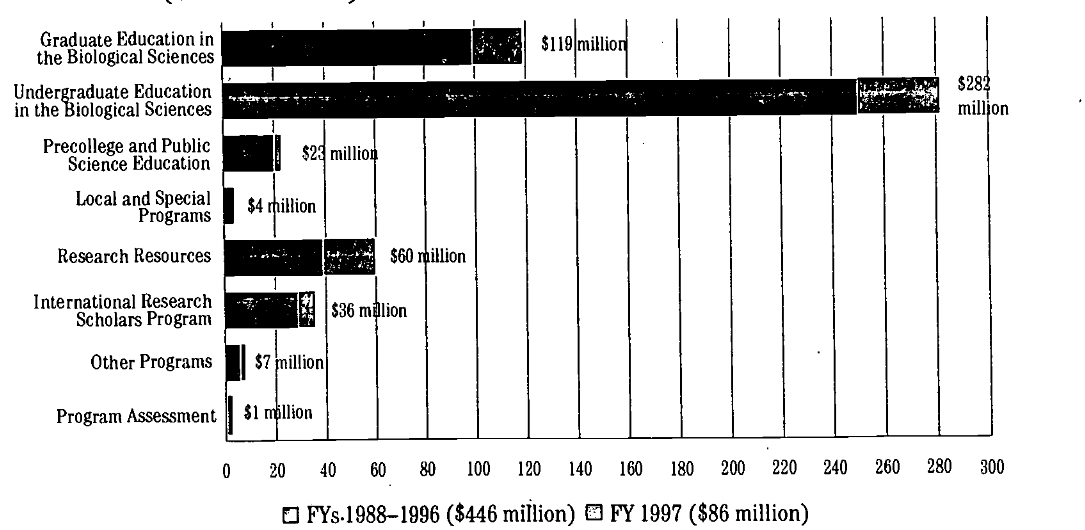
Of the $86 million of support to be awarded in 1997, $56 million will support science education programs, $21 million will support research resources, and $9 million will support research by scientists abroad. The funds for science education are distributed as follows: undergraduate, $31 million; graduate, $21 million; and precollege and public science education $4 million.

At HHMI we believe that it is important to support educational experience at all levels to open up a world of opportunities, by exposing new minds to science, reinvigorat-

Over the past decade the [Grants] program has grown to create a broad system of support for science education and research at all levels, from pre-kindergarten to postgraduate school and internationally, through its research scholars program.

Figure 1

Howard Hughes Medical Institute Grants Program Expenditures, 1988–1997 ($532 million)



The Institute has witnessed the development of an increasingly brighter outlook about the future of science education in the United States.

ing students and teachers who have strayed from science or who are seeking new knowledge, and by supporting the research endeavors of new investigators still in the midst of their training. Even with the relatively large size of the HHMI commitment, combined with the sizable contribution made by the federal government and the foundation community, resources are increasingly constrained for institutions dedicated to education and research. Funders of science education must carefully target their support to the areas where it can have the greatest impact.

The rapid growth of knowledge about biology, combined with innovative classroom and laboratory instruction, is creating a revolution in science education, a phenomenon that, despite its excitement, poses new challenges for funders, institutions, faculties, and students. The rules are changing for everyone, making this a time of high demands and great hope.

The Past as Prologue

Over the past decade the Institute has witnessed the development of an increasingly brighter outlook about the future of science education in the United States. There is some cause for hope. Students at the earliest levels of their education are doing better in math and science than their counterparts of a decade ago. In addition, children are spending more time learning science, teachers are spending more time teaching it, and more students are staying in science courses well into high school. At the undergraduate level, enrollments in life science courses are at an all-time high.

Yet problems remain in retaining student interest in science into the middle school years and there are still too many disparities in terms of access to creative reform efforts. And, despite the promising positive trends, support for reform must be steady and reliable or the course could rapidly reverse. Bruce Alberts, president of the National Academy of Sciences and keynote speaker at the 1995 HHMI precollege program directors meeting, speaks of the need for a "wise and stable platform for the continued improvement of science education." This means relentless and sustained efforts. Just because we have won some early battles does not mean the war is over.

Moreover, not all science education efforts are, or should be, groundbreaking. Some communities are providing reform merely by offering opportunities that never before existed. In the words of Jane Quinn, program director for educational efforts of the DeWitt Wallace–Reader's Digest Fund, "We could solve our education crisis if we as a society would just do enough of the right stuff for enough kids over a long enough period of time." Educational reform, like scientific investigation, requires persistence. As a society we love success stories, but we sometimes forget that change most often comes incrementally, relying

"We could solve our education crisis if we as a society would just do enough of the right stuff for enough kids over a long enough period of time."

—Jane Quinn, DeWitt Wallace–Reader's Digest Fund on support from a broad segment of the public, and on the work of many who may not receive the fanfare for their accomplishments. Winston Churchill once remarked that "success is nothing more than going from failure to failure with undiminished enthusiasm."

Over the past 10 years, the Institute has witnessed a growing number of successes in science education reform and an increasing awareness of what works. Approaches known to be effective are inquiry-based learning, direct exposure to research, provision of an environment that supplies mentors and encourages a supportive role for family, as well as encouragement of plain old hard work. We know that what makes a difference is how science and mathematics material is taught, making teacher development programs all the more important. In addition, we are finding that 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 the 1996 undergraduate meeting keynote speaker Daniel Koshland calls "the sacredness of the fact."

As we look back over the past decade and toward the future, two objectives stand out as deserving our attention. They cut across the varied activities of the HHMI grants program. First, we need to refine our efforts to assess and evaluate the impact of HHMI-supported programs in terms of scientific literacy and training future scientists. And second, we must take advantage of the new challenges and opportunities provided by information-based technologies, groundbreaking approaches to teaching students science and developing the skills and capabilities of those who teach them.

The Continual Challenge: Evaluating How Science Is Learned

A challenge to all those who care about science education reform is ongoing assessment of reform initiatives. Over the years, the Institute program staff have come to appreciate the difficulty of measuring the success or failure of a particular approach to science education. We hear anecdotal evidence and each of us "knows" when we see something that's right. But we need more than intuition and subjective measures. For example, systematic research has confirmed what we know from anecdotal data, that the intense experience of student research is an effective way to learn science.

Delineating the characteristics of successful programs enables such programs to be duplicated in other settings and provides funders with valuable feedback about the direction of their program. Clearly defined objectives, well-planned methodologies, and measurable outcomes are minimum requirements for effective evaluation. Assessments can provide important answers in the aggregate.

We must take advantage of the new challenges and opportunities provided by information-based technologies, groundbreaking approaches to teaching students science and developing the skills and capabilities of those who teach them.

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

We have learned from our grantee institutions and fellows, however, that what inspires one student may not ignite another. This makes assessment difficult. Human 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.

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

Certain findings from such evaluations provide useful guidance to the Institute as it plans future initiatives. For example, the Institute's own anecdotal evidence and some preliminary empirical studies show 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.

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.

Collecting Data on Science Education Programs

HHMI's Office of Grants and Special Programs is committed to a comprehensive assessment effort as an integral part of its grants programs. To further this assessment effort, the Institute has undertaken periodic surveys of private-sector support for science education. Both private and public funders of science education have an interest in assessing the impact of the programs they support. However, there is as yet no broad consensus in the science education community concerning issues such as how to define assessment, what kinds of assessment strategies are appropriate, and how best to obtain meaningful assessment data.

As a first step to determine the "lay of the land," in 1995, in connection with a workshop on the training

HHMI has for the past seven years funded the AAMC in a long-term project to assess the outcome of HHMI's research training programs for medical students and physicians.

of physician scientists and assessment of their career outcomes, HHMI conducted a survey of research training programs for physicians in the public and private sectors.[1] In 1996 HHMI surveyed foundation support for undergraduate and precollege science education.[2] A report of a survey of predoctoral research training programs in the public and private sectors is under way. Thus, the grants program is compiling information on five different levels of support: precollege, undergraduate, training of physician-scientists, training of Ph.D. scientists, and support for biomedical research.

In addition, assessment activities occur at each level of the Institute's education programs. At the graduate level HHMI has for the past seven years funded the Association of American Medical Colleges in a long-term project to assess the outcome of HHMI's research training programs for medical students and physicians. The project also monitors career outcomes of medical students and physicians who participate in HHMI fellowships and measures several key indicators of research involvement. Fellows submit a progress report each spring via the World Wide Web, resulting in an on-line directory accessible to fellows searching for information or entering progress reports.

To collect data on which to base future assessment activities, for example, HHMI's undergraduate program staff have developed a system that enables grantee institutions to submit annual program information over the World Wide Web. As part of this system, HHMI is requesting information at the undergraduate level on each student who participated in HHMI-supported laboratory research. The intent is to track HHMI-supported students as they complete their undergraduate education, enter graduate or medical school, and embark on careers. The Institute is also collecting information on faculty members who have been appointed with HHMI funds. By August 1998, all Institute grantees will be able to make annual Web-based submissions of program and financial reports. Those grantees lacking the capability to do so will be provided with assistance and support by the Institute.

Assessment at the precollege level is more complex because of the diverse nature of the educational activities and the wide learning range of the participants. No single approach can suffice. However, new science education standards from the National Research Council are already providing some help for institutions seeking the best means to measure the impact of their programs. Both numeric and anecdotal data attest to the value of hands-on, inquiry-based learning for young students, research experiences for older students, and strong family

By August 1998, all Institute grantees will be able to make annual Web-based submissions of program and financial reports.

[1]Office of Grants and Special Programs, Howard Hughes Medical Institute, 1997. *Training of Physician Scientists and Assessment of Career Outcomes.*

[2]Office of Grants and Special Programs, Howard Hughes Medical Institute, 1997. *Assessment Strategies for Science Education: Undergraduate and Precollege Programs.*

In the past year the grants program has established a central data archive that contains comprehensive information from all grant competitions, outcome information from grantees, and selected national education data.

and community support for all youths in stimulating an interest in the sciences.

Creating a Grants Archive

In the past year the grants program has established a central data archive that contains, in a standard format, comprehensive information from all grant competitions, outcome information from grantees, and selected national education data. Much of the archive work has focused on institutional standardization, expanding from colleges and universities in the United States to U.S. medical schools and teaching hospitals, U.S. research institutes, and foreign institutions. Standardization of the teaching hospitals and research institutes allows the Institute to focus its assessment activities not only on degree-granting institutions, but also on those important for graduate clinical training and postdoctoral research.

To allow assessment across years and programs, terminology and format have been standardized for institutions, scientific fields, names, degrees, and other variables. The archive is now an important source of cross-cutting program assessment analyses and will serve as a valuable analytical tool as the grants program enters the next 10 years.

In addition, a financial system is being developed containing all data on awards and payments for grants and direct charitable activities. Initial efforts focused on reconciliation of payment data; this past year has focused on award data and further elaboration of the database design. The system will not only play an analytic role, but also will be key in financial management: the system will generate individualized financial report "forms" (which will be used on the Web) and will subsequently facilitate an initial review of reported expenditures. The system will also generate the paperwork necessary for payments on grants (including check requests, which may be electronic in the future). On the analytic side the financial system will allow program staff to report on past activities and develop models when planning for future budgets.

Exploring the Potential of Information-Based Technologies

A second goal for the grants program is to fully explore how educational technologies can be used to enhance science learning. Educational technologies are penetrating the walls of our nation's schools, just as they have in science and commerce, amidst some controversy. Just what are the advantages to education in adopting these powerful new learning instruments? How can we disseminate, interpret, and evaluate the effectiveness of these new tools in an environment as diverse and fluid as education?

Proponents believe that with educational technology, students can search vast sources of information and explore these resources in ways never before possible, providing

A study by the Center for Applied Special Technology found that students who used the Internet as an educational tool scored higher on nine learning criteria, including greater insight into a topic and accuracy in handling information.

them with the freedom and responsibility of directing a portion of their own learning. A study by the Center for Applied Special Technology, an independent research group, found that students who used the Internet as an educational tool scored higher on nine learning criteria, including greater insight into a topic and accuracy in handling information. They were also better at presenting their ideas and could more easily understand different points of view.

Another claim made about the power of these technologies is that they provide new opportunities for teacher professional development. Now is a critical time in the teaching profession for a variety of reasons. The baby boom echo plus teacher retirements will require that we train hundreds of thousands of new teachers. Computer technology in the classroom has become an expectation if not yet a standard, and technology has the potential to provide teachers with something they have never had—a direct line to the outside world and a community. For these reasons, teacher training in technology at the pre-service and in-service levels will be critical.

Despite the great hope (and hype) surrounding educational technology, we know that many people remain deeply concerned about the digital divide, the disparity between rich and poor schools that only widens when computers, high-speed cable, and access to the Internet are introduced. Linda Roberts, the 1996 precollege meeting keynote speaker, reminded us that research shows that children who have a computer at home are exponentially more prepared than those who do not.

Formal education alone cannot be the great equalizer, if ever it was. For children who do not have a computer at home, access through their schools, libraries, museums, and churches becomes even more critical. U.S. schools still have a long way to go in achieving equitable access. The risk of losing students who are already disenfranchised and disinterested can only be exacerbated if they are passed by in the information revolution.

A Sustained Commitment to the Learning of Science

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

Linda Roberts reminded us that research shows that children who have a computer at home are exponentially more prepared than those who do not.

"Science—like no empire, no sect, no star—can eventually change the whole face and state of things throughout the world."

—Harold Varmus, Director, NIH

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...learning is the thing for you.

—T.H. White, *The Once and Future King*

The grants program for graduate education in the biological sciences complements the Institute's biomedical research program, providing support for the education of young scientists who show strong promise of becoming tomorrow's leading investigators. Through its graduate fellowships, the Institute seeks to foster excellence in research, complement other sources of support, and address unmet national needs.

Although projections of the future supply of biomedical scientists vary, there is agreement that the numbers of medically trained investigators engaged in fundamental research are relatively low and should be increased. Although women are well represented in the pool of new biology doctorates, some minority groups remain substantially underrepresented.

The Institute provides support for the training of new biomedical scientists through three programs: Predoctoral Fellowships in Biological Sciences, Research Training Fellowships for Medical Students, and Postdoctoral Research Fellowships for Physicians. The total dollar investment in these programs through fiscal year 1996 is $95 million. All fellows undertake full-time fundamental research—that is, research directed toward an understanding of basic biological processes and disease mechanisms.

Overview of Programs

The Predoctoral Fellowships in Biological Sciences were established in 1988. After nine rounds of awards, predoctoral fellowships now provide over $10 million annually to more than 350 students. Each fellow may receive up to five years of support for graduate study in selected biological sciences, including cell biology, genetics, immunology, neuroscience, and structural biology. Since the program's inception, a total of $53 million has been awarded to support more than 630 fellows who have been enrolled in outstanding graduate programs at 78 institutions.

The first Research Training Fellowships for Medical Students were awarded in 1989. These fellowships provide support for an intensive year of full-time laboratory investigation for medical students who have begun to consider research as part of their future. In 1990 the program was expanded so that a small number of fellows could continue their research for a second year or receive support for up to two years as they completed their medical studies. The Institute now provides $2.5 million annually for these new and continuing fellows. A total of $12 million has supported about 450 medical students.

In 1990 the Institute launched the Postdoctoral Research Fellowships for Physicians, which are intended to help increase the supply of well-trained physician scientists by providing three years of support for training in biomedical research to physicians who have completed at least two years of postgraduate clinical training. About $6 million is awarded annually. Since the program's inception, a total of almost

$20 million has been awarded to almost 200 physicians.

At annual meetings held at Institute headquarters in Chevy Chase, Maryland, fellows discuss their work, exchange ideas, and glean critical new insights from their colleagues. In May 1996 about 60 medical student fellows presented the results of their research (see *1996 Meeting of Medical Student Fellows, Program and Abstracts*). In June 1996 about 70 predoctoral and physician postdoctoral fellows described their research in oral and poster presentations (see *1996 Meeting of Predoctoral and Physician Postdoctoral Fellows, Program and Abstracts*).

To elicit a more in-depth picture of fellows' careers and involvement in research, the Institute periodically surveys all fellowship program alumni and publishes a directory of fellows for each of the three fellowship programs. Over time, the updates will provide a longitudinal picture of fellows' careers. The Institute is about to launch a system that uses the World Wide Web to survey alumni and generate the directories of fellows.

Predoctoral Fellowships in Biological Sciences

The goal of the Institute's Predoctoral Fellowships in Biological Sciences is to promote excellence in biomedical research by helping exceptional students obtain high-quality graduate education. Fellows must pursue a full-time graduate program leading to the Ph.D. or Sc.D. degree.

Predoctoral fellowships are awarded to students at or near the beginning of their graduate study toward a Ph.D. or Sc.D. in any of 16 eligible fields in the biological sciences. In general, these areas of fundamental research parallel those of the Institute's scientific program.

College seniors, college graduates with limited or no postbaccalaureate graduate study in the biological sciences, or first-year graduate students may apply for a predoctoral fellowship. Others who hold or are pursuing a medical or dental degree (M.D., D.O., D.V.M., or D.D.S.) may also apply if they meet eligibility criteria.

The predoctoral fellowship program is open to applicants from any country. Fellows who are U.S. citizens or nationals may study in the United States or abroad. Fellows who are foreign citizens or nationals may study only at U.S. institutions.

The National Research Council of the National Academy of Sciences conducts the predoctoral fellowship competition on the Institute's behalf. For the 1996 competition, panels of distinguished biomedical scientists evaluated about 1,400 applications. They were particularly attentive to each applicant's plan of study and research, reference letters, and previous research experience, in addition to such quantitative indicators as undergraduate grades and Graduate Record Examination scores. On the basis of the panels' evaluations, awards were made to applicants who had demonstrated superior scholarship and showed the greatest promise of achievement in biomedical research.

Figure 2

Predoctoral Fellowships in Biological Sciences, Program and Award Highlights

Fellowship Terms

- 80 awards annually
- Up to 5 years of support
- $28,500 annually
  - $14,500 stipend
  - $14,000 cost-of-education allowance

Eligibility

- Less than one year of graduate study completed
- Full-time study toward a Ph.D. or Sc.D. degree
- Selected biological sciences:
  - biochemistry
  - biophysics
  - biostatistics
  - cell biology
  - developmental biology
  - epidemiology
  - genetics
  - immunology
  - mathematical and computational biology
  - microbiology
  - molecular biology
  - neuroscience
  - pharmacology
  - physiology
  - structural biology
  - virology

1996 Awards

- Total number: 80
  - 34 women and 46 men
  - 63 U.S. citizens and 17 others
  - 32 college seniors (at the time of application) and 48 graduate students, including 2 medical students
  - 11 from minority groups underrepresented in the sciences
- Fellowship institutions: 32
- Distribution by field
  - 13 cell and developmental biology
  - 19 genetics and molecular biology
  - 12 immunology and microbiology
  - 5 mathematical biology and epidemiology
  - 18 neuroscience and physiology
  - 13 structural biology and biochemistry

All Current Predoctoral Fellows

- Total number: 356
  - 168 women and 188 men
  - 300 U.S. citizens and 56 others
  - 175 college seniors (at the time of application) and 181 graduate students, including 24 medical students and 1 physician
  - 46 from minority groups underrepresented in the sciences
- Fellowship institutions: 59
- Distribution by field:
  - 46 cell and developmental biology
  - 100 genetics and molecular biology
  - 38 immunology and microbiology
  - 19 mathematical biology and epidemiology
  - 98 neuroscience and physiology
  - 55 structural biology and biochemistry

Figure 3

Predoctoral Fellowships in Biological Sciences, Educational Origins of 1996 Fellows

Undergraduate Institutions

Angelo State University
Bates College
Beijing University (People's Republic of China), 2
Bennett College
Brigham Young University
Brown University, 2
California Institute of Technology
Carnegie Mellon University
College of William and Mary, 2
Concepcion University (Chile)
Cornell University
Franklin and Marshall College
Harvard University, 3
Harvey Mudd College
Indiana University at Bloomington
Johns Hopkins University, 2
Lafayette College
Louisiana State University and A&M College
Macalester College
Massachusetts Institute of Technology, 8
McGill University (Canada)
McMaster University (Canada)
Moscow State University (Russia)
Mount Holyoke College
Ohio University Main Campus
Pennsylvania State University Main Campus
Princeton University, 2
Purdue University Main Campus
Reed College
Regis University
Rhodes College
Santa Clara University
Smith College
Stanford University, 2
Trinity University
University of California–Berkeley, 3
University of California–Davis, 2
University of California–Los Angeles
University of California–Santa Barbara
University of California–Santa Cruz, 2
University of Dayton
University of Delaware
University of Georgia
University of Illinois at Urbana-Champaign, 2
University of Iowa
University of Kansas Main Campus
University of Maryland College Park
University of Miami
University of North Carolina at Chapel Hill
University of Puget Sound
University of Texas at Austin
University of Texas at San Antonio
University of Virginia
University of Wisconsin–Madison
Villanova University, 2
Waterloo University (Canada)
Williams College
Wilson College
Yale University

High Schools

Arizona
Canyon del Oro, Tucson
University, Tucson

California
Barstow, Barstow
Bear River, Grass Valley
Berkeley, Berkeley
Beverly Hills, Beverly Hills
Cupertino, Cupertino
Edison, Huntington Beach
Harvard School, Studio City
Mercy, San Francisco
Northgate, Walnut Creek
Palo Alto, Palo Alto
Quartz Hill, Quartz Hill
Thousands Oaks, Thousand Oaks
University, Irvine
Washington, Freemont

Colorado
Fort Collins, Fort Collins
Thomas Jefferson, Denver

Delaware
Tower Hill, Wilmington

Florida
Academy of the Holy Names, Tampa
Carol City Senior, Miami

Georgia
George Walton Comprehensive, Marietta

Illinois
Evanstown Township, Evanston
Naperville North, Naperville
William Fremd, Palatine

Indiana
Castle, Newburgh
Franklin Central, Indianapolis

Iowa
City, Iowa City

Kansas
Shawnee Mission South, Overland Park
Turner, Kansas City

Kentucky
Paducah Tishman, Paducah

Louisiana
Brother Martin, New Orleans
Louisiana School for Mathematics, Science and Art, Natchitoches

Maryland
Friends School, Baltimore
Randallstown, Randallstown

Michigan
H. H. Dow, Midland

Minnesota
Apple Valley, Apple Valley
Robinsdale Armstrong, Plymouth

Missouri
University City Senior, University City

New Jersey
Newark Academy, Livingston
West Morris Mendham, Mendham

New York
Brighton, Rochester
Hastings, Hastings on the Hudson
Island Trees, Levittown
Shoreham-Wading River, Shoreham
Stuyvesant, New York

North Carolina
W. G. Enloe, Raleigh

Ohio
Athens, The Plains
Revere, Richfield

Pennsylvania
Academy of Notre Dame, Villanova
Exeter Township, Reading
Octorara, Atglen
Peters Township, Peters Township

Tennessee
Dekalb County, Smithville
White Station, Memphis

Texas
Bellaire, Bellaire
King, Corpus Christi
Northside Health Careers, San Antonio
Pleasant Grove, Texarkana
Roy Miller, Corpus Christi

Virginia
James Madison, Vienna
Lafayette, Williamsburg
Thomas Jefferson High School for Science and Technology, Alexandria

Wisconsin
Robert M. La Follette, Madison

Wyoming
Sheridan, Sheridan

Outside the United States
Belize, St. Johns's College, Belize
Canada, Waterloo Collegiate Institute, Waterloo
Canada, York Mills Collegiate Institute, Don Mills
Chile, German, Concepcion
India, Air Force Bal Bharati School, New Delhi
India, Frank Anthony Public School, Bangalore
People's Republic of China, Fu Xing, Shanghai
People's Republic of China, No. 6 Middle School of Wuhan, Wuhan
People's Republic of China, Quzhou Second Middle School, Quzhou
People's Republic of China, Shanghai Foreign Language School, Shanghai
People's Republic of China, Middle School of Beijing University, Beijing
Peru, Colegio Peruano Britanico, Lima
Singapore, National Junior College
Ukraine, School No. 9, Sverdlovsk Lugansk
United Kingdom, Atlantic College, Liantwit Major

Figure 4

Predoctoral Fellowships in Biological Sciences, All Current Fellowship Institutions

Albert Einstein College of Medicine
Baylor College of Medicine
Brandeis University
Brown University
California Institute of Technology
Catholic University of America
Columbia University
Cornell University
Dartmouth College
Duke University
Emory University
Georgetown University
Harvard University
Indiana University at Bloomington
Johns Hopkins University
Massachusetts Institute of Technology
McGill University (Canada)
Northern Arizona University
Northwestern University
Oregon Health Sciences University
Pennsylvania State University Main Campus
Princeton University
Purdue University Main Campus
Rockefeller University
Rutgers the State University of New Jersey New Brunswick Campus
Scripps Research Institute
Stanford University
State University of New York at Stony Brook
University of Arizona
University of California–Berkeley
University of California–Irvine
University of California–Los Angeles
University of California–San Diego
University of California–San Francisco
University of California–Santa Cruz
University of Cambridge, Churchill College (United Kingdom)
University of Chicago
University of Colorado at Boulder
University of Colorado Health Sciences Center
University of Connecticut
University of Illinois at Urbana–Champaign
University of Maryland College Park
University of Miami
University of Minnesota–Twin Cities
University of New Mexico Main Campus
University of North Carolina at Chapel Hill
University of Oxford (United Kingdom)
University of Pennsylvania
University of Pittsburgh, Pittsburgh Campus
University of Texas Health Science Center at San Antonio
University of Texas at Austin
University of Texas Southwestern Medical Center at Dallas
University of Utah
University of Virginia
University of Washington
University of Wisconsin–Madison
Vanderbilt University
Washington University
Yale University

In 1996 the Institute selected 34 women and 46 men as fellows (Figure 2). Among these are four students from the People's Republic of China, three each from Canada and India, and one each from Belize, Chile, Russia, Singapore, Sri Lanka, Taiwan, and the United Kingdom. Included in the group are 11 outstanding students from minority groups underrepresented in the sciences, bringing to 46 the current number of predoctoral fellows who are black, Hispanic, Native American, or Native Pacific Islander. The 1996 fellows studied at 59 undergraduate institutions, including 6 abroad (Figure 3). They are pursuing their graduate studies at 32 U.S. and foreign institutions (Figure 4).

Figure 5

1996 Meeting of Predoctoral and Physician Postdoctoral Fellows

Program Synopsis

Howard Hughes Medical Institute
Office of Grants and Special Programs

1996 Meeting of Predoctoral and Physician Postdoctoral Fellows
Predoctoral Fellowships in Biological Sciences
Postdoctoral Research Fellowships for Physicians
HHMI Headquarters and Conference Center

Monday, June 10, 1996

Welcoming Remarks
Purnell W. Choppin, M.D., President

Invited Speaker
Of Mice and Men: Genetic Disorders of the Cytoskeleton
Elaine Fuchs, Ph.D., Investigator, Howard Hughes Medical Institute, and Amgen Professor of Basic Sciences, University of Chicago

Tuesday, June 11, 1995

Fellows' Presentations—Scheduled Talks
Immune System Biology
T Cell and Other Receptors
Structural Biology
Neurobiology

Fellows' Presentations—Posters
RNA Synthesis
Virology
Control of Growth and Development
Structure-Function Relations
Membrane Transport

Fellows' Presentations—Scheduled Talks
Cell Cycle and Other Signaling Systems
Transcription
Enzyme Biology and Biochemistry

Wednesday, June 12, 1996

Fellows' Presentations—Scheduled Talks
Molecular Approaches to Disease
Tumor Biology
Membrane and Cell Surface Phenomena
Developmental Biology

As of June 1996, 356 predoctoral fellows are receiving support at 59 academic institutions at an annual cost of over $10 million.

As the Institute invests in graduate education, it seeks to encourage diversity among students who are working full-time toward a doctorate in the biological sciences. If current program trends continue in future competitions, about 15 percent of fellows will be from minority groups

Figure 6

Predoctoral Fellowships in Biological Sciences, 1996 Fellows

Name
Department
Fellowship institution

Cell and Developmental Biology

Pamela Lynn Bradley
Biochemistry, Cellular and Molecular Biology
Johns Hopkins University

Brian Andrew Davies
Division of Cell and Molecular Biology
University of Texas Southwestern Medical Center at Dallas

Julie Ann Gates
Human Genetics
University of Utah

Zemer Gitai
Biological Sciences
University of California–San Francisco

Arash Komeili
Biological Sciences
University of California–San Francisco

Richard Chin-Hung Kuo*
Biological Sciences
Stanford University

Yilun Liu
Molecular Biophysics and Biochemistry
Yale University

Jeffrey Meier Marcus*
Genetics
Duke University

Madhubonti Mitra Mustaphi
Biological Sciences
Stanford University

Christina Adrianna Onufryk
Biochemistry and Molecular Biology
University of California–San Francisco

Andrei Georgievich Petcherski
Biochemistry
University of Wisconsin–Madison

Victoria Anne Smith
Biology
Indiana University at Bloomington

Jue Wang
Biophysics and Biochemistry
University of California–San Francisco

Genetics and Molecular Biology

Mary Catherine Alexander
Molecular Biology
Princeton University

Jessica Sarah Blumstein
Biological Sciences
University of California–San Francisco

Christopher Ryan Brodie
Molecular, Cellular, Developmental Biology and Genetics
University of Minnesota–Twin Cities

Bin Chen
Ecology and Evolution
University of Chicago

Shane Patrick Crotty
Biochemistry
University of California–San Francisco

Ridgley McLean Fisk
Division of Medical Sciences
Harvard University

Samantha Lee Gray
Biology
Rockefeller University

Emmanuel Jerry Green
Cell and Molecular Biology
Catholic University of America

Carolyn Mary Hutter
Genetics and Development
Cornell University

Benjamin Simon Leader
Division of Medical Sciences
Harvard University

Cathyryne Kapiolani Manner
Biomedical Sciences
University of California–San Diego

Sean Gregory Megason
Molecular and Cellular Biology
Harvard University

Carolyn Nicole Pettibone
Division of Medical Sciences
Harvard University

Zhe Qian
Cell and Molecular Biology
University of Wisconsin–Madison

Daniel René Richards
Genetics
Stanford University

Sheldon Stanley Rowan
Division of Medical Sciences
Harvard University

Alvaro Sagasti
Biochemistry and Biophysics
University of California–San Francisco

Marc Adam Suchard*
Clinical Medicine
University of Oxford (United Kingdom)

Emily Cecile Walsh
Biochemistry, Genetics Division
University of California–San Francisco

Immunology and Microbiology

Alexander Jude Adduci
Pathology
Georgetown University

Suneet Agarwal
Division of Medical Sciences
Harvard University

Doris Renee Brown
Microbiology
University of Texas Health Science Center at San Antonio

Dina Sharon Gould
Biology
Massachusetts Institute of Technology

Raquel Eugenia Izumi
Microbiology and Immunology
University of California–Los Angeles

Aaron Jacob Kelly
Division of Medical Sciences
Harvard University

John Michael Lyle
Microbiology and Immunology
Stanford University

John Cranston Randell
Division of Medical Sciences
Harvard University

Navin Rao
Immunology
Harvard University

Daniel Nathan Shriner
Microbiology
University of Washington

Patrick Joseph Stern
Biology
Massachusetts Institute of Technology

Yu Xia
Chemistry
Stanford University

Mathematical Biology and Epidemiology

Andrea Linn Graham
Ecology and Evolutionary Biology
Cornell University

Jorge Eduardo Lopez
Ecology and Evolution
University of Chicago

Susan Elizabeth Ptak
Biological Sciences
Stanford University

Roberto Jaime Sánchez
Biology
Rockefeller University

Jovonne Williams
Biostatistics -
Harvard University

Neuroscience and Physiology

Stephen Alexander Baccus
Neuroscience
University of Miami

Michelle Lyn Cunningham
Pharmacology
University of North Carolina at Chapel Hill

Joe Chao-Peng Hao
Molecular and Cellular Biology
University of California–Berkeley

James Matthew Kittelberger
Neurobiology
Duke University

Melissa Gail Kramer*
Biology and Biomedical Sciences
Washington University

David Douglas Laws
Chemistry
University of California–Berkeley

Albert Kimin Lee
Brain and Cognitive Sciences
Massachusetts Institute of Technology

Kenneth Rajan Leslie
Biology
Brandeis University

Clare Risa Ozawa
Neuroscience
Stanford University

Kit Erica Purdy
Physiology
University of North Carolina at Chapel Hill

Devesh Raj
Applied Physics
Yale University

Hemaka Anthony Rajapakse
Chemistry and Chemical Biology
Harvard University

Jack Schonbrun
Biophysics
University of California–San Francisco

Kurt Stephen Thorn
Biophysics
University of California–San Francisco

Yvonne Michelle Ulrich
Neuroscience
University of Minnesota–Twin Cities

Yongping Wang
Pharmacology and Toxicology
Dartmouth College

Julie Lynn Wilsbacher
Cell Regulation
University of Texas Southwestern Medical Center at Dallas

Noa Zerangue
Neuroscience
University of California–San Francisco

Structural Biology and Biochemistry

Jessica Lee Blazyk
Chemistry
Massachusetts Institute of Technology

Kartik Chandran
Biochemistry
University of Wisconsin–Madison

Tara Rena Evans
Biomolecular Chemistry
University of Wisconsin–Madison

Victor Fernando Holmes
Biochemistry and Molecular Biology
University of California–Berkeley

Colin James Loweth
Chemistry
University of California–Berkeley

Angela Robin Newhoff
Biochemistry and Biophysics
University of California–San Francisco

Megan Elizabeth Núñez
Chemistry
California Institute of Technology

Randall Theodore Peterson
Molecular and Cellular Biology
Harvard University

Steven Cary Rothman
Molecular and Cell Biology
University of California–Berkeley

Raymond Courtney Trievel
Biochemistry and Biophysics
University of Pennsylvania

Jeffrey Gilbert Varnes
Chemistry and Chemical Engineering
California Institute of Technology

Kira Juliet Weissman
Biochemistry
University of Cambridge, Churchill College (United Kingdom)

Inn Huam Yuk
Chemical Engineering
Massachusetts Institute of Technology

*Award deferred from 1995

underrepresented in the sciences and half will be women.

The predoctoral fellows selected in the 1988–1995 competitions continue to demonstrate exceptional ability as biomedical researchers. During the past year current fellows published 134 peer-reviewed articles as well as numerous book chapters, review articles, and abstracts based on fellowship research. In addition, they gave 217 oral and poster presentations at international, national, and regional scientific meetings. Those who have completed their degrees are being accepted for postdoctoral training at leading laboratories in the United States and abroad.

About 51 predoctoral fellows near the end of their fellowship term were convened at a June 1996 meeting (Figure 5). In their research presentations, they gave further evidence of their skill and productivity and showed enthusiasm for careers as scientists. (See the Institute publication *1996 Meeting of Predoctoral and Physician Postdoctoral Fellows, Program and Abstracts.*)

The 1996 predoctoral fellows are listed in Figure 6.

Research Training Fellowships for Medical Students

The Research Training Fellowships for Medical Students have as their primary objective an increase in the proportion of physicians who are significantly involved in research. The fellowships provide support for an intensive year of laboratory investigation for medical students who have begun to consider research as part of their career.

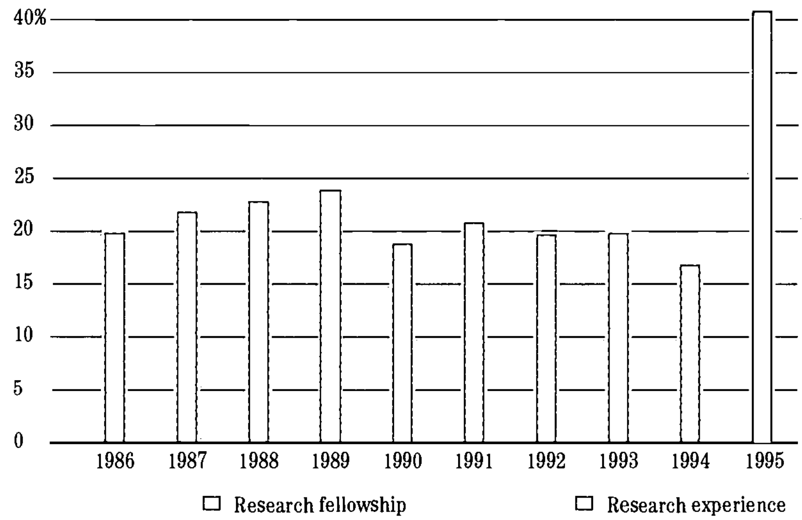
The pool of potential physician-scientists is drawn from current medical students with a keen interest in research. The Association of American Medical Colleges (AAMC) annually surveys all students who receive an M.D. degree (Figure 7). Responses to the 1995 AAMC graduation questionnaire indicate that 52.5 percent of M.D. recipients had been an investigator in a research project while in medical school and 28.4 percent were sole or joint authors of a published research paper. Just over 40 percent of graduating medical students indicated that graduate medical education (GME) plans included research experience. Of these, 12.9 percent intend to focus on basic medical sciences. Thus, the GME plans of about 5 percent of all questionnaire respondents include research experience with a basic science focus.

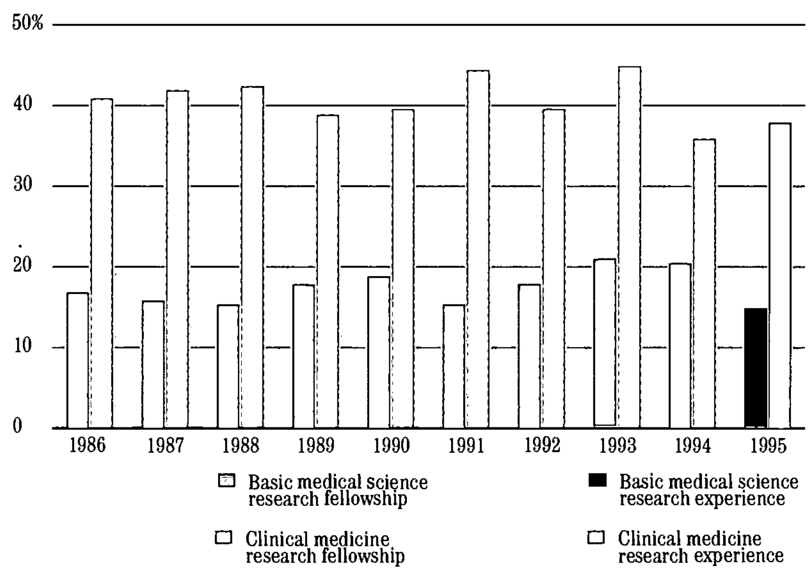
According to the questionnaire responses, about 12 percent of M.D. graduates foresee being significantly involved in research during their medical careers. About 1.6 percent of graduates indicate a preference for a career as a basic scientist, either as a full-time academic or as a salaried researcher. Thus, fewer than one-third of those who intend to seek training in basic science plan a career as a basic scientist. This points to the importance that these young clinicians place on obtaining a thorough grounding in the basic science that underpins contemporary medical advances. It also under-

Figure 7

M.D. Plans at Graduation, 1986–1995

Intention to Seek a Research Fellowship (1986–1994) or Research Experience (1995)*





Source: AAMC Graduation Questionnaire, *annual.*

**Note that the 1995 data are not comparable to those for 1994 and earlier. The question changed from "fellowship" to "experience."*

Figure 8

Research Training Fellowships for Medical Students, Initial Awards

Fellowship Terms

- Up to 60 awards annually
- One year of support
- $26,000 fellowship
  - $14,500 stipend
  - $5,000 research allowance
  - $5,000 institutional allowance
- Continued support possible for a second year of research
- Continued support possible for up to two years while completing medical school

Eligibility

- Currently enrolled in a U.S. medical school
- Fundamental research (basic biological processes or disease mechanisms)
- Full-time research
- Fellowship year at any academic or nonprofit research institution in the United States, except NIH in Bethesda, Maryland
- Not enrolled in an M.D./Ph.D. program

1996 Awards

- Total number: 58
  - 16 women and 42 men
  - 8 from minority groups underrepresented in the sciences
  - Medical school level completed
    - Year 1: 1 fellow
    - Year 2: 34 fellows
    - Year 3: 20 fellows
    - Year 4: 3 fellows
- Fellowship institutions: 24
- Distribution by field
  - 13 cell and developmental biology
  - 14 genetics and molecular biology
  - 10 immunology and microbiology
  - 17 neuroscience and physiology
  - 4 structural biology and biochemistry

lines the continuing importance of nurturing student interest and providing training opportunities in fundamental research.

For the last 10 years, the Research Scholars Program—sponsored jointly by HHMI and the National Institutes of Health (NIH)—has brought selected medical students to NIH's intramural laboratories for a year of fundamental research. The Research Training Fellowships for Medical Students were initiated to increase the number of students able to benefit from such an experience. Medical student fellows may affiliate with a laboratory at any academic or nonprofit research institution in the United States (except NIH in Bethesda, Maryland). Thus, the two programs are complementary.

Figure 9

Research Training Fellowships for Medical Students, Educational Origins of 1996 Initial Research Fellows

Undergraduate Institutions

Amherst College
Auburn University
Brown University, 3
California Institute of Technology
Cincinnati College of Mortuary Science
City University of New York Queens College
Columbia University
Cornell University
Dublin City University (Ireland)
Duke University, 2
Emory University, 2
Harvard University, 4
Indiana University at Bloomington
Johns Hopkins University, 3
Mankato State University
Massachusetts Institute of Technology, 4
Middlebury College
Morehouse College
Oberlin College
Occidental College
Princeton University
St. John's College, Maryland
Stanford University, 6
State University of New York at Buffalo
Tufts University
University of California–Berkeley, 4
University of California–Los Angeles, 2
University of California–San Diego
University of Michigan–Ann Arbor
University of North Carolina at Chapel Hill
University of Pennsylvania, 3
University of Wisconsin–Madison
Yale University, 3

High Schools

Alabama
Enterprise, Enterprise

Arizona
University, Tucson

California
Cerritos, Cerritos
El Cerrito, El Cerrito
Francisco Bravo Medical, Los Angeles
Galileo, San Francisco
Hemet, Hemet
Henry M. Gunn, Palo Alto
La Jolla, La Jolla
Marlborough School, Los Angeles
Redwood, Larkspur
University, Los Angeles

Georgia
Berkmar, Lilburn
Westminster School, Atlanta

Hawaii
Punahou, Honolulu

Illinois
Brighton, Brighton
Hinsdale South, Darien
Illinois Mathematics and Science Academy, Aurora
Libertyville, Libertyville
Wheaton North, Wheaton

Massachusetts
Northfield Mount Hermon, Northfield

Michigan
Okemos, Okemos

Minnesota
Columbia Heights, Columbia Heights

Missouri
John Burroughs, St. Louis

New Hampshire
Phillips Exeter Academy, Exeter

New Jersey
Cherry Hill, Cherry Hill
Delbarton School, Morristown
Montville, Montville
Parsippany Hills, Parsippany
Red Bank Regional, Little Silver

New York
Albany Academy, Albany
Bronx High School of Science, New York
Brooklyn Technical, New York
Cardinal Spellman, New York
Clarkstown, New City
F.D. Roosevelt, New York
Greece Athena, Rochester
Herricks, Roslyn
Horace Mann School, New York
Midwood, New York
Ramaz School, New York

Ohio
Columbus Academy, Gahanna
Elyria, Elyria
Maumee Valley Country Day School, Toledo
Oak Hills, Cincinnati
Woodward, Cincinnati

Pennsylvania
Central Catholic, Allentown
Pennridge, Perkasie

Texas
St. Johns School, Houston

Utah
Provo, Provo

Vermont
Rile, Burlington

Virginia
Lexington, Lexington
Virginia Episcopal School, Lynchburg

Wisconsin
Roncalli, Manitowoc

Outside the United States
Haiti, Institution St. Louis de Gonzaguez, Port-au-Prince
Ireland, St. Fintans, Dublin
Israel, Boyar, Jerusalem

Figure 10

Research Training Fellowships for Medical Students, All Current Fellowship Institutions

Albert Einstein College of Medicine
Baylor College of Medicine
Boston University
Columbia University
Cornell University Medical Campus
Duke University
Emory University
Georgetown University
Harvard University
Johns Hopkins University
Massachusetts Institute of Technology
Mount Sinai School of Medicine of the City University of New York
Saint Louis University
Stanford University
State University of New York at Buffalo
University of Alabama at Birmingham
University of California–Los Angeles
University of California–San Diego
University of California–San Francisco
University of Chicago
University of Colorado Health Sciences Center
University of Cincinnati
University of Iowa
University of Kansas Medical Center
University of Michigan–Ann Arbor
University of New Mexico Main Campus
University of North Carolina at Chapel Hill
University of Vermont
Vanderbilt University
Washington University
Wayne State University
Yale University

Initial Year of Research

Research Training Fellowships for Medical Students are awarded to applicants who show the greatest promise of achievement in biomedical research and who have demonstrated superior scholarship in their undergraduate and medical school work. Applicants must be enrolled in a medical school in the United States. A panel of biomedical scientists convened by the Institute evaluates each application, placing special emphasis on the research plan, the mentor's plans for training the student, and the applicant's letters of reference.

The 1996 competition resulted in awards to 58 new fellows, including 16 women and 42 men, for one year of full-time laboratory research (Figure 8). These fellows are enrolled in medical school at 25 institutions and are graduates of 33 colleges and universities (Figure 9). Twelve fellows are conducting research in a laboratory not affiliated with their medical school. The total number of fellowship institutions, including those for continued fellows, is 32 (Figure 10).

By the end of June of the fellowship year, six papers by fellows selected in the 1995 competition had been accepted for publication in peer-reviewed journals. Fellows participated in regional, national, and international scientific meetings and presented 21 talks and posters. The medical student fellows were also convened in Chevy Chase at a May 1996 meeting (Figure 11), where they provided further evidence of a productive year and enthusiasm for continued involvement in fundamental science. (See the Institute publication *1996 Meeting of Medical Student Fellows, Program and Abstracts.*)

Figure 11

1996 Meeting of Medical Student Fellows

Program Synopsis

Howard Hughes Medical Institute
Office of Grants and Special Programs

1996 Meeting of Medical Student Fellows
Research Training Fellowships for Medical Students
HHMI Headquarters and Conference Center

Monday, May 20, 1996

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

Invited Speaker
Viruses, Cytokines, and Kaposi's Sarcoma:
Medicine as the Great Tutor of Biology
Don Ganem, M.D., Investigator, Howard Hughes Medical Institute, and Professor of Microbiology and Immunology and of Medicine, University of California

Tuesday, May 21, 1996

Fellows' Presentations
Immune System Biology
Molecular Approaches to Treatment of Disease
Macromolecular Structure and Structure-Function Relations
Genetic Insights Into Pathogenesis and Treatment

Laboratory Visits with Research Scholars at NIH

Wednesday, May 22, 1996

Fellows' Presentations
Infectious and Parasitic Diseases
Cell Biology
Vascular System Biology
Neurobiology

Continued Support

Medical student fellows may apply for support for a second year of research. They may also compete for continued fellowship support for up to two years while they complete their study toward the M.D. degree. Medical students at NIH under the auspices of the HHMI-NIH Research Scholars Program are also eligible to apply for continued sup-

Figure 12

Research Opportunities for Medical Students

Two Howard Hughes Medical Institute programs provide opportunities for medical students in the United States to spend a year doing intensive research. Participants in both programs are selected on the basis of a national competition. Students may apply to only one of these programs in a given year. A comparison of the two programs follows.

	HHMI-NIH Research Scholars Program (Cloister Program)	HHMI Research Training Fellowships for Medical Students Program
Time	Appointment is for 9 months to 1 year. Some scholars may obtain an extension for an additional year of research.	Fellowship term is 1 year. Some fellows may obtain an extension for an additional year of research.
Place	Research is conducted at NIH in Bethesda, Maryland. The Cloister, a residential facility for scholars, is available on the NIH campus. Travel to and from Bethesda is provided.	Research is conducted at an academic or nonprofit research institution in the United States chosen by the fellow. Research may not be conducted at NIH in Bethesda, Maryland.
Salary/Stipend	The annual salary for scholars is $16,800. Research scholars are employees of HHMI, with fringe benefits.	Effective June 1997, the annual stipend for fellows is $15,000. Fellows are not HHMI employees and receive no fringe benefits. However, a portion of the $5,500 allowance paid to the fellowship institution may be used to provide health insurance for the fellow.
Research Topic	The research project is selected upon arrival at NIH, after a round of laboratory visits.	The research project must be described in the fellowship application.
Research Costs	There is no special research allowance. Costs are covered by the scholar's laboratory.	A $5,500 research allowance on behalf of the fellow is provided to the fellowship institution in addition to a $5,500 institutional allowance.
Citizenship	Scholars must be citizens or permanent residents of the United States.	There are no citizenship requirements. However, applicants must be attending medical school in the United States.
Medical School Support	Students from each program may compete for a small number of awards for up to 2 additional years of fellowship support while completing medical school. Effective June 1997, this support will consist of a $15,000 annual stipend and a $15,000 annual allowance toward tuition and other education-related expenses.	
For Information and Applications	HHMI-NIH Research Scholars Program Howard Hughes Medical Institute 1 Cloister Court, Department G Bethesda, MD 20814-1460 (301) 951-6770 or (800) 424-9924 e-mail <gpub@hhmi.od.nih.gov>	Research Training Fellowships for Medical Students/GSE97 Howard Hughes Medical Institute Office of Grants and Special Programs 4000 Jones Bridge Road Chevy Chase, MD 20815-6789 (301) 215-8889 fax (301) 215-8888 e-mail: fellows@hhmi.org http://www.hhmi.org/fellowships

Figure 13

Research Training Fellowships for Medical Students, Continued Awards

Fellowship Terms

- Completion of medical studies
  $28,500 annually for up to two years
  - $14,500 annual stipend
  - $14,000 educational allowance
- Second year of research
  $24,500 for one year
  - $14,500 stipend
  - $5,000 research allowance
  - $5,000 institutional allowance

Awards—Completion of Medical Studies or Second Year of Research

- Total number: 42*
  14 women and 28 men
  4 minorities underrepresented in the sciences

**Includes 11 medical student fellows and 10 HHMI-NIH Research Scholars selected in 1996 for continued fellowship support for completion of medical studies, 19 fellows selected in 1995 who are in the second year of such support, and 2 medical student fellows selected in 1996 for a second year of research.*

port toward the completion of medical studies (Figure 12).

Candidates for continued fellowship support are evaluated on the basis of their demonstrated ability during the research year, their promise for future achievement in biomedical research, and their career intentions, including any plans for additional research training after completion of medical school. Two fellows were awarded support for a second year of research, and 21 fellows and research scholars were selected for up to two years of fellowship support while completing medical school. These new awards bring to 42 the number of continued fellows currently receiving support for their studies toward the M.D. degree (Figure 13).

The recipients of the 1996 Research Training Fellowships for Medical Students are listed in Figure 14.

The Institute is conducting long-term tracking of the education and careers of medical student fellows and research scholars as part of its program assessment activities. Of special interest are the students' continued involvement in research and pursuit of further training, either toward the Ph.D. degree or in postdoctoral positions. By the end of the initial fellowship year, several of the 1995 fellows reported plans to pursue a Ph.D. degree in addition to the M.D. as a result of the fellowship experience. Others intend to pursue postdoctoral research training after completing medical school and postgraduate clinical training.

The Institute is interested not only in the career paths of its fellows but also in the size and composition of the national pool of physician scientists and in the activities of individuals in this pool. The Institute works with the Association of Amer-

Figure 14

Research Training Fellowships for Medical Students, 1996 Fellows

Fellow
Research mentor
Department
Fellowship institution
Research project

Initial Awards— First Year of Research

Cell and Developmental Biology

Ron Alexander Birnbaum
Kevin M. Shannon, M.D.
Pediatrics
University of California–San Francisco
Is malignant growth in Nf1$^{-/-}$ myeloid cells dependent on granulocyte-macrophage colony-stimulating factor?

Aamer Zahid Farooki
David L. Epstein, M.D.
Ophthalmology
Duke University
The effects of tyrosine kinase inhibitors on cell junctions and implications for the treatment of glaucoma

John Phillip Forman
John K. Rose, Ph.D.
Pathology
Yale University
Recombinant vesicular stomatitis virus expressing HIV-1 gag and env proteins

Laura April Gago
Ernest E. Moore, M.D.
Surgery
University of Colorado Health Sciences Center (University of California–San Diego*)
PMN priming and activation post-trauma: does delayed orthopedic fixation decrease multiple organ failure?

Heather Elizabeth Gibson
Merton Bernfield, M.D.
Pediatrics
Harvard University
Transcriptional regulation of the syndecan-1 gene

Timothy Eugene Graham
Janet M. Oliver, Ph.D., and Bridget S. Wilson, Ph.D.
Cell Pathology
University of New Mexico Main Campus
Ras-*independent pathways to MAP kinase activation*

Wayne Wei Kuang
Ronald J. Weigel, M.D., Ph.D., and Roel Nusse, Ph.D.†
Surgery
Stanford University
Identification of genes differentially expressed in estrogen receptor-positive versus estrogen receptor-negative breast carcinomas

Danny Yi-Hung Lin
Victor J. Dzau, M.D., and C. Ronald Kahn, M.D.
Medicine
Stanford University
In vivo *gene transfer to study the pathobiologic role and cellular mechanisms of insulin receptor in vascular smooth muscle proliferation*

Gary LaMont Little
Julie Glowacki, Ph.D.
Orthopedic Research
Harvard University
Changes in gene expression of human dermal fibroblasts cultured with demineralized bone powder

Daniel Eric Meltzer
Arthur I. Skoultchi, Ph.D.
Cell Biology
Albert Einstein College of Medicine
Functional characterization of Myc-*associated proteins in cancer and differentiation*

Vishal Nigam
Robert J. Schwartz, Ph.D.
Cell Biology
Baylor College of Medicine
Characterization of the cis-*regulatory elements of the Nkx-2.5 gene*

Ravi Ranchhod Pankhaniya
Edward J. Goetzl, M.D.
Microbiology and Immunology
University of California–San Francisco (Emory University*)
DNA damage and differences in gene expression in human glioma cells that differ in radiation sensitivity

Joseph Laurence Schindler
Roy L. Silverstein, M.D.
Medicine
Cornell University Medical Campus (Tufts University School of Medicine*)
Molecular basis of CD36-oxidized LDL interactions

Genetics and Molecular Biology

Jayme Dawn Allen
Heather N. Yeowell, Ph.D.
Medicine, Division of Dermatology
Duke University
Analysis of the active site of lysyl hydroxylase by site-directed mutagenesis

Gerard Joaquim Carvalho
Anil K. Lalwani, M.D.
Otolaryngology–Head and Neck Surgery
University of California–San Francisco
Application of intracochlear gene therapy to prevent spiral ganglion loss following ototoxic insult using adeno-associated virus containing neurotrophin-3

Obed Moses Cepeda
Richard P. Lifton, M.D., Ph.D.†
Medicine and Genetics
Yale University
Investigation of the genetics of cavernous malformations

David Jin-Woo Chang
Michael I. Centrella, Ph.D., and Thomas L. McCarthy, Ph.D.
Surgery
Yale University
Regulation of TGF-β type I receptor gene expression by glucocorticoid

Ajai Chari
Charles L. Sawyers, M.D.
Medicine, Division of Hematology-Oncology
University of California–Los Angeles
Investigation of the effects of restoring E-cadherin function in advanced stage human prostate cancer

Marcoli Cyrille
Nancy Berliner, M.D.
Internal Medicine
Yale University
Characterization of the lactoferrin gene silencer

Conor Joseph Heaney
Val C. Sheffield, M.D., Ph.D., and Edwin M. Stone, M.D., Ph.D.
Pediatrics
University of Iowa
Identification of genes involved in eye disease

Paula Marie Hertel
Huda Y. Zoghbi, M.D.†
Pediatrics, Molecular and Human Genetics, and Neurology
Baylor College of Medicine (University of Minnesota–Twin Cities*)
Characterization of a murine model for spinocerebellar ataxia type 1: analysis of DNA instability and protein expression

Tracey Michelle Hessel
Deborah Dean, M.D.
Internal Medicine
University of California–San Francisco
Chlamydial hsp60 in the immunopathogenesis of chlamydial ocular infections

Siavash Khavar Kurdistani
Sam W. Lee, Ph.D.
Medicine
Harvard University
Characterization of a novel gene, SK23, *in human mammary cell development and its role in tumorigenicity*

Diana Pin-Cheng Lin
Tomohiro Matsumoto, Ph.D.
Radiation Oncology
Albert Einstein College of Medicine
Molecular dissection of the checkpoint control in a model system, S. pombe

Jason Harris Pomerantz
Ronald A. DePinho, M.D.
Microbiology and Immunology
Albert Einstein College of Medicine
Development of a mouse model for malignant melanoma

Cary Cecile Ward
Andrew R. Marks, M.D.
Medicine
Mount Sinai School of Medicine of the City University of New York (University of Virginia*)
Regulation of calcium release channel function

Mark Anthony Williams
Joseph S. Solomkin, M.D.
Surgery
University of Cincinnati
Effect of TNFα and C5a on neutrophil (PMN) IL-8 receptor/ligand interactions

Immunology and Microbiology

Todd Arthur Fehniger
Michael A. Caligiuri, M.D.
Molecular Medicine
State University of New York at Buffalo
Functional assessment of innate immunity in patients with AIDS-associated malignancies receiving cytokine therapy

Cosmas Chris Giallourakis
Paul B. Rothman, M.D.
Microbiology; Medicine
Columbia University (UMDNJ–New Jersey Medical School*)
The relationship between cytokine signaling and transformation by v-abl

Justin Samuel Goodman
Dennis A. Carson, M.D.
Medicine
University of California–San Diego
The role of interferon-α in determining Th subset differentiation

Ravi Vivekanand Joshi
Lawrence J. Stern, Ph.D.
Chemistry
Massachusetts Institute of Technology (Harvard University*)
Physicochemical characterization of Class II MHC-peptide binding interactions

Matthew Frank Kalady
Jeffrey L. Platt, M.D.
Surgery
Duke University
Molecular biology of impaired fibrinolysis in xenograft rejection

Michael Donald Radosevich
Santa Jeremy Ono, Ph.D.
Medicine
Harvard University (Johns Hopkins University*)
Molecular mechanisms mediating glucocorticoid repression of MHC class II gene expression

**A medical school affiliation other than the fellowship institution is indicated in parentheses.*

†Howard Hughes Medical Institute investigator.

Research Training Fellowships for Medical Students, 1996 Fellows

Alice Song
Jeffrey L. Platt, M.D.
Surgery
Duke University
The mechanism of altered antigenic expression in accommodation

Courtney Dawn Thornburg
Eli Gilboa, Ph.D., and Herbert K. Lyerly, M.D.
Surgery
Duke University
Immunotherapy of breast cancer with autologous dendritic cells

Arthur John Ulm, III
John N. Whitaker, M.D.
Neurology
University of Alabama at Birmingham
T cell anergy induced by an anti-idotypic antibody

Arun Venkatesan
Asim Dasgupta, Ph.D.
Microbiology and Immunology
University of California–Los Angeles
Selective inhibition of viral translation by a small yeast RNA

Neuroscience and Physiology

Michael Paul Bolognesi
James R. Urbaniak, M.D.
Surgery
Duke University
Mediators of leukocyte adhesion in ischemic reperfusion injury

Damon Barrett Chandler
Stephen L. Hauser, M.D.
Neurology
University of California–San Francisco (Duke University*)
T cell response to MOG protein in the C. jacchus *model of EAE*

Ivan Cheng
David I. Soybel, M.D.
Surgery
Harvard University
Effects of Ca^{2+} receptor activation on gastric epithelial function

Wing Sze Cheung
Stuart A. Lipton, M.D., Ph.D.
Neurology
Harvard University
S-nitrosylation of critical regulatory sulfhydryl group(s) in the cyclic-nucleotide gated channel

Carole Ho
Kenneth S. Kosik, M.D.
Neuroscience
Harvard University (Cornell University Medical Campus*)
mRNA localization in dendrites: requisite sequences for Arc mRNA

Petar Gordan Igic
Jay M. Goldberg, Ph.D.
Pharmacological and Physiological Sciences
University of Chicago
Organization of the efferent fibers in the vestibular nerve

Jonathan Oren Lipton
John A. Kessler, M.D.
Neuroscience/Neurology
Albert Einstein College of Medicine
The role of bone morphogenetic proteins in astrocytic lineage commitment

Eun-Ha Park
Randy L. Jirtle, Ph.D.
Radiation Oncology and Pathology
Duke University
Genomic imprinting of the M6P-IGF2 receptor: potential mechanism for enhanced susceptibility to breast cancer

Jennifer Louise Penzotti
Harry A. Fozzard, M.D.
Pharmacology and Physiology
University of Chicago
The structure of the voltage-gated Na channel determined by toxin affinities for native and mutant channels

Scott Edward Porter
Andrew F. Scott, M.D.
Endocrinology
Yale University
The role of PTHrP in the proliferation of pancreatic islet cells

Amer Samdani
Ted Dawson, M.D., Ph.D., and Valina Dawson, Ph.D.
Neurology
Johns Hopkins University
Nitric oxide mediates potentiation of neurotoxicity by neurotrophins

Michael James Schlosser
Gregory McCarthy, Ph.D.
Surgery/Neurological Surgery
Yale University
Development of functional magnetic resonance imaging of language processing as a pre-surgical tool

Aimee Lee Sison
Frederick Naftolin, M.D., Ph.D.
Obstetrics and Gynecology
Yale University (University of California–San Diego*)
The effects of estrogen on CNS development and plasticity

Arielle Doree Stanford
Jeff W. Lichtman, M.D., Ph.D.
Anatomy and Neurobiology
Washington University
A quantitative study of the effect of protein synthesis inhibition on acetylcholine recepton density and mobility at the neuromuscular junction

Raymond Tabibiazar
Larry I. Benowitz, Ph.D.
Neurosurgery
Harvard University
Isolation of the gene that encodes AF-1, a factor that stimulates retinal ganglion cells to regenerate axons in goldfish

Robert Anthony Taylor
Steven Aaron Siegelbaum, Ph.D.†
Pharmacology
Columbia University
Subunit assembly domains in cyclic-nucleotide-gated channels

Gretchen Kathleen Wieck
Douglas Lee Falls, M.D.
Biology
Emory University
Protein interactions with ARIA's cytoplasmic tail

Structural Biology and Biochemistry

Asim Aminsharif Ahmed
Yuet W. Kan, M.D.†
Laboratory Medicine
University of California–San Francisco (Baylor College of Medicine*)
Hematopoietic stem cell-specific targeting of retroviral vectors through ligand-receptor interactions

Patty Peng-Jung Chi
Henry R. Bourne, M.D.
Cellular and Molecular Pharmacology
University of California–San Francisco
Engineering metal-binding sites to probe mechanism of G protein activation

Arthur Yichia Chow
John P. Kane, M.D., Ph.D.
Biochemistry
University of California–San Francisco
Phospholipid transfer protein: a prospective new protein in high density lipoprotein formation

Brendan Joseph Collins
Richard N. Pierson III, M.D., and Brian W. Christman, M.D.
Cardiac and Thoracic Surgery
Vanderbilt University
Mechanisms of eicosanoid production in hyperacute lung rejection

Continued Awards—Second Year of Research

Adam Robert Burkey
Luc Jasmin, M.D., Ph.D.
Neurosurgery
Georgetown University
Functional anatomy of cortical pain inhibition

Melinda Jean Fan
Sergei Y. Sokol, Ph.D.
Microbiology and Molecular Genetics
Harvard University
Role of Xenopus Fringe *in early development*

Continued Awards—Completion of Medical Studies

Eyal Chai Attar
University of North Carolina at Chapel Hill

Christiana Goh Bardon
Harvard University

Sylvia Irene Becker
Duke University

Roosevelt Bryant III
Boston University

Matthew Callister
Duke University

S. Debbie Chirnomas
Albert Einstein College of Medicine

Hans Christian Fromm
Dartmouth College

Jonathan S. Hott
Wayne State University

Joon Lee
Yale University

John Christopher Maize Jr.
Medical University of South Carolina

Mark Andrew Mallory
Duke University

Jeffrey Abraham Meyerhardt
Yale University

Vamsi F. Mootha
Harvard University

Kimberly Anne Moore
Johns Hopkins University

Jennifer Braemer Ogilvie
Harvard University

Anil Abraham Panackal
Yale University

Ashok Panigrahy
Boston University

Jonathan A. Stiber
New York University

Kerry Uzendoski
University of Illinois College of Medicine at Peoria

Christina Wjasow
Albert Einstein College of Medicine

Douglas Ellis Wright
Stanford University

**A medical school affiliation other than the fellowship institution is indicated in parentheses.*
†Howard Hughes Medical Institute investigator.

ican Medical Colleges, using national databases to monitor trends, and in 1995 hosted a workshop on the careers of physician scientists (see the Institute publication *Workshop on the Training of Physician Scientists and the Assessment of Career Outcomes*).

Postdoctoral Research Fellowships for Physicians

In recent years the pace of fundamental discoveries emerging from biomedical research has been remarkable, yielding significant new understanding of basic biological processes and disease mechanisms. To reap the full benefit of this knowledge now and in the future, it is vital that physicians remain involved in fundamental research.

The Institute's Postdoctoral Research Fellowships for Physicians are designed to help increase the supply of well-trained physician scientists. The awards, first made in 1990, are intended for physicians who are seeking additional research training with a view to becoming independent investigators. The fellowship experience should produce physician scientists who are highly competitive for NIH career development awards, research project grants, and similar private and public-sector research support.

Physicians who have completed at least two years of postgraduate clinical training and less than two years of postdoctoral training in fundamental research are eligible to apply for these fellowships, which provide support for three years of full-time research training in a laboratory of the applicant's choice. Support is provided for fundamental research directed toward an understanding of basic biological processes or disease mechanisms, especially in the areas of interest of the Institute's scientific program. Awards are made to applicants who have demonstrated superior scholarship and show the greatest promise of achievement in biomedical research. Those who elect to work in HHMI laboratories are appointed as HHMI employees.

Physician postdoctoral fellowship applications are evaluated by a panel of distinguished biomedical scientists from universities and medical centers throughout the United States. In 1996 about 250 applications were considered. On the basis of the panel's review, the Institute named 30 physician postdoctoral fellows and 8 HHMI associates to receive their research training under the guidance of superb mentors at 22 universities, research institutes, and hospitals (Figure 15). The awardees come from a diverse mix of medical and graduate schools in the United States and abroad (Figure 16).

The Institute plans to award 30 three-year physician postdoctoral fellowships annually through an international competition. Awards are made on the basis of the applicants' ability and promise and the quality of the research training to be obtained through this program. As of September 1996, 80 physician postdoctoral fellows at 35 institutions were being

Figure 15

Postdoctoral Research Fellowships for Medical Students, Continued Awards

Fellowship Terms

- 30 awards annually
- 3 years of support
- $69,000–$86,500 annually
  - $40,000–$57,500 stipend
  - $16,000 research allowance
  - $13,000 institutional allowance

Eligibility

- M.D., M.D./Ph.D., D.O., M.B.B.S., or equivalent degree
- Full-time fundamental research (basic biological processes or disease mechanisms)
- Any academic or nonprofit research institution
- No faculty appointment
- At the start of the fellowship
  - not enrolled in a graduate degree program
  - at least 2 years of postgraduate clinical training
  - no more than 2 years of postdoctoral research training
  - no more than 10 years since first medical degree

1996 Awards

- Total number: 38*
  - 8 women and 30 men
  - 33 U.S. citizens and 5 others
  - 11 M.D.'s and 27 M.D./Ph.D.'s
- Fellowship institutions: 22
- Distribution by field
  - 6 cell and developmental biology
  - 12 genetics and molecular biology
  - 9 immunology and microbiology
  - 2 mathematical biology and epidemiology
  - 5 neuroscience and physiology
  - 4 structural biology and biochemistry

All Current Physician Postdoctoral Fellows

- Total number: 80*
  - 19 women and 61 men
  - 64 U.S. citizens and 16 others
  - 24 M.D.'s and 56 M.D./Ph.D.'s
  - 2 from minority groups under-represented in the sciences
- Fellowship institutions: 35
- Distribution by field
  - 14 cell and developmental biology
  - 31 genetics and molecular biology
  - 16 immunology and microbiology
  - 2 mathematical biology and epidemiology
  - 11 neuroscience and physiology
  - 6 structural biology and biochemistry

**Fellows who select mentors at HHMI laboratories are appointed as HHMI employees. Of the 38 awardees from the 1996 competition, 8 are employees. No HHMI employees are included in the data on all current fellows.*

supported at an annual cost of about $6 million (Figure 17).

About 19 of the physician postdoctoral fellows in the second or third year of their fellowship term participated in the 1996 Meeting of Predoctoral and Physician Postdoctoral Fellows (see Figure 5). Attendees presented the results of their fellowship research, which they dis-

Figure 16

Postdoctoral Research Fellowships for Physicians, Educational Origins of 1996 Fellows

Medical Schools

Baylor College of Medicine, 2
Case Western Reserve University School of Medicine
Duke University School of Medicine, 2
Harvard Medical School, 7
Johns Hopkins University School of Medicine
Medical College of Wisconsin
National Taiwan University College of Medicine (Taiwan)
New York University School of Medicine
Stanford University School of Medicine, 3
Sydney University (Australia)
University of Alabama School of Medicine
University of Basel (Switzerland)
University of California, Los Angeles, UCLA School of Medicine, 3
University of California, San Francisco, School of Medicine
University of Chicago Division of the Biological Sciences and Pritzker School of Medicine
University of Hamburg (Germany)
University of Iowa College of Medicine
University of Leiden (Netherlands)
University of Michigan Medical School
University of Minnesota Medical School–Minneapolis
University of Oxford (United Kingdom)
University of Pennsylvania School of Medicine
University of Washington School of Medicine
Vanderbilt University School of Medicine
Washington University School of Medicine
Yale University School of Medicine

Graduate Schools (M.D./Ph.D.'s)

Baylor College of Medicine
Case Western Reserve University, 2
Cornell University Medical Campus
Duke University
Harvard University
Johns Hopkins University
Massachusetts Institute of Technology
Medical College of Wisconsin
New York University
Rockefeller University
Stanford University, 2
State University of New York at Stony Brook
University of California–Los Angeles, 3
University of California–San Francisco
University of Chicago, 2
University of Iowa
University of Leiden (Netherlands)
University of Oxford (United Kingdom)
University of Pennsylvania
University of Washington
Vanderbilt University
Washington University

Undergraduate Institutions

Baylor University
Cornell College
Cornell University
Dartmouth College
Harvard University, 3
Haverford College
Johns Hopkins University
Rhodes College
Stanford University, 3
University of Arizona
University of California–Los Angeles
University of California–Riverside
University of California–San Diego
University of Chicago, 2
University of Massachusetts
University of Michigan–Ann Arbor, 4
University of Minnesota–Twin Cities
University of Pennsylvania
University of Southern Mississippi
University of Utah
University of Wisconsin–Madison
Wellesley College
Yale University, 2

High Schools

Alabama
John Carroll, Birmingham
Arizona
Camelback, Phoenix
California
Berkeley, Berkeley
Beverly Hills, Beverly Hills
John F. Kennedy, La Palma
Lynbrook, San Jose
Miraleste, Rancho Palos Verdes
North Tahoe, Tahoe City
Sir Francis Drake, San Anselmo
Connecticut
Amity Regional Senior, Woodbridge
Ridgefield, Ridgefield
Florida
Fort Lauderdale, Fort Lauderdale
Illinois
Libertyville, Libertyville
Maryland
Pikesville Senior, Baltimore
Massachusetts
Lincoln-Sudbury Regional, Sudbury
Norwell, Norwell
Winsor School, Boston
Michigan
Berkley, Berkley
Huron, Ann Arbor
Minnesota
Blake School, Minneapolis
St. Louis Park, St. Louis Park
Mississippi
Gulfport, Gulfport
New Jersey
Kinnelon Public, Kinnelon
West Orange, West Orange
North Carolina
Chapel Hill, Chapel Hill
Pennsylvania
Lower Merion, Ardmore
Wilson Senior, West Lawn
Texas
Coronado, El Paso
Highland Park, Dallas
Utah
Skyline, Salt Lake City
Wisconsin
St. Mary's Central, Menasha
Outside the United States
Australia, Ryde, Sydney
Germany, Gymnasium Kaltenkirchen, Kaltenkirchen
Netherlands, Rijnlands Lyceum Oegstgeest, Oegstgeest
Switzerland, Classical School, Basel
Taiwan, Taichung First Senior, Taichung
United Kingdom, Emanuel School, London

Figure 17

Postdoctoral Research Fellowships for Physicians, All Current Fellowship Institutions

Albert Einstein College of Medicine
Beth Israel Hospital
Brigham and Women's Hospital
Children's Hospital (Boston)
Children's Hospital of Philadelphia
Dana-Farber Cancer Institute
Duke University Medical Center
Fred Hutchinson Cancer Research Center
Harvard Medical School
Harvard School of Public Health
Harvard University
J. David Gladstone Institutes
Massachusetts General Hospital
Massachusetts Institute of Technology
Memorial Sloan–Kettering Cancer Center
National Institutes of Health
New England Medical Center
Northern California Institute for Research and Education
Northwestern University
Princeton University
Rockefeller University
Stanford University School of Medicine
Tufts University School of Medicine
University of California–Irvine
University of California–Los Angeles
University of California–San Francisco
University of Colorado Health Sciences Center
University of Miami School of Medicine
University of Minnesota–Twin Cities
University of Pennsylvania
University of Texas Southwestern Medical Center at Dallas
University of Washington
Washington University
Whitehead Institute for Biomedical Research
Yale University School of Medicine

cussed with predoctoral fellows, Institute staff, and invited guests. Additional fellowship accomplishments were reported to the Institute in the fellows' annual progress reports. In the past year fellows presented numerous talks and posters at regional, national, and international scientific meetings and published many journal articles, book chapters, review articles, and abstracts.

As part of its program assessment activities, the Institute will continue to monitor the participation of M.D.'s and M.D./Ph.D.'s in research and will track the careers of former Institute physician postdoctoral fellows, including their faculty appointments and receipt of research grants. Fellows' progress reports and updates to the directories of predoctoral and physician postdoctoral fellows indicate early success in achieving faculty appointments at leading research-oriented medical schools.

The 1996 physician postdoctoral fellows are listed in Figure 18.

Figure 18

Postdoctoral Research Fellowships for Physicians, 1996 Fellows

Name
Research mentor
Department
Fellowship institution
Research project

Cell and Developmental Biology

Michael Kane Cooper, M.D.
Philip A. Beachy, Ph.D.*
Molecular Biology and Genetics
Johns Hopkins University
Elucidation of zinc hydrolase function in sonic hedgehog signaling and neural tube patterning

Dennis Hyun Oh, M.D., Ph.D.
Philip C. Hanawalt, Ph.D.
Biological Sciences and Dermatology
Stanford University School of Medicine
Repair of sequence-specific DNA damage caused by psoralen-conjugated antigene oligonucleotides

Melissa Kay Thomas, M.D., Ph.D.
Joel F. Habener*
Molecular Endocrinology
Massachusetts General Hospital
Transcription factor regulation of the insulin gene in diabetes

Maria L. Wei, M.D., Ph.D.
Regis B. Kelly, Ph.D.
Biochemistry and Biophysics
University of California–San Francisco
Regulated secretion of an insulin responsive storage vesicle containing a glucose transporter

Keith Allen Wharton Jr., M.D., Ph.D.
Matthew P. Scott, Ph.D.*
Developmental Biology
Stanford University
Function of naked, *a negative regulator of transcription and signal transduction*

Michael Bruce Yaffe, M.D., Ph.D.
Lewis C. Cantley, Ph.D.
Medicine
Beth Israel Hospital
The role of the 90-kDa heat shock protein in regulating signal transduction following injury

Genetics and Molecular Biology

Ravi Allada, M.D.
Michael M. Rosbash, Ph.D.*
Biology
Brandeis University
Identification of transcription factors which mediate period *autoregulation and photosensitivity*

Michael Angelo Bender, M.D., Ph.D.
Mark T. Groudine, M.D., Ph.D.
Basic Sciences
Fred Hutchinson Cancer Research Center
Targeted mutation analysis of the mouse β-globin locus control region

Mark Russell Benson, M.D., Ph.D.
Kevin Struhl, Ph.D.
Biological Chemistry and Molecular Pharmacology
Harvard Medical School
Transcriptional repression by the Not complex

John Scott Cameron, M.D., Ph.D.
H. Robert Horvitz, Ph.D.*
Biology
Massachusetts Institute of Technology
Initiation of the cell death program in C. elegans

Leif William Ellisen, M.D., Ph.D.
Daniel A. Haber, M.D., Ph.D.
Tumor Biology
Massachusetts General Hospital
The Wilms tumor gene, WT1, in hematologic differentiation and malignancy

Dean Walton Felsher, M.D., Ph.D.
J. Michael Bishop, M.D.
Microbiology and Immunology
University of California–San Francisco
A transgenic model system using a c-myc *oncogene whose activity can be regulated*

Mark Walter Frohlich, M.D.
Clifford A. Lowell, M.D., Ph.D., and Yuet W. Kan, M.D.*
Laboratory Medicine
University of California–San Francisco
Receptor-targeted gene delivery to hematopoietic stem cells using retroviral vectors

Rajesh Tim Gandhi, M.D.
David Baltimore, Ph.D.
Biology
Massachusetts Institute of Technology
Mechanisms of apoptotic cell death during HIV-I infection: a novel approach

Cheryl Elaine Gariepy, M.D.
Masashi Yanagisawa, M.D., Ph.D.*
Molecular Genetics
University of Texas Southwestern Medical Center at Dallas
The role of the endothelin-B receptor in development of the enteric nervous system and adult homeostasis

Karen Webster Gripp, M.D.
Maximilian Muenke, M.D.
Joseph Stokes Jr. Research Institute, Division of Human Genetics and Molecular Biology
Children's Hospital of Philadelphia
Positional cloning of the gene for autosomal dominant holoprosencephaly: HPE3

Melanie Kay Kuechle, M.D.
Beverly Ann Dale, Ph.D.
Oral Biology
University of Washington
Filaggrin expression and evidence of apoptosis: identification of biochemical markers of apoptosis and important filaggrin sequences involved in terminal differentiation of keratinocytes

Thomas Edward Wilson, M.D., Ph.D.
Michael R. Lieber, M.D., Ph.D.
Pathology
Washington University
Immunoglobulin isotype class switch recombination: substrate analysis and the link to DNA repair

Immunology and Microbiology

David Owen Beenhouwer, M.D.
Matthew D. Scharff, M.D., and Betty Diamond, M.D.
Cell Biology; Medicine
Albert Einstein College of Medicine
The role of somatic mutation in autoimmunity

Jonathan Howard Blum, M.D., Ph.D.
John J. Mekalanos, Ph.D.
Microbiology and Molecular Genetics
Harvard Medical School
Isolation of anti-bacterial molecules that inhibit virulence factors of V. cholerae

Kathleen Loretta Collins, M.D., Ph.D.
David Baltimore, Ph.D.
Biology
Massachusetts Institute of Technology
Recognition of HIV infected cells by cytotoxic T cells

Randy Quentin Cron, M.D., Ph.D.
David B. Lewis, M.D.
Pediatrics
University of Washington
The role of NF-AT proteins in transcriptional regulation of IL-4 expression

Nam Hoang Dang, M.D., Ph.D.
Brian Seed, Ph.D.
Molecular Biology
Massachusetts General Hospital
Search for novel structures involved in T cell apoptosis

Alexander Khoruts, M.D.
Marc K. Jenkins, Ph.D.
Microbiology
University of Minnesota–Twin Cities
The functional response of antigen-specific CD4+ T cells to oral antigen administration: induction of tolerance, immunity, and disease

Wajahat Zafar Mehal, M.B. B.Ch., D.Phil.
Ian N. Crispe, M.B. B.S., Ph.D.
Biology, Section of Immunobiology
Yale University School of Medicine
Hepatic localization and activation induced cell death of peripheral CD8 cells

George Joji Murakawa, M.D., Ph.D.
Stanley Falkow, Ph.D., and Lucy S. Tompkins, M.D., Ph.D.
Microbiology and Immunology
Stanford University School of Medicine
Pathogenesis of B. henselae *in cutaneous and systemic disease*

Marcel Rudolf Maria van den Brink, M.D., Ph.D.
Steven J. Burakoff, M.D., Ph.D.
Pediatric Oncology
Dana-Farber Cancer Institute
The role of mitogen-activated protein kinases in interleukin-2 production and apoptosis in T lymphocytes

Mathematical Biology and Epidemiology

Megan Blanche Murray, M.D.
James M. Robins, M.D. and Barry R. Bloom, Ph.D.*
Epidemiology
Harvard School of Public Health (Dr. Bloom is at Albert Einstein College of Medicine)
Molecular epidemiology of tuberculosis

Thomas Dee Wu, M.D., Ph.D.
Douglas L. Brutlag, Ph.D.
Biochemistry
Stanford University School of Medicine
Probabilistic methods for predicting the location and structure of genes in DNA sequences

Neuroscience and Physiology

Matthew Peter Anderson, M.D., Ph.D.
Susumu Tonegawa, Ph.D.*
Brain and Cognitive Science
Massachusetts Institute of Technology
Brain-derived neurotrophic factor and its receptor TrkB in plasticity of the adult central nervous system

Robert Francis Hevner, M.D., Ph.D.
John L. R. Rubenstein, M.D., Ph.D.
Psychiatry
University of California–San Francisco
The role of homeobox genes in forebrain development

Eric JinSheng Huang, M.D., Ph.D.
Louis F. Reichardt, Ph.D.*
Physiology
University of California–San Francisco
The roles of Brn-3 family transcription factors in neurotrophin-regulated sensory neuron development

Genevieve Anne Laforet, M.D., Ph.D.
Neil Aronin, M.D.
Medicine and Cell Biology
University of Massachusetts Medical Center
Huntingtin interactions in brain cells

Samuel Jeremy Pleasure, M.D., Ph.D.
Daniel H. Lowenstein, M.D., and Marc Tessier-Lavigne, Ph.D.*
Neurology and Neuroscience
University of California–San Francisco
Chemotactic axon guidance molecules in hippocampal development

Structural Biology and Biochemistry

Robert Charles Flaumenhaft, M.D., Ph.D.
Bruce Furie, M.D.
Hematology-Oncology
New England Medical Center
Signal transduction via phosphohistidine in platelets

John Hwa, M.B. B.S., Ph.D.
H. Gobind Khorana, Ph.D.
Biology; Chemistry
Massachusetts Institute of Technology
The study of ligand binding and activation of G-protein coupled receptors using retinitis pigmentosa mutants in rhodopsin

Christoph Andreas Meier, M.D.
William W. Chin, M.D.
Medicine
Brigham and Women's Hospital
Interaction of the peroxisome proliferator-activated receptors with other nuclear proteins

Raghavendra G. Mirmira, M.D., Ph.D.
Daniel V. Santi, M.D., Ph.D.
Pharmaceutical Chemistry
University of California–San Francisco
Cloning and characterization of type II peptide synthetase domains

**Howard Hughes Medical Institute Investigator*

Undergraduate Biological Sciences Education

Since 1988 the Institute's Undergraduate Biological Sciences Education Program has awarded more than $335 million in grants to 220 colleges and universities (Figure 19). The principal goal of the undergraduate program is to support efforts to strengthen the quality of U.S. college 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 broaden access to the sciences for women and members of minority groups underrepresented in the sciences, including blacks and Hispanic and Native Americans.

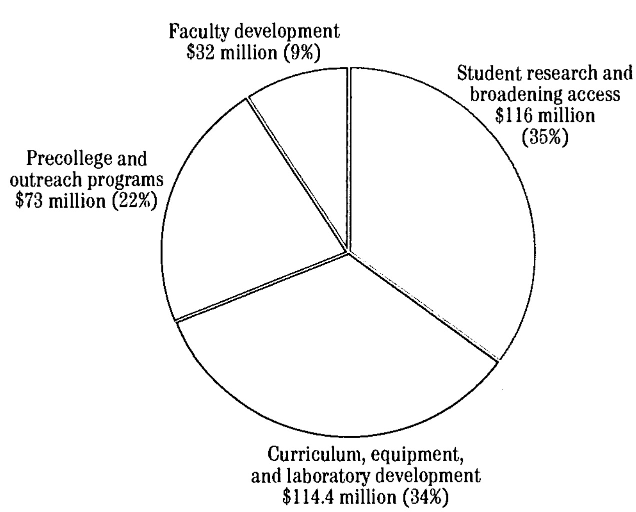
College-level science is a pivotal stage in the development of future scientists and the formation of attitudes about science in students who pursue other careers. College science departments are using their HHMI grants to develop a range of activities that address key areas of undergraduate science education, including curricula for nonscience majors.

Many departments are providing preservice and in-service programs for precollege teachers and extending outreach activities to precollege students, especially young women and underrepresented minorities. To meet the demands of a diversifying student population, science departments are also developing programs for prefreshmen, community-college transfer students, and other nontraditional students.

Having made its seventh round of awards in 1996, the Undergraduate Biological Sciences Education Program continues to evolve in response to developing national trends in science education. Over the past nine years, the Institute has endeavored

Figure 19

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



to assess the impact of its undergraduate awards. Through annual progress reports and presentations at annual program directors' meetings, grantee institutions are beginning to document the success of their Institute-supported programs.

Eligibility and Award Process

Colleges and universities are invited to compete for undergraduate grants on the basis of an assessment of their recent records of preparing students for advanced study and careers in research and medicine. Classifications by the Carnegie Foundation for the Advancement of Teaching are used to identify institutions for this assessment.

In categorizing institutions (e.g., as research universities, doctoral universities, master's colleges and universities, or baccalaureate colleges), the Foundation takes into account such factors as the range of the baccalaureate program, number of Ph.D. degrees awarded annually, and amount of federal support for research and development, as appropriate.

For the 1988–1994 competitions, the Institute's assessments of institutions were based on the 1987 Carnegie Foundation classifications. For the 1996–1998 competitions, assessments were based on the 1994 classifications[1] (Figure 20).

Selected institutions are invited to submit proposals that reflect the par-

[1]Further information may be found in Classification of Institutions of Higher Education, Carnegie Foundation for the Advancement of Teaching, Princeton, NJ, 1994.

Figure 20

Carnegie Classifications, 1994

The following classifications and categorical definitions were used for the 1988-1996 competitions, which included public and private institutions.

Research Universities I: 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 $40 million or more in federal support annually.

Research Universities II: 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 between $15.5 million and $40 million in federal support annually.

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

Master's Colleges and Universities I (Comprehensive Colleges and Universities I*): 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 (Comprehensive Colleges and Universities II*): 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 (Liberal Arts Colleges I*): These institutions are primarily undergraduate colleges with a 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 (Liberal Arts Colleges II*): These institutions are primarily undergraduate colleges with a 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.

Schools of Engineering and Technology: These institutions offer programs almost exclusively to technical fields of study and award at least a bachelor's degree.

**1987 Carnegie Foundation classifications* ticular strengths, needs, and future directions of their undergraduate science programs. Proposals are first reviewed by a panel of distinguished scientists and educators. The panel's evaluations are then reviewed by an internal Institute committee, which makes recommendations to the Institute's Trustees, who authorize funding. The Institute provides multiyear grants for initiatives that address one or more of the program elements supported by the undergraduate program.

Program Development, 1988–1996

With its 1996 round of awards, the undergraduate program entered its third phase. Each phase builds on those that preceded it on the basis of information the Institute receives through program directors meetings, other meetings on focused topics, and annual program reports submitted by grantee colleges and universities. The Institute's Trustees, management, and staff also bring broad experience and important insights to program development.

In the first phase of the undergraduate program (1988–1992), the Institute awarded $175.4 million in grants to 181 institutions. Program elements supported were student and faculty development, curriculum and laboratory development, and precollege and outreach programs (Figure 21).

The 1993 and 1994 competitions represented a second phase for the undergraduate program, developed in part in response to the Institute's ongoing assessments. In this phase, the Institute made awards totaling $114.5 million to 109 colleges and universities. Program elements supported in Phase II were student research and broadening access to science for women and minority students, equipment and laboratory development, and precollege and outreach programs (Figure 22).

Figure 21

Undergraduate Awards, Phase I, 1988–1992

- Five-year awards
- Program elements
  - student research and broadening access to science for women and underrepresented minority students
  - faculty development
  - curriculum and laboratory development (support for equipment and laboratory renovation limited to 30 percent of the grant)
  - precollege and outreach programs
- Awards ($175.4 million to 181 institutions)
  - 1988 $30.4 million awarded to 44 colleges and universities (99 competing). Of 81 liberal arts and comprehensive colleges and 18 historically black institutions competing, 34 and 10 received awards.
  - 1989 $61 million awarded to 51 research and doctorate-granting universities (101 competing)
  - 1991* $31.5 million awarded to 44 comprehensive and liberal arts colleges and universities (98 competing). Of the 44, 10 had strong records of educating underrepresented minority students in the sciences.
  - 1992 $52.5 million awarded to 42 research and doctorate-granting universities (98 competing)

**No competition was held in 1990.*

Figure 22

Undergraduate Awards, Phase II, 1993–1994

- Four-year awards
- Program elements

  student research and broadening access to science for women and minority students

  equipment and laboratory development (no limitation on equipment funding, and renovation funding limited to 50 percent of the grant)

  precollege and outreach programs
- Awards ($114.5 million to 109 institutions)

  1993 $28.5 million awarded to 47 comprehensive and liberal arts colleges and universities (175 competing). Of the 47, 18 had a significant record of educating minority students in the sciences.

  1994 $86 million awarded to 62 research and doctorate-granting universities (140 competing)

Figure 23

Undergraduate Awards, Phase III, 1996

- Four-year awards
- Program elements

  student research and broadening access to science for women and minority students

  faculty and curriculum development

  equipment and laboratory development (no limitation on equipment funding, and renovation funding limited to 50 percent of the grant)

  precollege and outreach programs
- Awards

  1996 $45.4 million awarded to 52 master's and baccalaureate institutions (189 competing)

New Awards, 1996

In July 1996 the Institute announced the results of the seventh round of competition for undergraduate program grants. A total of $45.4 million over four years was awarded to 52 master's and baccalaureate institutions, who were selected from 189 competing institutions. These grants are supporting student research and broadening access to science for women and minority students, faculty and curriculum development, equipment and laboratory development, and precollege and outreach programs (Figures 23 and 24).

Student Research and Broadening Access

For many students, research experience brings science to life by enabling them to explore real scientific problems in a laboratory setting. Such experiences are often a student's first step toward a scientific career. For students who pursue other career paths, these experiences can enrich classroom learning and impart a lifelong appreciation of science.

One objective of this program element is to provide research opportunities for women and members of minority groups such as blacks, Hispanics, and Native Americans who have traditionally been underrepresented in science.

Approximately $12.5 million of the $45.4 million awarded in 1996 is supporting laboratory research experiences for undergraduates, ranging from incoming freshmen to seniors at 51 institutions. Institute funds will enable those students to conduct hands-on research in close collaboration with faculty members at their own institutions, at other institutions, and in industrial laboratories. Students will have the opportunity to do research full-time during the summer, part-time during the academic year, and in some cases during both periods.

Some institutions are offering special laboratory training or enrichment programs to build skills and prepare students to make the most of their research experiences. Others will open their research programs to students from other institutions, especially those enrolling significant numbers of minority students underrepresented in science. Figure 25 provides examples of student research programs supported by the 1996 awards.

Faculty and Curriculum Development

Institutions have emphasized the importance of support for faculty and curriculum development in enabling them to attract new faculty scientists and update science curricula by adding new courses in cutting-edge fields, developing interdisciplinary courses that focus on the connections between fields, and revising existing courses to incorporate not only new scientific knowledge but also new teaching approaches, including those that make use of educational technology.

Educational technology is playing an increasingly important role in the undergraduate science curriculum. Computer simulations of biological processes and experiments, tools for visualizing the structure and function of molecules, and other applica-

Figure 24

Undergraduate Awards to 52 Universities ($45.4 million) by Program Component, 1996 Competition

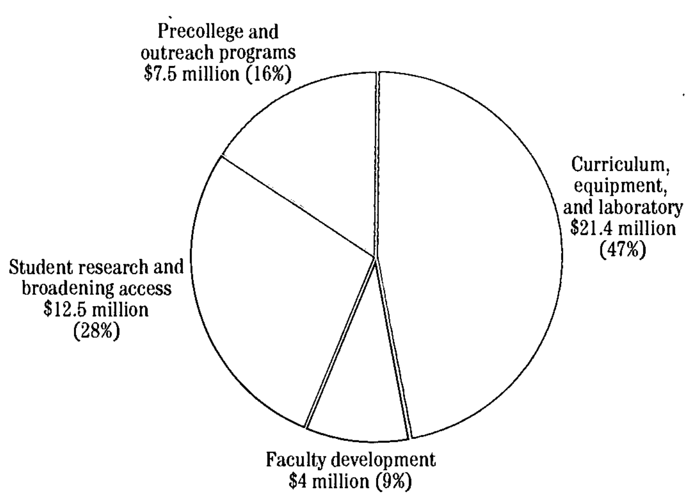


Figure 25

Examples of Student Research and Broadening Access to Science Programs, 1996

Canisius College

This urban college with a high first-generation population seeks to increase its representation of women and minorities while providing solid training for all students. On the basis of experience, the College has identified characteristics such as weak mathematics and study skills that place entering students at risk of not succeeding in science. The grant will provide opportunities for students to strengthen basic skills and, if necessary, take the curriculum at a slower pace. All prospective science majors will participate in a prefreshman mentoring program that will continue during the freshman year with a program of interdisciplinary seminars. Once these basic skills are in place, students will begin on- or off-campus summer and/or academic year research.

Carleton College

Student research is considered a central aspect of science education at Carleton College, an institution with a strong record of preparing students for graduate and medical school. The grant will support students conducting summer research in biology and chemistry, in areas including visualization and manipulation of molecular models, neurochemistry and behavior, and immunology. Grant funds will provide graphics and modeling equipment and will support laboratory upgrades. The College will provide students--including those at risk of dropping out of the sciences--with additional mentoring, academic counseling and support, and advice and information on graduate and medical school.

Colgate University

Colgate's program at the National Institutes of Health will expand research opportunities for undergraduates from Colgate and other institutions. Students will participate in a research-intensive paid internship at NIH and attend a course on biomedical research. A science mentoring program will encourage and support Colgate students, particularly minorities underrepresented in the sciences, to pursue graduate study and science careers. The grant will strengthen the Introduction to Research program and provide additional research activities for molecular biology students on the Colgate campus. Workshops on campus will feature NIH scientists. Travel funds will enable students to visit graduate or professional schools.

Colorado College

A major part of this grant-funded initiative will be the expansion of a successful program supported by earlier HHMI awards that eases the transition to college science for high school students in southwestern states, beginning in their junior year and including students from minority groups underrepresented in the sciences. The program bolsters students' quantitative and scientific skills and prepares them for the rigors of college science. Undergraduates will pursue research on campus with a faculty mentor, or off campus under the supervision of a scientist at such research-intensive institutions as the University of Colorado Health Sciences Center and the National Jewish Hospital in Denver. Undergraduates' research activities will be supplemented by special seminars, research presentations, and opportunities to attend professional meetings.

Earlham College

HHMI support will expand current student-faculty research opportunities both on and off campus. Each year students will receive support to conduct research on campus with faculty mentors. Both faculty and students will have the opportunity to attend meetings and seminars at other colleges. Students will also have opportunities to conduct research off-campus in the laboratories of Earlham alumni at other universities, federal agencies, and medical centers. HHMI support will fund student travel to and from the off-campus research sites and summer stipends (including living expenses). Students will present their research at an on-campus colloquium series and at local and national meetings.

Figure 25 (*continued*)

Examples of Student Research and Broadening Access to Science Programs, 1996

Florida Agricultural and Mechanical University

To accommodate unprecedented growth in the number of majors and graduates in biology and to assure the continued quality of the University's undergraduate science program, the grant will support a range of development activities for African American students. Matriculating students will have an opportunity to prepare for college courses during the summer before their freshman year and to take advantage of a science and mathematics tutoring center. As undergraduates, students will receive stipends and other support for research experiences in laboratories at such institutions as the University of Florida and the University of Miami and at pharmaceutical companies.

Macalester College

The College seeks to make its "culture of science" accessible to a more diverse student body. The grant will provide ongoing academic support, ranging from prefreshman programs to career counseling, for students throughout their four years of undergraduate study. Because the College is in a geographic area where minorities are not well represented, it will enlist the aid of alumni, who will serve as host families to provide crucial social support for students from minorities underrepresented in the sciences. The academic program will include summer and academic-year research and interdisciplinary seminars that will be held from the prejunior summer through senior year and will be followed by student attendance, with faculty mentors, at national scientific meetings.

Middlebury College

The freshman year has been identified in national studies as a key period in the development of young scientists, when many talented students struggle unsuccessfully with the rigors of college-level science and mathematics. This grant will focus on first-year students, providing academic support and laboratory training designed to give them a head start in their studies and to integrate them into the College's scientific community. Grant funds will also support expansion of a faculty-student summer research program and provide for travel support and mini-grants that will be awarded to students on a competitive basis.

Oakland University

This grant will support student research and other activities principally focused on the theme of biological communications from the organismal through the intracellular and molecular levels. Students will learn scientific problem-solving and experimental design and will use sophisticated instruments to study contemporary biology. Students will participate in a colloquium and receive credits for research conducted during the academic year. Grant funds will provide stipends and cover students' room and board during the summer research program. The grant will also cover general research supplies and travel to national meetings.

Occidental College

Undergraduates at the College will be able to choose from a range of opportunities in the sciences, including laboratory research with faculty in such areas as molecular genetics, structural biology, and biochemistry. Students may also collaborate with faculty in designing and testing new laboratory experiments to be used in courses. The grant will also support a prefreshman bridging program to ease students' transition into introductory courses and will provide laboratory experiences for entering students who are highly motivated but underprepared for college-level science and mathematics.

Figure 25 (*continued*)

Examples of Student Research and Broadening Access to Science Programs, 1996

St. Mary's University

This University, which has a primarily Hispanic student population, is initiating a comprehensive effort to retain students in science and encourage them to enter biomedical careers. Much of the effort will consist of a proven, cost-effective tutorial program, which will closely train and supervise upperclassmen as tutors for freshmen and sophomores in introductory biology, chemistry, mathematics, and physics courses. Intensive prefreshman laboratory training will precede off-campus summer research experience. These activities will provide students with an entree to programs that encourage advanced study and research for students from minorities underrepresented in the sciences, such as the Minority Access to Research Careers program of the National Institutes of Health.

Tuskegee University

Prior HHMI grants have supported the University's program to strengthen preresearch skills in matriculating students, which has led to several examples of individual success. Now the University seeks to widen its effort by including more students and broadening the number of science disciplines represented. Prefreshmen will take courses and laboratories on topics such as English, critical thinking, and computers. This will be followed by freshman honors investigative laboratories in biology and chemistry. In the summer before the sophomore year, students will participate in research off campus. Some students will be eligible for on-campus research following the sophomore year.

Villanova University

Follow-up studies of former participants in the University's HHMI-supported research and broadening access program indicate some notable accomplishments. Several students have gone on to pursue advanced degrees and earn prestigious fellowships, awards, and honors. With continued HHMI support, Villanova will expand undergraduate involvement in research in biology and other scientific disciplines. A special effort will be made to recruit students from historically black universities and large state university campuses with substantial African American and Hispanic student populations to participate in the program.

tions are becoming an indispensable supplement to laboratory and classroom instruction.

The Institute renewed support for faculty and curriculum development in the 1996 competition, awarding $8 million to 51 institutions. Examples of faculty and curriculum development programs supported by the 1996 awards are presented in Figure 26.

Laboratory Development and Equipment

Modern teaching equipment and laboratories are essential to sustaining effective college-level programs in the life sciences. As the knowledge base in biology rapidly expands, so do the demands on undergraduate instructional laboratories. Science departments must be equipped with sophisticated laboratories and instrumentation to teach the principles and techniques of genetics, cellular and molecular biology, and other disciplines.

In 1996 the Institute awarded $17.4 million to 51 institutions for equipment acquisition, laboratory renovation, and other enhancements

Figure 26

Examples of Faculty and Curriculum Development Programs, 1996

Allegheny College

The College is introducing a neuroscience major with tracks in cellular and cognitive neuroscience. Grant funds will support two new faculty members—a developmental or molecular neurobiologist and a cognitive or clinical neuropsychologist or psychobiologist—whose presence will expand student research opportunities and who will develop new courses such as a neuroscience seminar. Existing faculty members will receive release time to expand their neuroscience research skills and either develop new neuroscience courses or hone the neuroscience focus of existing courses.

Bates College

The grant will support neuroscience curriculum development, summer faculty development institutes, and a mathematics resource center. Three Bates faculty members with expertise in the neurosciences will receive partial release time to design a new major in neuroscience and to travel to meetings on pedagogy and curriculum development. Faculty support will also include the development of institutes on science literacy and pedagogy. Grant funds will provide stipends for participants, outside speakers, and consultants; materials for the institutes; and materials for the implementation of new and revised courses.

Beloit College

The program will focus on BioQuest, a curriculum development learning laboratory in the biological sciences. Grant support will broaden faculty development efforts through workshops on the Beloit campus and elsewhere and increase dissemination of program information through newsletters, a web site, and conferences. The development of new curricula and modification of biology and chemistry courses will enable students to become active participants in the learning process. Goals are to increase the number of BioQuest modules to about 60 and increase the number of participating institutions to about 150. Grant funds will support salaries for BioQuest staff, faculty release time, and travel to present new curricular materials.

Centenary College of Louisiana

The grant will provide start-up funds and partial salary for a new faculty member in neurobiology, with an emphasis on molecular neurobiology and neural imaging, who will expand the disciplinary scope of the biology department in terms of both teaching and student research and serve as a liaison to Louisiana State University (LSU) Medical Center, which has targeted neurobiology as a research focus and sponsors off-campus research for College students. Funds for faculty development will enable existing faculty to expand and upgrade their research skills in training sessions at LSU, in step with College-supported curricular shifts to more interdisciplinary, community-based, and active learning as well as to molecular rather than classical genetics.

City University of New York Brooklyn College

With grant support, the College will undertake a major revision of its biology curriculum to incorporate enriched sequences for science majors and nonmajors, a new core introductory course covering cellular and molecular biology, and updated intermediate and advanced laboratories. Undergraduate teaching laboratories will be equipped with modern instruments and networked computer workstations, which will be enhanced with multimedia software. A new faulty member in neuroscience will be appointed to develop courses and undergraduate research opportunities currently not offered in that department.

Figure 26 (*continued*)

Examples of Faculty and Curriculum Development Programs, 1996

Haverford College

A new interdisciplinary program on biology, medicine, and society will be established, expanding the traditional definition of biomedical careers. A visiting scholar and released faculty members will develop the program, which will include new courses in bioethics and public health policy. The College will build on its successful revision of the biology curriculum by expanding its curriculum revision efforts to other disciplines. Physics and mathematics faculty members will revise and team-teach biology-related courses such as an introductory calculus course targeted to natural science majors. Start-up funds will support a new faculty member in chemistry.

Hope College

Start-up funds will assist three new faculty members in neuroscience, biophysical chemistry, and environmental biology to expand their interdisciplinary teaching and research. Release time will allow faculty members to develop research-oriented laboratories for middle- and upper-level biology and chemistry courses as has already been done at the introductory level. A course on mathematical approaches to environmental problem-solving will be developed for nonmajors. Two interdisciplinary mini-grant initiatives will provide awards for faculty members from science and nonscience departments to conduct collaborative research and revise courses such as biostatistics that are taken by many science majors.

Nebraska Wesleyan University

This grant will enable the University to continue the work begun under its previous HHMI grant in upgrading courses and laboratories in biology, chemistry, physics, and mathematics. Faculty members will receive support for participation in national workshops, professional meetings, and off-campus research at major institutions and for the integration of new knowledge and techniques into the curriculum. A focus of these efforts will be the development of interdisciplinary courses that link biology with other fields. University faculty members will work with colleagues at Philander Smith College, a historically black institution in Arkansas, to establish collaborative research, student exchange, and precollege teacher training programs.

St. John's College

This grant will support the revamping of the science equipment and laboratory infrastructure to enhance the College's classical, individualized pedagogy (which includes reading original sources) with modern biological concepts and methodologies. Summer salaries will be provided for faculty members to revise the curriculum by developing interdisciplinary investigative laboratories and other initiatives and to create a faculty summer study program. Faculty members will also attend national meetings on science education. By the end of the grant, a substantial number of faculty members will have participated in the study program, providing a springboard for the modernization effort.

Spelman College

HHMI support will focus on the establishment of a computer-based laboratory to expand students' analytical skills and ability to design and run sophisticated experiments. Faculty development support will enable faculty members to expand their expertise and establish new laboratory techniques. A new tenure-track faculty appointment will be made, and research start-up funds will be provided for the appointee. A visiting lecture series will bring practicing scientists to the campus. In addition to serving as role models for students, the visiting scientists will collaborate with faculty members to design and implement mini-courses and symposia.

Figure 26 (*continued*)

Examples of Faculty and Curriculum Development Programs, 1996

Swarthmore College

This grant, to be supplemented by College funds, will support a new faculty member in molecular evolutionary biology who will provide additional courses and cutting-edge research opportunities for students. Faculty development funds will provide release time for one faculty member each in the biology, chemistry, and physics departments to implement and evaluate a new interdisciplinary research thesis–based honors program. In addition, honoraria and travel expenses will be provided for visiting speakers for the chemistry senior honors study seminar.

Wellesley College

Following a two-year review of its curriculum, the College has begun to address a major obstacle to women's success in science and mathematics: a lack of quantitative skills that are essential to advanced scientific study. The grant will support a curriculum-wide effort to strengthen mathematics education for science majors and nonmajors through increased tracking and testing of students' abilities and new courses designed to bolster numerical and symbolic reasoning. Faculty members will receive support to develop this curriculum and to update existing courses and create new courses that bridge scientific disciplines.

Whitman College

Collaborations between such departments as biology and chemistry at the College have resulted in enriched curricula that reflect the interdisciplinary nature of biomedical research. The grant will enable the College to appoint a new faculty member in biophysics, an important field not currently represented in the curriculum. This faculty member will establish cross-departmental links between biology and physics and create new courses covering such areas as cell and membrane physiology, spectroscopy, and bioelectronics. The grant will provide salary support as well as computer equipment and laboratory start-up funding.

Wesleyan University

A two-year internal study of Wesleyan's natural sciences and mathematics programs has identified key areas of the faculty and curriculum that the grant program will address, including new curricula in such areas as structural biology and computational neuroscience; enriched science education for nonscience majors; and increased use of electronic communications, including the World Wide Web, for science teaching. Start-up support will be provided for new faculty appointments in cellular biology—with a likely emphasis on developmental biology—and molecular biology (focusing on gene regulation or the biochemistry of cellular processes related to molecular genetics).

that will broaden student research opportunities and strengthen undergraduate instruction in the biological sciences and related fields. Examples of activities to be undertaken with Institute support for equipment and laboratory development appear in Figure 27.

Precollege and Outreach Programs

Approximately $7.5 million was awarded to 46 institutions for the establishment or expansion of outreach programs that provide science activities for students and teachers from elementary, middle, and high schools, including those with signifi-

Figure 27

Examples of Equipment and Laboratory Development Programs, 1996

Benedictine University

The grant will support laboratory renovations and equipment acquisitions for a major revision of the introductory biology, chemistry, and physics courses into a single integrated four-semester laboratory course for all science majors. The combined laboratory will include networked computer workstations to improve scientific communications and data analysis and permit team-oriented interdisciplinary study of complex biological structures such as macromolecules. Laboratory upgrades and equipment will also expand faculty-student research into areas of faculty expertise, including the use of synthetic peptides to study ligand binding.

Bryn Mawr College

Grant support for facility renovations and equipment will enhance the teaching of biology and related disciplines. Funded activities will include the renovation of a central lecture room and the creation of two new teaching laboratories. The lecture room will be renovated into a multimedia facility that will be used in introductory biology and other science and mathematics courses. A large laboratory will be converted into two smaller laboratories—one for general purposes, the other for advanced computing—that will be used for new courses in toxicology, computer modeling, and integrated sciences, as well as for outreach activities. Advanced workstations and other computing and networking equipment will be purchased. A computer resource person will maintain the laboratory and contribute to curriculum projects and outreach activities.

City University of New York Queens College

A computational biology center will be established to support the integration of inquiry-based learning to enhance both undergraduate research and biology instruction. The center will be incorporated into the laboratory curricula for selected science courses. Students will use the computers for data acquisition and manipulation and to access on-line educational and research-oriented resources, including DNA and protein sequence databases. Lecture and laboratory curricula will be enhanced by integrating inquiry-based learning. Laboratory space and new equipment will be purchased for courses in cell and molecular biology, animal physiology, and introductory and organic chemistry and biochemistry.

Hampshire College

Funding will be used to purchase new equipment and to expand and renovate laboratories, increasing students' access to research-quality equipment and facilities. Major equipment purchases include a high-performance liquid chromatograph, an image analysis system for gel electrophoresis, microscopes, and computers. Equipment will be used in introductory and advanced research courses in the biomedical sciences as well as for outreach activities in molecular biology. Students in advanced courses will carry out investigative research in small groups. The grant will also provide funds for technical support and equipment maintenance.

Kenyon College

Equipment purchased with grant funds will enhance student research capabilities through introductory- to upper-level courses that integrate teaching and research in a range of disciplines from molecular biology to physics and mathematics. The instrumentation that will be acquired includes networked workstations and digital imaging for fluorescence microscopy (for biology), molecular genetics workstations, and sensory data acquisition (for neuroscience and psychology). Grant funds will also provide laboratory start-up support for a new faculty member in bio-organic chemistry.

Figure 27 (*continued*)

Examples of Equipment and Laboratory Development Programs, 1996

Mount Holyoke College

The College will develop inquiry-based laboratories that will be used by student investigators in all biology courses. Through these laboratories, students will learn about biological phenomena and design experiments and procedures to test hypotheses. General-purpose workstations will be built that can be used by students in their independent research as well as in science courses. HHMI support will fund laboratory equipment for workstations, equip a computer laboratory for teaching and research in molecular modeling, and renovate existing teaching laboratories.

Ohio Wesleyan University

Building on renovations and equipment acquisitions that were funded by a previous HHMI grant, the University will further enhance the research environment for students and infuse the curriculum with technology for multidisciplinary teaching. Funds will be used to upgrade existing zoology and microbiology and botany courses to include molecular biology components. A facility to support the study and use of high-performance computing and computational science in undergraduate science and mathematics instruction and a computational science/ multimedia classroom and laboratory will be developed. In addition, funds will be used to procure equipment to enable junior faculty to establish research programs.

Point Loma Nazarene College

Equipment acquisitions and laboratory renovations will help to strengthen the quality of laboratory instruction and the summer research program. The grant will support a cold room used for laboratory exercises in biochemistry and molecular biology courses and research. In addition, genetics and chemistry teaching laboratories will be refurbished. Equipment purchases will include microscopes (inverted and fluorescence), laminar flow hoods, centrifuges, incubators, and other small instruments that will enable students to gain hands-on experience in cell culture techniques and to apply them in cell, molecular, and developmental biology.

Pomona College

This grant will support the integration of computational biology throughout the science curriculum as an adjunct to wet-lab experiences. This will be accomplished by the renovation and equipping of a life sciences molecular modeling laboratory that will be used in lower- and upper-level courses and faculty-student research. Another aim is to enhance student research capabilities in laboratories by providing equipment such as thermal cyclers and videomicroscopes for investigative laboratories in biology, molecular biology, and neuroscience. The grant will also provide laboratory start-up funding for a new faculty member in biology and molecular biology.

Reed College

Grant funds will be used to increase access to computing resources and to implement new curricular initiatives to enhance students' quantitative skills. Three new simulation initiatives (molecular imaging, image analysis, and biodiversity) will be developed for introductory and upper-division courses. These initiatives will use the computer facility and will be developed with the assistance of a computer programmer. Existing facilities will be reconfigured and expanded to accommodate a biology computer hub. Computers with CD-ROM and multimedia capabilities for biology teaching will be upgraded, and teaching laboratories will be networked.

Figure 27 (*continued*)

Examples of Equipment and Laboratory Development Programs, 1996

Saint Olaf College

The grant will provide computers, accessories, and networks to integrate computer technology into the entire science curriculum. The computers will be used for both problem-solving and data acquisition in biology courses ranging from human biology for nonmajors to cellular biology and genetics, as well as for molecular calculations in chemistry courses such as structural chemistry and equilibrium. The local and College-wide networks will complete an already integrated teaching and research setting. Grant funds will also be used to purchase instrumentation such as videomicroscopes and spectrometers for biology and chemistry teaching laboratories.

Washington and Jefferson College

This grant will support the integration of molecular biology and computer technology into the biology curriculum by updating basic equipment for a molecular, cell biology, and biochemistry facility and providing computers and accessories for teaching laboratories and curricular development in biology and chemistry. In addition, equipment will be purchased for biochemistry, microbiology, and biological applications in chemistry and physics, and a cell culture room will be renovated and equipped. These enhancements will create new opportunities in teaching laboratories, research courses, and independent student research.

Williams College

To address increased enrollments and rapidly changing technologies in such areas as biochemistry, genetics, and neuroscience, the College will use its grant to equip teaching laboratories in these areas. For example, laboratories that were formerly used for advanced-level courses are being updated for use by introductory-level students. New exercises that emphasize open-ended laboratory exploration will be added to upper-division courses. Likely areas of focus will be computational neuroscience, chemistry, developmental biology, molecular genetics, and the study of biological structures.

cant enrollments of minority students underrepresented in science, and for faculty and students from two- and four-year colleges.

These activities include summer and academic-year laboratory experiences for teachers and students in biology and in chemistry, physics, and mathematics as they relate to biology; summer science camps; and workshops to develop new science teaching materials.

Students and teachers, including women and members of minority groups underrepresented in science, from both urban and rural schools have the opportunity to work with university faculty members in laboratories and other settings. In many cases, Institute support for undergraduate laboratory and equipment acquisitions will also enrich the experience of outreach program participants. Examples of precollege and outreach activities supported by the 1996 awards are presented in Figure 28.

1998 Program Competition

The 1998 competition continues the undergraduate program's third

Figure 28

Examples of Precollege and Outreach Programs, 1996

Bard College

Local high school teachers in biology, chemistry, and physics will participate in summer-long interdisciplinary laboratory research with College faculty members over a four-year period. Teachers and faculty will also collaborate on the design of laboratory experiments for high school students in such areas as recombinant gene expression, photochemistry, and the physics of nonlinear phenomena. Undergraduates interested in science teaching careers will have opportunities to work with the high school teachers in their classrooms.

Barnard College

This grant will support the continuation and expansion of a partnership program with LaGuardia Community College to encourage its students, particularly minorities underrepresented in the sciences, to continue their science education and pursue careers in science. Each program cycle will include an intensive summer residential program at Barnard, enrollment in science courses at Barnard and neighboring Columbia University, and research internships in Barnard and Columbia laboratories.

Colby College

Building on precollege outreach activities with four local school districts that were supported by a previous HHMI grant, the College will undertake a range of initiatives for elementary, middle, and secondary school teachers. The College will provide teachers with on-line access to science teaching resources on the World Wide Web, as well as training and technical support to implement this technology in the classroom. A program that provides laboratory equipment on loan and workshops for teachers to enrich classroom teaching will be expanded. To enable teachers to participate in workshops and laboratory activities with College faculty, the grant will also support release-time replacement teachers.

College of the Holy Cross

Selected Worcester public school science teachers will spend year-long sabbaticals at the College to update their knowledge, pedagogy, and curricula. Teachers will also receive multimedia instruction and computers and printers for their classrooms. The grant will support the salaries of their teaching replacements, who will be College science graduates, some of whom will elect to stay in teaching. Two previous HHMI grants have permitted about a third of Worcester's science teachers to take sabbaticals. Another program will allow teachers to attend summer science institutes for kindergarten-through-twelfth-grade curriculum development. With support from the current and previous grants, virtually all Worcester public school science teachers will be able to attend these institutes.

Davidson College

With this grant, the College will link its outreach initiatives for at-risk students from the Charlotte-Mecklenburg public school system with its summer research program for undergraduates. Beginning in the ninth grade, students will participate in a summer residential program on the Davidson campus. The program is designed to strengthen their academic skills and encourage them to pursue college studies. Selected participants will receive stipends to conduct laboratory research in collaboration with College science faculty members and undergraduates. In addition, science and mathematics teachers from local schools will receive stipends to participate in the summer program as instructors and mentors for College students who are considering teaching careers.

Humboldt State University

The University will use its grant to build on existing outreach programs that aim to attract and retain Native American students in the sciences by providing laboratory research experiences as well as mentoring and tutoring. Students from two-year tribal colleges who wish to pursue their science degrees will receive stipends to participate in laboratory research with faculty members from both Humboldt State and the University of California, San Francisco. Tribal college faculty members will receive release-time support to mentor students and encourage their pursuit of advanced science degrees.

Figure 28 (*continued*)

Examples of Precollege and Outreach Programs, 1996

Lawrence University

Grant funds will support a comprehensive approach that is targeted at Native American students and their teachers. Summer institutes for high school teachers will include hands-on laboratories, curriculum development workshops, mobile laboratories, and weekend workshops with counselors and University faculty members. Programs for students will consist of laboratory-based weekend workshops during the academic year for seniors and a summer research program for prefreshmen. Entire schools will be linked to the JASON project, an interactive, satellite-based science initiative.

Oberlin College

The aims of this program are to provide preservice training for science undergraduates and to share the College's science resources with elementary, middle, and secondary schools in both urban and rural communities. To this end, teams of faculty, undergraduates, and teachers will develop elementary and secondary school curricula, and undergraduates will assist teachers in the classroom implementation of the new curricula. The College will establish a partnership with a community-based educational organization to broaden the scope of curricular reforms to include county-wide schools and to foster community involvement to ensure that the reform efforts are systemic.

Smith College

A girls' health curriculum based on a course designed for Smith students will be developed, tested, and disseminated. Workshops will be offered for teams of math, science, and health teachers and for administrators and guidance counselors. A program will be extended to Native American women to encourage community college students from minorities underrepresented in the sciences to continue their education at four-year institutions. Tribal college faculty members will receive support to participate in this program. Assessments will be conducted in the program's second and fourth years.

University of Texas at San Antonio

Outreach activities will be directed to community colleges and middle and high school teachers and students. The community college program will enroll students from minorities underrepresented in the sciences in introductory and advanced laboratory summer programs. Participants will receive financial aid and mentoring support. Teachers will participate in a three-week summer institute, where they will develop portable experiments to take back to their classrooms. Teachers will also have access to the University's web site. A series of Science Saturdays focusing on neuroscience will be implemented for up to 300 middle and high school students per year. Students will be recruited from three school districts with predominantly minority populations.

Western Maryland College

This grant will support in-service training for life-science teachers in the middle schools of neighboring Prince George's County, Maryland. Teachers will attend summer workshops that will provide instruction in up-to-date science content, educational and communications technology, pedagogy, and resources for at-risk students. Each middle school will receive a videomicroscope and CD-ROM computer for its life-science program. The involvement of the College's School of Education will strengthen the likelihood of the program's success.

Xavier University of Louisiana

This grant will enable the University to continue and enhance its science outreach programs, which have been replicated widely at colleges and universities across the country. Grant funds will support summer enrichment programs in biology, chemistry, physics, and mathematics for approximately 400 African American students a year in grades 7–12. These precollege activities are part of an educational pathway in the sciences for students who go on to enroll as undergraduates at Xavier and to receive academic and financial support to continue their studies in medical and graduate school. A mini-grant program for junior and senior high school science and mathematics teachers will support teaching improvements in New Orleans public schools.

phase. Activities eligible for funding are student research and programs to broaden access to science, including opportunities for women and underrepresented minority students; laboratory renovations and equipment acquisitions for undergraduate education; science faculty development, including start-up funding for new appointments, faculty development activities related to undergraduate teaching, and science curriculum development, including restructuring of programs and courses; and precollege and outreach programs (Figure 29).

The Institute invited 205 institutions classified by the Carnegie Foundation for the Advancement of Teaching as public and private research and

Figure 29

1998 Undergraduate Program Competition

Program Components

- Prefreshman bridging initiatives in the sciences and mathematics; student research and programs to broaden access to science for women and underrepresented minorities, including on- and off-campus laboratory experiences; prefreshman bridging initiatives in the sciences and mathematics; opportunities for students to participate in scientific meetings and other activities; and laboratory opportunities for students from other institutions
- Equipment, including laboratory teaching instrumentation and infrastructure for information-based technology and scientific communication, and laboratory renovation (expenditure on laboratory renovation is limited to 50 percent of the grant total; there is no limitation on expenditure for equipment)
- Faculty development, including activities to involve science faculty in undergraduate teaching, and curricular enhancements, including restructuring of existing courses and programs and development of science courses for nonscience majors and science majors who pursue nonscience careers
- Precollege and outreach programs that link science departments with elementary and secondary schools, community colleges, or other four-year institutions for the development of faculty, teachers, and students and for enrichment of laboratory courses and other initiatives to strengthen the preparation of preservice science teachers

Goals

- To support efforts to strengthen the quality of U.S. college education in the biological sciences and other scientific disciplines as they relate to biology
- To support outstanding programs that seek to broaden access to scientific careers for women and members of minority groups underrepresented in the sciences

Awards

- $1,200,000 to $2,200,000 over four years
- A total of $90 million will be awarded

doctorate-granting universities to participate in the 1998 competition. Institutions invited to submit proposals are selected from a composite index based on the percentage and number of graduates from each institution who have gone on to matriculate in medical schools or to earn doctorates in biology, chemistry, physics, or mathematics (Figure 30). The Institute also takes into account an institution's record of graduating students from minority groups underrepresented in the sciences who go on to pursue careers in science and medicine.

A total of $90 million will be awarded in the 1998 competition. Awards are expected to range from $1,200,000 to $2,200,000 over four years. Institutions invited to submit proposals are listed in Figure 31.

Summary of Undergraduate Program Activities, 1988–1996

The Institute's undergraduate program supports activities in areas that reflect broad objectives in science education as well as the direct needs of science departments (Figure 32). Figure 33 shows the number of grantee institutions by Carnegie Classification. Total Institute support over the past six years in each of the four program areas is summarized on pages 43–48.

Figure 30

Assessment Criteria, 1989–1998

From 1989 to 1998, the eligibility of institutions to participate in the Undergraduate Biological Sciences Education Program was assessed on the basis of the percentage (calculated with data on total baccalaureate degree production collected by the U.S. Department of Education) and absolute number of graduates from each institution who have:

- matriculated in medical schools
  Data source: Association of American Medical Colleges
- earned doctorates in biology
  Data source: National Research Council of the National Academy of Sciences
- earned doctorates in chemistry, physics, or mathematics
  Data source: National Research Council of the National Academy of Sciences

Note: Assessment for the 1989–1990 competition was based on data for 1978–1986 (for medical school matriculation) and 1977–1986 (for doctorates earned in biology, chemistry, physics, or mathematics). Assessments for the 1991–1994 competitions were based on data for 1979–1988 (for medical school matriculation and doctorates earned in biology, chemistry, physics, or mathematics). Assessment for the 1996 competition was based on data for 1983–1992 (for medical school matriculation and doctorates earned in biology, chemistry, physics, or mathematics). Assessment for the 1998 competition was based on data for 1986–1995 (for medical school matriculation and doctorates earned in biology, chemistry, physics, or mathematics).

Figure 31

Invited Institutions–1998 Competition

Adelphi University
Garden City, New York
Andrews University
Berrien Springs, Michigan
Arizona State University
Tempe, Arizona
Auburn University
Auburn University, Alabama
Baylor University
Waco, Texas
Boston College
Chestnut Hill, Massachusetts
Boston University
Boston, Massachusetts
Bowling Green State University
Bowling Green, Ohio
Brandeis University
Waltham, Massachusetts
Brigham Young University
Provo, Utah
Brown University
Providence, Rhode Island
California Institute of Technology
Pasadena, California
Carnegie Mellon University
Pittsburgh, Pennsylvania
Case Western Reserve University
Cleveland, Ohio
Catholic University of America
Washington, D.C.
Clark Atlanta University
Atlanta, Georgia
Clark University
Worcester, Massachusetts
Clarkson University
Potsdam, New York
Clemson University
Clemson, South Carolina
Cleveland State University
Cleveland, Ohio
College of William and Mary
Williamsburg, Virginia
Colorado School of Mines
Golden, Colorado
Colorado State University
Fort Collins, Colorado
Columbia University
New York, New York
Cornell University
Ithaca, New York
Dartmouth College
Hanover, New Hampshire
DePaul University
Chicago, Illinois
Drexel University
Philadelphia, Pennsylvania
Duke University
Durham, North Carolina
Duquesne University
Pittsburgh, Pennsylvania
Emory University
Atlanta, Georgia
Florida Institute of Technology
Melbourne, Florida
Florida State University
Tallahassee, Florida
Fordham University
Bronx, New York
George Mason University
Fairfax, Virginia
George Washington University
Washington, D.C.
Georgetown University
Washington, D.C.
Georgia Institute of Technology
Atlanta, Georgia
Harvard University
Cambridge, Massachusetts
Hofstra University
Hempstead, New York
Howard University
Washington, D.C.
Idaho State University
Pocatello, Idaho
Illinois Institute of Technology
Chicago, Illinois
Illinois State University
Normal, Illinois
Indiana University at Bloomington
Bloomington, Indiana
Indiana University of Pennsylvania
Indiana, Pennsylvania
Iowa State University
Ames, Iowa
Johns Hopkins University
Baltimore, Maryland
Kansas State University
Manhattan, Kansas
Kent State University
Main Campus
Kent, Ohio
Lehigh University
Bethlehem, Pennsylvania
Loma Linda University
Loma Linda, California
Louisiana State University
A&M College
Baton Rouge, Louisiana
Louisiana Tech University
Ruston, Louisiana
Loyola University of Chicago
Chicago, Illinois
Marquette University
Milwaukee, Wisconsin
Massachusetts Institute of Technology
Cambridge, Massachusetts
Miami University
Oxford, Ohio
Michigan State University
East Lansing, Michigan
Michigan Technological University
Houghton, Michigan
Mississippi State University
Mississippi State, Mississippi
Montana State University
Bozeman, Montana
New Mexico State University
Main Campus
Las Cruces, New Mexico
New York University
New York, New York
North Carolina State University
Raleigh, North Carolina
North Dakota State University
Main Campus
Fargo, North Dakota
Northeastern University
Boston, Massachusetts
Northern Arizona University
Flagstaff, Arizona
Northern Illinois University
DeKalb, Illinois
Northwestern University
Evanston, Illinois
Ohio University Main Campus
Athens, Ohio
Oklahoma State University
Main Campus
Stillwater, Oklahoma
Old Dominion University
Norfolk, Virginia
Oregon State University
Corvallis, Oregon
Pennsylvania State University
University Park, Pennsylvania
Polytechnic University
Brooklyn, New York
Portland State University
Portland, Oregon
Princeton University
Princeton, New Jersey
Purdue University Main Campus
West Lafayette, Indiana
Rensselaer Polytechnic Institute
Troy, New York
Rice University
Houston, Texas
Rutgers the State University of New Jersey
New Brunswick, New Jersey
Rutgers the State University of New Jersey
Newark, New Jersey
Saint John's University
Jamaica, New York
Saint Louis University
Saint Louis, Missouri
San Diego State University
San Diego, California
Seton Hall University
South Orange, New Jersey
Southern Illinois University at Carbondale
Carbondale, Illinois
Southern Methodist University
Dallas, Texas
Stanford University
Stanford, California
State University of New York
Syracuse, New York
State University of New York at Albany
Albany, New York
State University of New York at Binghamton
Binghamton, New York
State University of New York at Buffalo
Buffalo, New York
State University of New York at Stony Brook
Stony Brook, New York
Stevens Institute of Technology
Hoboken, New Jersey
Syracuse University Main Campus
Syracuse, New York
Temple University
Philadelphia, Pennsylvania
Texas A&M University
College Station, Texas
Texas Christian University
Forth Worth, Texas
Texas Tech University
Lubbock, Texas
The American University
Washington, D.C.
The Ohio State University
Main Campus
Columbus, Ohio
The University of Akron
Main Campus
Akron, Ohio
The University of Memphis
Memphis, Tennessee
Tufts University
Medford, Massachusetts
Tulane University
New Orleans, Louisiana

Figure 31 (*continued*)

Invited Institutions–1998 Competition

University of Alabama
Tuscaloosa, Alabama

University of Alabama at Birmingham
Birmingham, Alabama

University of Alabama in Huntsville
Huntsville, Alabama

University of Alaska Fairbanks
Fairbanks, Alaska

University of Arizona
Tucson, Arizona

University of Arkansas Main Campus
Fayetteville, Arkansas

University of California–Berkeley
Berkeley, California

University of California–Davis
Davis, California

University of California–Irvine
Irvine, California

University of California–Los Angeles
Los Angeles, California

University of California–Riverside
Riverside, California

University of California–San Diego
La Jolla, California

University of California–Santa Barbara
Santa Barbara, California

University of California–Santa Cruz
Santa Cruz, California

University of Central Florida
Orlando, Florida

University of Chicago
Chicago, Illinois

University of Cincinnati Main Campus
Cincinnati, Ohio

University of Colorado at Boulder
Boulder, Colorado

University of Connecticut
Storrs, Connecticut

University of Delaware
Newark, Delaware

University of Denver
Denver, Colorado

University of Florida
Gainesville, Florida

University of Georgia
Athens, Georgia

University of Hawaii at Manoa
Honolulu, Hawaii

University of Houston–University Park
Houston, Texas

University of Idaho
Moscow, Idaho

University of Illinois at Chicago
Chicago, Illinois

University of Illinois at Urbana–Champaign
Champaign, Illinois

University of Iowa
Iowa City, Iowa

University of Kansas Main Campus
Lawrence, Kansas

University of Kentucky
Lexington, Kentucky

University of Louisville
Louisville, Kentucky

University of Maine–Orono
Orono, Maine

University of Maryland Baltimore County
Baltimore, Maryland

University of Maryland College Park
College Park, Maryland

University of Massachusetts at Amherst
Amherst, Massachusetts

University of Massachusetts Lowell
Lowell, Massachusetts

University of Miami
Coral Gables, Florida

University of Michigan–Ann Arbor
Ann Arbor, Michigan

University of Minnesota–Twin Cities
Minneapolis, Minnesota

University of Mississippi
University, Mississippi

University of Missouri–Columbia
Columbia, Missouri

University of Missouri–Kansas City
Kansas City, Missouri

University of Missouri–Rolla
Rolla, Missouri

University of Missouri–Saint Louis
Saint Louis, Missouri

University of Montana
Missoula, Montana

University of Nebraska–Lincoln
Lincoln, Nebraska

University of Nevada, Reno
Reno, Nevada

University of New Hampshire
Durham, New Hampshire

University of New Mexico Main Campus
Albuquerque, New Mexico

University of New Orleans
New Orleans, Louisiana

University of North Carolina at Chapel Hill
Chapel Hill, North Carolina

University of North Carolina at Greensboro
Greensboro, North Carolina

University of North Dakota Main Campus
Grand Forks, North Dakota

University of North Texas
Denton, Texas

University of Notre Dame
Notre Dame, Indiana

University of Oklahoma Norman Campus
Norman, Oklahoma

University of Oregon
Eugene, Oregon

University of Pennsylvania
Philadelphia, Pennsylvania

University of Pittsburgh, Pittsburgh Campus
Pittsburgh, Pennsylvania

University of Puerto Rico Rio Piedras Campus
Rio Piedras, Puerto Rico

University of Rhode Island
Kingston, Rhode Island

University of Rochester
Rochester, New York

University of San Diego
San Diego, California

University of South Carolina–Columbia
Columbia, South Carolina

University of South Dakota
Vermillion, South Dakota

University of South Florida
Tampa, Florida

University of Southern California
Los Angeles, California

University of Southern Mississippi
Hattiesburg, Mississippi

University of Southwestern Louisiana
Lafayette, Louisiana

University of Tennessee, Knoxville
Knoxville, Tennessee

University of Texas at Arlington
Arlington, Texas

University of Texas at Austin
Austin, Texas

University of the Pacific
Stockton, California

University of Toledo
Toledo, Ohio

University of Tulsa
Tulsa, Oklahoma

University of Utah
Salt Lake City, Utah

University of Vermont
Burlington, Vermont

University of Virginia
Charlottesville, Virginia

University of Washington
Seattle, Washington

University of Wisconsin–Madison
Madison, Wisconsin

University of Wisconsin–Milwaukee
Milwaukee, Wisconsin

University of Wyoming
Laramie, Wyoming

Utah State University
Logan, Utah

Vanderbilt University
Nashville, Tennessee

Virginia Commonwealth University
Richmond, Virginia

Virginia Polytechnic Institute and State University
Blacksburg, Virginia

Wake Forest University
Winston-Salem, North Carolina

Washington State University
Pullman, Washington

Washington University
Saint Louis, Missouri

Wayne State University
Detroit, Michigan

West Virginia University
Morgantown, West Virginia

Western Michigan University
Kalamazoo, Michigan

Wichita State University
Wichita, Kansas

Worcester Polytechnic Institute
Worcester, Massachusetts

Wright State University Main Campus
Dayton, Ohio

Yale University
New Haven, Connecticut

Yeshiva University
New York, New York

Student Research and Broadening Access to Science

Of the total funding of $335.4 million provided in the first six years of the undergraduate program, approximately $116 million is being used at 177 institutions to recruit and retain students in the sciences (including women; blacks; Hispanic and Native Americans; and others who traditionally have been underrepresented in science) by providing research opportunities and activities that broaden student access to science. Many participants in such programs are students with little or no laboratory experience. Several institutions have enhanced these research experiences through training activities and opportunities for students to present and publish their research.

Since 1988 the undergraduate program has supported more than 25,000 undergraduates conducting research. Of this total, 56 percent are women and 27 percent are students from minority groups underrepresented in science (Figure 34). Figures 35 and 36 describe these research experiences by site (on

Figure 32

Undergraduate Biological Sciences Education Program Activities and Guidelines, 1988–1998

Phase I (1988–1992)

- Student development, supporting undergraduate research experiences and opportunities for women and minority students underrepresented in the sciences
- Laboratory development and renovations and equipment (limited to 30 percent of the total grant amount)
- Faculty and curriculum development, including support for new faculty appointments
- Precollege and outreach programs
- Five-year grant period

Phase II (1993–1994)

- Student development, supporting undergraduate research experiences and opportunities for women and minority students underrepresented in the sciences
- Laboratory development and renovations and equipment acquisitions (funding for laboratory renovation limited to 50 percent of total grant amount, no limitation on funding for equipment)
- Precollege and outreach programs
- Four-year grant period

Phase III (1996–1998)

- Student development, supporting undergraduate research experiences and opportunities for women and minority students underrepresented in the sciences
- Laboratory development and renovation and equipment acquisitions (funding for laboratory renovation limited to 50 percent of the grant total, no limitation on funding for equipment)
- Faculty and curriculum development, including support for appointment of new faculty
- Precollege and outreach programs
- Four-year grant period

Figure 33

Number of Grantee Institutions by Carnegie Foundation Classification, 1988–1996

Carnegie Classification*	Number		
	Phase I 1988–1992	Phase II 1993–1994	Phase III 1996
Research Universities I	55	38	0
Research Universities II	21	11	0
Doctoral Universities I (Doctorate-Granting Universities I)	11	8	0
Doctoral Universities II (Doctorate-Granting Universities II)	5	5	0
Master's Colleges and Universities I (Comprehensive Universities and Colleges I)	20	18	13
Master's Colleges and Universities II (Comprehensive Universities and Colleges II)	3	2	2
Baccalaureate Colleges I (Liberal Arts Colleges I)	56	22	37
Baccalaureate Colleges II (Liberal Arts Colleges II)	8	5	0
Schools of Engineering and Technology	2	0	0
Total	**181**	**109**	**52**

**Terms in parentheses were used in the 1987 Carnegie classifications, which were used in assessing eligibility for the 1988–1994 competitions. Assessments for the 1996–1998 competitions used the 1994 Carnegie classifications.*

campus, off campus, or both) and by academic period (summer, academic year, or both).

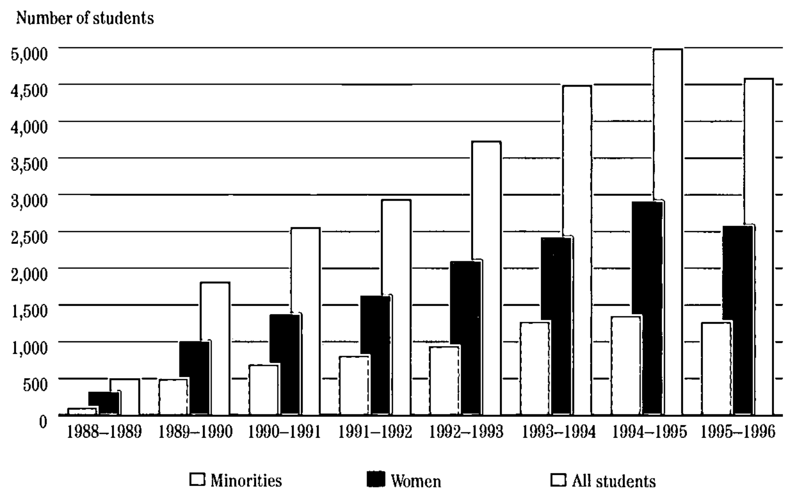
Grantee institutions have reported that undergraduate research opportunities are a critical element in attracting student interest in the sciences and helping to sustain that interest through the college years and beyond. Participating students have indicated that HHMI-supported research experiences have been major factors in their acceptance by graduate and medical programs or in being awarded national fellowships. Several undergraduates receiving such support have gone on to receive fellowships in the Institute's highly competitive fellowship program for graduate students.

Faculty Development in the Sciences

Since 1988 Institute funds have enabled 104 colleges and universities to appoint 239 faculty members in biology and other scientific disciplines. This includes 112 women and 28 members of underrepresented minority groups (Figure 37). A total of $32 million has been awarded in phases I and III of the undergraduate program for science faculty development, which includes both new appointments and involvement of existing research faculty in under-

Figure 34

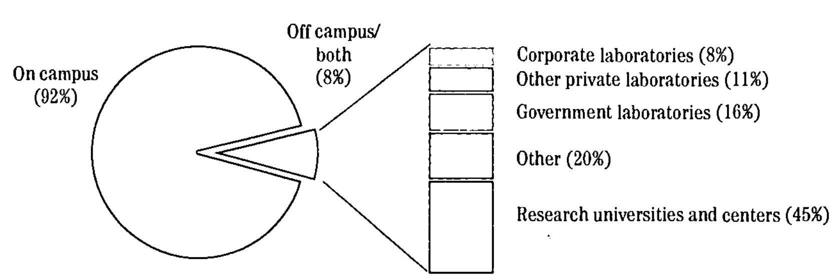
Student Participation in Undergraduate Research, 1988–1996



	Number	Percent
All students	25,856	100
Women	14,400	56
Minorities	6,926	27

Figure 35

Undergraduate Research by Site, 1988–1996



All research sites

Off-campus research sites

Figure 36

Undergraduate Research by Academic Period, 1988–1996

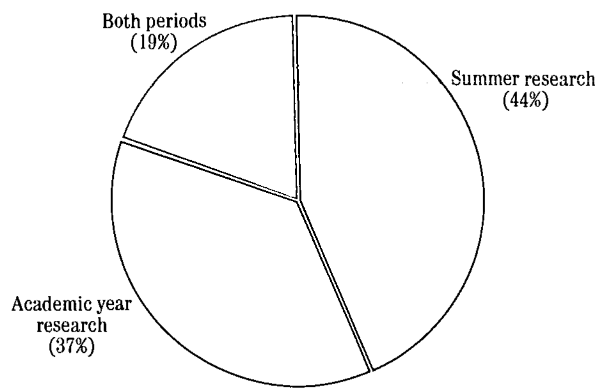


Figure 37

New Faculty Appointments, 1988–1996

	Number	Percent
All faculty appointments	239*	100
Women	112	47
Underrepresented minorities	28	12

**Includes 186 tenure track appointments.*

graduate teaching and other activities.

The scientific disciplines in which Institute-supported faculty have been appointed include cell or molecular biology, biochemistry/biophysics, and neuroscience (Figure 38). These appointments are providing departments with opportunities to broaden their scientific expertise, develop new courses and new areas of research, and update and expand existing curricula. New faculty members are making important contributions in teaching, research, and institutional service. In several cases they have enabled institutions to develop interdisciplinary programs (for example, by bridging biology and chemistry).

The Institute also provides funds for activities that enrich current faculty members' knowledge of their fields and enhance their ability to convey new knowledge to students. Science faculty members have received support to participate in on- and off-campus workshops, seminars, and training programs and to attend professional meetings.

Curriculum and Laboratory Development and Equipment

A total of $114.4 million has been directed to the development of science curricula and laboratories and equipment purchases, enabling nearly all 220 grantee institutions to enhance the quality of instruction in the biological sciences and other disciplines as they relate to biology. HHMI grant support in this area is principally directed to laboratory renovation and the acquisition of modern scientific instrumentation. The development of new experiments for use in courses, laboratory manuals, and other instructional materials is also supported.

Since 1988 HHMI has supported the development or revision of more than 5,000 courses covering a wide range of scientific disciplines, such as genetics, molecular and cell biology, and neuroscience (Figure 39). Numerous institutions are using their awards to develop more interdisciplinary courses such as those that relate biology to chemistry, physics, mathematics, and computer science. In some cases biological examples are integrated into laboratory courses in the physical sciences and other areas.

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

Figure 38

New Faculty Appointments by Scientific Field, 1988–1996

Field	Number of Appointments
Cell or molecular biology	62
Biochemistry, biophysics	40
Neuroscience	30
General biology	13
Chemistry	13
Embryology, developmental biology	11
Genetics	10
Immunology	9
Physiology	9
Ecology, environmental sciences	7
Biometry, biostatistics, computational biology	5
Microbiology, bacteriology, virology	5
Physics	4
Other scientific fields	21
Total	**239**

To ensure that all students are exposed to the process of scientific discovery, institutions are using these approaches in curricula for nonscience majors as well as those for science majors. Institutions report that these experiences stimulate many students' interest in science majors and careers.

The undergraduate program has supported efforts at colleges and universities to establish or improve communication and information resources for undergraduate science education. These include the acquisition of computers for laboratory instruction, the development of electronic communications infra-

Figure 39

Selected New or Revised Courses by Scientific Field, 1988–1996

Area	Number of Courses
General biology	580
Chemistry	500
Molecular biology	420
Biochemistry	408
Cell biology	381
Neuroscience	306
Genetics	274
Physics	229
Physiology	247
Laboratory techniques	256
Topics in biological sciences	180

structure, and other activities that enable new educational technologies to be used in undergraduate teaching. Institutions are developing innovative courses and programs that provide interactive learning in such areas as structural biology, biochemistry, and neuroscience.

Precollege and Outreach Programs

HHMI has awarded $73 million to 193 grantee colleges and universities to expand or create links with precollege and other institutions, including community colleges and historically black colleges and universities, with the intent of improving the national quality of science education.

These awards are also intended to attract and retain students in the sciences, particularly women and students from underrepresented minority groups. Programs include summer and academic-year laboratory experiences for teachers and students; summer science camps; equipment loans; and courses for students in biology and chemistry, physics, mathematics, and other areas as they relate to the biological sciences.

Since 1988 more than 21,000 teachers, of whom 60 percent are women and 20 percent are members of underrepresented minority groups, have taken part in Institute-supported outreach programs (Figure 40a). More than 65,000 students, of whom 55 percent are women and 51 percent are members of underrepresented minority groups, have participated (Figure 40b). Of the participating teachers, 58 percent have been from high schools (Figure 41a). Among the students, 60 percent have been from high schools (Figure 41b).

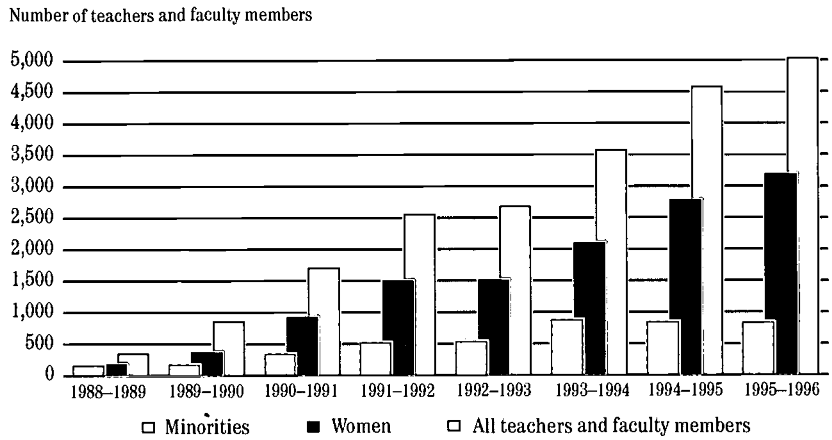
Colleges and universities have reported on the laboratory activities of precollege students in HHMI-supported outreach programs. Some of these students have received recognition for their research through such programs as the Westinghouse Science Talent Search and in local, regional, and national science fairs. Many have also been accepted into undergraduate science programs. In addition, teachers from elementary and secondary schools have noted improvements in their science teaching as a consequence of participation in HHMI programs.

Use of the World Wide Web

The Institute has a home page on the World Wide Web, with direct links to all grant programs and

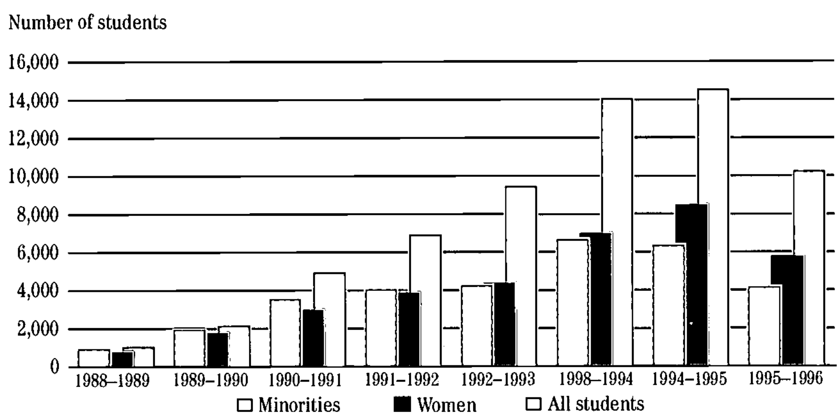
Figure 40

Teachers and Students in Outreach Programs, 1988–1996



Teachers and Faculty Members

	Number	Percent
All teachers and faculty members	21,689	100
Women	12,980	60
Minorities	4,135	20



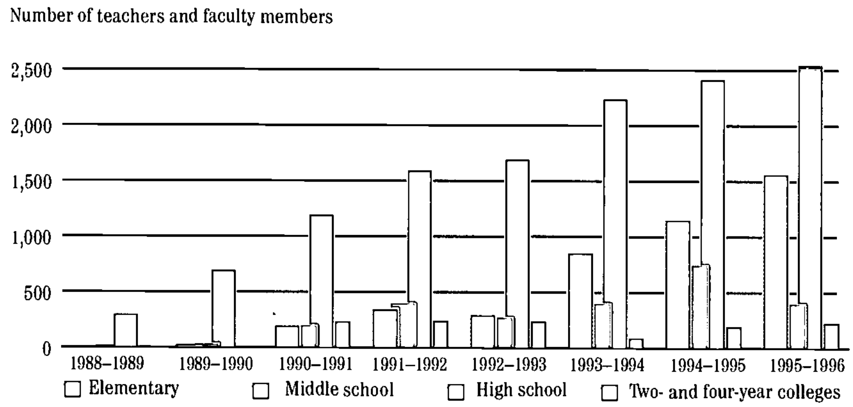
Students

	Number	Percent
All students	65,611	100
Women	36,325	55
Minorities	33,141	51

**Includes data only on students participating in programs lasting longer than two full weeks. Excludes participants in programs shorter than two full weeks.*

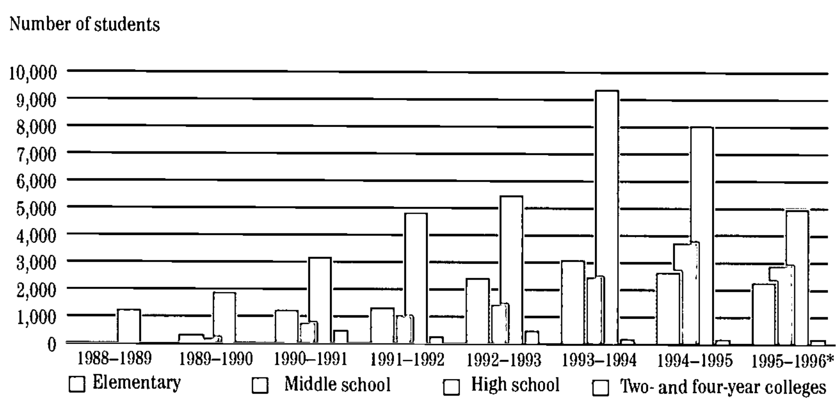
Figure 41

Teachers and Students in Outreach Programs, by Grade Level, 1988–1996



Teachers and Faculty Members

	Number	Percent
	21,689	**100**
Elementary school	4,477	21
Middle school	3,227	15
High school	12,703	58
Two- and four-year colleges	1,282	6



Students

	Number	Percent
	65,611	**100**
Elementary school	13,305	20
Middle school	12,264	19
High school	39,095	60
Two- and four-year colleges	947	1

**Includes data only on students participating in programs lasting longer than two full weeks. Excludes participants in programs shorter than two full weeks.*

grantee institutions. The universal resource locator (URL) for the undergraduate program is <http://hhmi.org/undergraduate/>. New features planned for the undergraduate Web site include a searchable catalogue of laboratory research and other opportunities funded through the program, a discussion group on science education issues, and a module from an interactive electronic biochemistry manual that was developed at the University of California–San Diego with HHMI support.

HHMI's undergraduate program staff has developed a system that enables grantee institutions to submit annual program information over the Web. Each grantee has access to an electronic report form on a dedicated, secure site on HHMI's home page. Data on student research participation, new faculty appointments, precollege teacher and student involvement, and other program activities can be submitted and directly loaded into HHMI's archival database. This system, introduced in spring 1997, replaces printed forms and diskettes.

Undergraduate Program Directors Meetings

The directors of HHMI-supported programs meet annually at Institute headquarters in Chevy Chase, Maryland. These meetings are essential to the undergraduate grants program because they serve as a forum for participants to discuss their experiences in directing Institute programs, consider broad policy issues related to undergraduate science education, and generally have an intellectual exchange. The meetings also include demonstrations of educational technology developed with Institute support and exchanges of educational materials used in undergraduate and precollege programs.

To accommodate changing student needs and new directions in both science and science education, institutions must be dynamic and adaptable. The program directors meetings enable faculty members and administrators to discuss and formulate ideas about how programs can best respond to changing circumstances.

The meetings include program directors with different levels of experience in the implementation of HHMI-funded programs. This mix is important because directors of newer programs can profit from the experiences of their colleagues and more experienced directors can gain fresh perspectives. The meetings provide the Institute with valuable insights into current developments and challenges in undergraduate science teaching.

To date, the Institute has held six program directors meetings, each with its own theme reflecting current directions in the program. The 1996 meeting, which focused on assessment, is summarized below.

1996 Program Directors Meeting—Assessing Science Pathways[2]

Assessment was the overarching theme of the 1996 undergraduate program directors meeting, which was held at Institute headquarters in September 1996. The topic was woven into almost all of the meeting discussions. Although participants had many questions and concerns about assessment, they were in no doubt that it is an increasingly important issue in science education. The fundamental issues surrounding assessment were summed up as what, how, and when to assess.

Representatives of foundations making grants in science and education, attending the 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 to see the value of its investment. Raymond Bacchetti, William and Flora Hewlett Foundation, observed that without assessment, there is no basis for making the case that higher education is important and effective.

The importance of thinking about assessment criteria up front when designing a program was emphasized. Clearly defined objectives, well-planned methodologies, and measurable outcomes are necessary but not sufficient conditions for good assessment, said Michael Gaines, University of Miami. He and other participants felt that many benefits of science education programs are intangible.

Discussions of how to assess frequently focused on the difficulty of establishing appropriate control groups. Robert Lichter, Camille and Henry Dreyfus Foundation, said that it is not clear from the evaluation literature that controlled experiments, which scientists tend to favor, are always necessary. Linkages with cognitive and social scientists who have experience in program assessment are essential. As for when to assess, participants generally felt that the most valuable data are likely to come from long-term studies.

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

Predictors of Success in Science

Mary Allen, Wellesley College, presented an overview of the results to date of the project Pathways for Women in the Sciences, a longitudinal study of career choices among Wellesley science graduates, funded by the Alfred P. Sloan Foundation. Among the study's key findings are that students who have mentors and who participate in undergraduate research are more likely to pursue

[2]Copies of the report *Assessing Science Pathways* may be obtained by writing to the Office of Grants and Special Programs, Howard Hughes Medical Institute, 4000 Jones Bridge Road, Chevy Chase, MD 20815. Also see HHMI's home page at <http://www.hhmi.org/ undergraduate/>.

graduate education and science careers. Parental encouragement is also crucial.

The personal stories related by student participants at the meeting offered anecdotal support for the accuracy of the Wellesley study's findings. Keith Amos, a graduate of Xavier University who is a student at Harvard Medical School and a former participant in the HHMI-NIH Research Scholars Program, told how a mentor's personal interest in him at age 14 had encouraged him to pursue a science career.[3]

Beatriz Blanco, who transferred to the University of Miami after participating in an HHMI-supported bridging program at Miami-Dade Community College, said parental encouragement had been the biggest factor in her success. Scott Santos, a graduate of the University of Hawaii at Manoa who is now studying at the State University of New York at Buffalo, said that his interest in science stemmed from having worked at Waikiki Aquarium's blue-water marine laboratory while he was in high school.

Importance of Undergraduate Research

Student participants spoke of the importance of undergraduate research experience in motivating them to pursue careers in science. Several of them said that independence, while 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.

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. The need for a balance between research experience and fundamental course work was stressed.

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.

Student participants had no illusions about their prospects for pursuing careers in academic research. Kristin Baldwin, a graduate of Duke University who is now an HHMI Predoctoral Fellow in the laboratory of HHMI Investigator Mark Daris at Stanford University, said that her colleagues are considering many career options, such as working in industry and going into investment banking.

Several attendees said that colleges and universities need to expand links with industry and pro-

[3] A profile of Keith Amos is among the new features being developed for the HHMI undergraduate program's World Wide Web site <www://hhmi.org/undergraduate>.

vide more opportunities for students to obtain research experience in an industrial setting. Program directors described interactions with industry at Lehigh University, Florida A&M University, and Macalester College. It was noted that research experience in industry gives students valuable exposure to collaborative science.

Several institutions' programs to encourage biology majors to enter precollege teaching and to provide financial support for training in postgraduate teaching training were described. Attendees also observed that a science education can be valuable in unpredictable ways for people who do not pursue careers in science.

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. Several program directors described their HHMI-supported programs that focus on the recruitment and retention of minorities.

It is difficult to assess quantitatively the impact of such programs because students enter from unequal starting points. Charles Putman said that the most important lesson he had learned from Duke University's broad-spectrum program to attract women and minorities into science was "how critical it is for institutions to take risks."

Several program directors noted that women greatly outnumber men in undergraduate research programs targeted at underrepresented minorities. 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 mean that colleges and universities cannot accommodate all students in resource-intensive undergraduate research programs. 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.

Because inquiry-based teaching appoaches are time-intensive, science faculty often fear that students will lack the content knowledge necessary to do well on standardized tests. Kathleen Blits, St. John's College, noted that her institution's 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.

At many institutions information technology is a catalyst for classroom innovation.[4] Gavin, however, worried that the widespread integration of information technology into the classroom will put students who cannot afford computers at a disadvantage.

Research and Teaching: Finding a Balance

As competition stiffens for 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.

Young faculty members at research-intensive institutions face a dilemma if they wish to excel at both teaching and 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.[5] At predominantly undergraduate institutions, by contrast, 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, said de Paula.

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 laboratory space and equipment, sabbatical leaves, and release time to attend scientific meetings.

Some research-intensive institutions have introduced a nontenured lecturer career track for faculty who focus on teaching and are not involved in research. Attendees expressed concern that the lecturer track would exacerbate the separation of research and teaching and could become a de facto academic ghetto for women.

The abolition of the mandatory retirement age for faculty means that institutions must reconsider the role of tenure, said Susan Henry, Carnegie Mellon University. She and Frank Vellaccio, vice provost of the College of the Holy Cross, stressed that faculty—not administrators—make the rules that govern the tenure and promotion process.

Outreach to Precollege Teachers

Meeting participants heard from several HHMI grantees who have developed innovative collaborative programs to enhance the preparation and professional development of precollege science teachers.

[4]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/undergraduate/meeting/start.htm>.

[5]Dr. Maddock's story is told in *Beyond Bio 101* (1996), available from the Office of Communications, Howard Hughes Medical Institute, 4000 Jones Bridge Road, Chevy Chase, MD, or on the World Wide Web at <http://www. hhmi.org/BeyondBio101>.

Peter Bruns, Cornell University program director, and Mary Colvard, a high school biology teacher in upstate New York,[6] described the Cornell Institute of Biology Teachers (CIBT) network, which links teachers with both colleagues and Cornell faculty. Ongoing assessment and a strong partnership between the teachers and the faculty participants make the program effective, they 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. Key program elements are a summer institute for teachers and one-year sabbaticals.

The goals of both the Cornell and Holy Cross programs are to increase students' science literacy and enthusiasm for science and to encourage more students to seek further education or careers in science. However, because these outcomes are extremely difficult to measure at the local level, the programs focus on teacher outcomes, such as subject matter knowledge, self confidence, and the ability to use hands-on approaches, collaborative learning techniques, and educational technology.

Studies showing that elementary school teachers spend little classroom time on science and that students begin to lose interest in the subject by the fourth grade prompted the University of Nebraska–Lincoln to focus its precollege outreach efforts on revising science instruction for preservice elementary education majors. Four hands-on science courses—in biology, chemistry, physics, and earth science—have been developed so far. Assessment data for the biology course, which was developed first, suggest that the course has positively affected preservice teachers' attitudes toward science and confidence in their ability to teach the subject, said program director George Veomett.

Jerome Pine, California Institute of Technology, and Sandra Mims, an elementary school teacher in the Pasadena Unified School District, described a collaboratively developed preservice teacher-training program in biology and physics that is based on cooperative learning techniques and class discussion. Students are graded on the basis of projects, homework, science notebooks, and class participation.

[6]A profile of Mary Colvard is among the new features being developed for the HHMI undergraduate program's World Wide Web site <www://hhmi.org/undergraduate>.

Conclusions

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 assessment technique exists. 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.

Figure 42

Committee on Undergraduate Science Education of the National Research Council/National Academy of Sciences

Award

- $800,000
- Four-year term, 1995–1999

Objective

- To conduct a national assessment of science education technology, including technologies developed by HHMI grantees. The award will provide the higher-education community with access to information on electronic materials for science and mathematics education and will help build a national consensus about effective electronic tools for teaching undergraduate science.

Program Activities

- To conduct a national assessment and review of science education technologies that would build on HHMI's efforts in this area
- To support activities that would improve the quality, use, and accessibility of educational technology in undergraduate science education
- To support an electronic database on undergraduate science education to be made available on the World Wide Web
- To extend to the science education community the growing body of knowledge about effective educational technologies, including those supported by HHMI

Other Undergraduate Program Activities

Committee on Undergraduate Science Education of the National Research Council/National Academy of Sciences

In 1995 the Institute awarded a grant of $800,000 over four years to the Committee on Undergraduate Science Education of the National Research Council/National Academy of Sciences to provide science faculty members and others information about undergraduate science education and guidance on the use of new technologies in science education (Figure 42).

The grant is supporting the development of an Internet-accessible database, which now has over 500 entries on undergraduate science education. The database contains an annotated bibliography and information on organizations, courses, and programs, including those funded by HHMI. Directors of HHMI undergraduate programs have access to the database, which is linked to the World Wide Web sites of HHMI and other organizations, such as the National Science Foundation and the U.S. Department of Education. The URL for the database is <http://www2.nas.edu/cuselib/index.html>.

In this way, information about HHMI-supported undergraduate programs is disseminated to greater numbers of college and university faculty and administrators, precollege teachers and administrators, state and national policy makers, students, and others.

The grant to the NRC also supports a national review of science education technology and demonstrations of technologies that show promise of providing low-cost, effective teaching supplements. Topics addressed in the ongoing review include quality control in educational software development, an assessment of the need for educational software development by scientific discipline, and issues of equity in access to educational technology. Results of the review are expected to be published in 1998.

Institutions that received undergraduate awards in 1996 are listed in Figure 43, and the awards are summarized in Figure 44.

Figure 43

1996 Awardees

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 Brooklyn, New York	$1,200,000
City University of New York Queens 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 Agricultural and Mechanical 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 St. 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
Saint Olaf College Northfield, Minnesota	$1,300,000
Smith College Northampton, Massachusetts	$1,600,000
Spelman College Atlanta, Georgia	$800,000
St. John's College Annapolis, Maryland	$1,000,000
St. Mary's University San Antonio, Texas	$600,000
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 South College Midtown, 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**

79

Figure 44

Undergraduate Biological Sciences Education Program 1996 Grant Summaries

Allegheny College, Meadville, Pennsylvania

$600,000 to support (1) start-up equipment for two new neuroscience faculty members and laboratories for a new major; (2) two new faculty positions in biology and psychology, and release time for faculty to learn neuroscience research techniques and develop neuroscience curricula; (3) on- and off-campus research for undergraduates, including women, students from minorities underrepresented in the sciences, and neuroscience majors; and (4) summer mathematics preparation for prefreshmen and career development for rising high school juniors.

Bard College, Annandale-on-Hudson, New York

$600,000 to support (1) renovations and equipment for instructional laboratories in general biology, biochemistry, cellular and molecular biology, and other disciplines; (2) a prefreshman summer program in biology and chemistry for incoming students (including those from minority groups underrepresented in the sciences), providing faculty mentoring, tutoring, and other academic support; and (3) summer laboratory experiences for local secondary science teachers with College faculty and students, featuring ongoing professional development and collaboration.

Barnard College, New York, New York

$1,100,000 to support (1) renovations and equipment to enable extension of the curriculum into interdisciplinary areas, and multimedia equipment for two lecture rooms used in teaching biology and chemistry courses; (2) continuation of a summer residential in partnership with LaGuardia Community College, courses, and research assistantships at Barnard or Columbia University; (3) a prefreshman bridge program, featuring activities that include research opportunities and seminars; and (4) integration of multimedia into introductory biology and chemistry courses.

Bates College, Lewiston, Maine

$600,000 to support (1) on-campus individual and group research projects, off-campus opportunities for research, and student travel to conferences to present research results; (2) faculty release time to develop a new neuroscience major, funds for a mathematics resource center, and support for preprofessional advising; (3) equipment to support research and courses in neuroscience, chemistry, biochemistry, and biology; (4) outreach activities serving rural Maine communities through science and mathematics Saturdays at Bates College for local schools, science demonstrations in schools and on the World Wide Web, and summer research opportunities for high school teachers.

Beloit College, Beloit, Wisconsin

$1,200,000 to support (1) a learning laboratory called BioQuest for curriculum development in the biological sciences and activities to increase science faculty participation in developing additional curricular modules; (2) continuation of summer teacher workshops and science activities for sixth-grade girls and their parents and teachers, expansion of BioQuest outreach, and enrichment programs in science and mathematics for eighth- through twelfth-graders; (3) on- and off-campus summer research for freshmen and sophomores; (4) computer equipment for data collection, analysis, simulation, and modeling, to be used in the biology and chemistry laboratories; and (5) course development in biology.

Benedictine University, Lisle, Illinois

$600,000 to support (1) laboratory equipment for the science curriculum, including a new interdisciplinary introductory sequence in biology and the physical sciences and laboratories in biochemistry and molecular biology; (2) summer stipends for students collaborating with faculty members in interdisciplinary teams, studying specific research topics, and opportunities to present research at national meetings; and (3) release time and supplies for faculty members to develop the new introductory sequence in biology and the physical sciences.

Bryn Mawr College, Bryn Mawr, Pennsylvania

$1,000,000 to support (1) renovations and equipment for laboratories and teaching classrooms used in biology and computer sciences courses for undergraduates and participants in outreach programs; (2) two-week summer institutes for Philadelphia-area high school teachers, to include topics on the brain, behavior, and other areas; (3) summer laboratory research activities for students working with Bryn Mawr faculty members and continued research collaborations for Morehouse College students; and (4) development of interdisciplinary courses in computational modeling and integrated science.

Canisius College, Buffalo, New York
$650,000 to support (1) a prefreshman program, to include mentoring and preparatory courses, and laboratories and on- and off-campus research and colloquia for undergraduates, with a curriculum plan for at-risk students, to include a fifth-year laboratory research or internship experience; (2) two new faculty members in physiology/endocrinology and molecular biology and faculty workshops to develop interdisciplinary curricula; (3) start-up equipment for two new faculty members and renovations for laboratories, to include neurobiology, genetics, cell biology, and computational biology; and (4) development of cell biology curricula and equipment lockers for middle school teachers, and an interdisciplinary laboratory for high school teachers and students.

Carleton College, Northfield, Minnesota
$650,000 to support (1) renovations and equipment to enhance biology education, especially in computer graphics, modeling, microscopy, and science communications infrastructure; (2) expanded student summer research opportunities with faculty mentors, a prefreshman mathematics and science program for students from minorities underrepresented in the sciences, and an interdisciplinary visiting speakers program for science majors; (3) opportunities for science faculty to develop new scientific skills that will be valuable in both teaching and research through extended visits to major research laboratories; and (4) scholarships for students from minorities underrepresented in the sciences to participate in Carleton's middle school program, Introduction to Mathematical and Scientific Reasoning.

Centenary College of Louisiana, Shreveport, Louisiana
$600,000 to support (1) renovation of and equipment for laboratories that serve a new biosciences core, which includes the disciplines of biology, chemistry, and biophysics, and start-up costs for a new faculty member in neurobiology; (2) an on- and off-campus multiyear research program for undergraduates, beginning in the prefreshman summer; (3) faculty development; and (4) a summer research program and travel to science meetings for high school students and teachers.

City University of New York Brooklyn, Brooklyn, New York
$1,200,000 to support (1) enriched opportunities for science and nonscience majors, including an interdisciplinary, laboratory-based seminar for first-year students who have not declared a science major, increased opportunities to conduct research with faculty members, and peer tutoring; (2) laboratory equipment for new courses in cell and molecular biology and microbiology, with computer upgrades; (3) expansion of an existing outreach program with a local high school, involving student research, mentoring, and other activities, to include a middle school and in-service and pre-service science teacher training; and (4) appointment of a new faculty member in neuroscience and development of new courses for science majors.

City University of New York Queens, Flushing, New York
$600,000 to support (1) renovations and equipment to upgrade advanced laboratories in chemistry and biology and a computational biology center that will be integrated into both science courses and research; (2) an academic-year research program and an honors program for first- and second-year students; (3) outreach programs for pre- and in-service teachers, including workshops and a certification program; and (4) revision of the physical chemistry laboratory course to include computational analysis of molecular structure, and expansion of research opportunities for students through the addition of a new faculty member.

Colby College, Waterville, Maine
$1,000,000 to support (1) renovation of a clean room for tissue culture and new laboratories in neurobiology and biomechanics/animal physiology, instrumentation for upper-division courses in the latter two areas, computer upgrades for the teaching of molecular design, and shared equipment for interdisciplinary courses in introductory biology, chemistry, and physics; (2) release time, workshops, and travel for faculty to develop scientific skills and integrate new knowledge into the curriculum; (3) equipment purchases and networked computers, science and information technology workshops, and science training for local junior and senior high school teachers through a teacher release program; and (4) expanded opportunities for students to conduct research (through research fellowships and workshops) and to present their findings at national scientific meetings.

Colgate University, Hamilton, New York
$650,000 to support (1) renovations and equipment for teaching laboratories in molecular biology, genetics, and microbiology; (2) a science mentoring program that makes the sciences more accessible to underprepared students; (3) undergraduate research opportunities both on- and off-campus, including a student/scholar exchange with the National Institutes of Health; and (4) outreach activities including research opportunities and summer workshops on new technologies in science education for high school teachers and collaborative science curriculum development activities, focusing on elementary and middle schools.

College of the Holy Cross, Worcester, Massachusetts
$1,100,000 to support (1) a sabbatical study program for Worcester public school science teachers, to include courses and multimedia computers, salaries for College science graduates serving as the teachers' replacements, and curriculum development summer institutes for teachers; (2) multimedia technology for biology courses for majors and nonmajors and equipment for new biology laboratories for nonmajors, to include genetics and physiology; (3) science and educational technology workshops and faculty travel for laboratory training and conferences, and an educational technology coordinator to train teachers and faculty members; and (4) research and travel to scientific meetings for undergraduates, to include women and members of minorities underrepresented in the sciences, and improvements in library resources for nonscience majors and teachers.

Colorado College, Colorado Springs, Colorado
$750,000 to support (1) a program of summer and academic-year student research in on- and off-campus laboratories, including mini-grants for supplies, travel to scientific meetings and off-campus research sites, and assistance in publishing research findings; (2) expansion of an existing outreach program to students in the Southwest, including those from minority groups underrepresented in the sciences, that provides a bridge into college-level science, academic counseling, and other support; (3) laboratory renovations, equipment to be used in teaching and student research, and computers for data collection and analysis; and (4) professional development for current faculty members and start-up funding for new faculty members.

Davidson College, Davidson, North Carolina
$650,000 to support (1) laboratory equipment to implement curricular initiatives in neuroscience and cell biology; (2) summer research for biology and neuroscience students, with mentoring programs for women in the sciences; (3) the appointment of a new cell biologist to the faculty; and (4) expansion of an existing program for students from Charlotte-Mecklenburg public schools to provide year-round enrichment in science and mathematics for teachers and on-campus summer research assistantships for high school students, with college student mentors.

Earlham College, Richmond, Indiana
$600,000 to support (1) undergraduate research opportunities both on- and off-campus in the laboratories of Earlham alumni and a summer and fall bridge program for admitted students and mentoring for minority students; (2) equipment and renovations for teaching laboratories that are also used for summer outreach activities; (3) outreach programs to include a three-week summer program for high school students and activities for women in science; and (4) support for an interdisciplinary course in toxicology that involves collaboration between the biology and chemistry departments.

Florida Agricultural and Mechanical University, Tallahassee, Florida
$700,000 to support (1) a program to attract and retain students in the sciences through prefreshman training in science, mathematics, and other areas; ongoing freshman-year academic support and research experiences; and summer research opportunities; (2) equipment for teaching laboratories in organic chemistry and biotechnology; (3) release-time support for faculty members to develop biology curricula; and (4) science outreach activities for teachers in Florida middle and high schools.

Hampshire College, Amherst, Massachusetts
$1,300,000 to support (1) scientific instrumentation and laboratory renovations to enhance the research-based curriculum, increasing students' access to research facilities; (2) increased opportunities for student research through introductory research courses taken by all students and new research courses for advanced majors and support for student and faculty travel to scientific meetings; (3) outreach activities, to include a summer program in molecular biology for high school teachers, a science club for high school students, and hands-on laboratory activities for middle-school girls and inner-city students; and (4) release time for faculty members to develop one advanced research course.

Haverford College, Haverford, Pennsylvania
$750,000 to support (1) undergraduate research programs, to include laboratory opportunities, seminars, and peer tutoring for students, including minorities underrepresented in the sciences; (2) equipment for biology, biochemistry, and physics laboratories; (3) curriculum and faculty development, including a new program in biology, medicine, and society; (4) release time for faculty to revise introductory courses in physics and develop introductory calculus courses and start-up costs for a new faculty member in chemistry; and (5) lectures and laboratories led by faculty and student researchers for middle and high school students from minorities underrepresented in the sciences and laboratory equipment and computers for participating schools.

Hope College, Holland, Michigan
$700,000 to support (1) a precollege outreach program that provides activities ranging from recreational science activities for sixth- and seventh-graders to summer research for high school students; (2) start-up funding for three new faculty members in biology and chemistry; (3) a research program in biology and chemistry, to include seminars and travel to scientific meetings, for women and undergraduates from minorities underrepresented in the sciences; (4) curriculum development, including biology and chemistry for majors and environmental mathematics for nonmajors; and (5) interdisciplinary research programs for faculty members.

Humboldt State University, Arcata, California
$650,000 to support (1) instrumentation to equip a teaching laboratory in cell biology and technical assistance for undergraduate laboratories; (2) a collaborative outreach program of mentoring, tutoring, and laboratory research for Native American students and faculty members from tribally controlled community colleges, involving both Humboldt State University and the University of California–San Francisco; (3) summer and academic-year research for University undergraduates; and (4) retention programs for students, including those from minority groups underrepresented in the sciences, providing small-group study in biology, mathematics, and the physical sciences.

Kenyon College, Gambier, Ohio
$1,500,000 to support (1) laboratory start-up for a new faculty member and computer and laboratory equipment for biology, chemistry, neuroscience, physics, and mathematics; (2) a first- and second-year research program, to include symposia for first-generation students and students from minorities underrepresented in the sciences, and a lecture series for students and the local community; (3) outreach to rural schools, including classroom assistance for middle school teachers, workshops for high school physics teachers, and activities for elementary schools; (4) a new tenure-track position in bio-organic chemistry; and (5) faculty release time for curriculum development.

Lawrence University, Appleton, Wisconsin
$800,000 to support (1) renovation of laboratories, to include zoology and botany, and equipment for a new course in investigative zoology; (2) summer institutes and mobile laboratories for high school teachers and weekend workshops for high school students, including those from Native American schools, and initiation of the distance-learning JASON project in local elementary and middle schools; (3) research and peer mentoring for prefreshmen from minority groups underrepresented in the sciences, especially Native Americans, and research opportunities for undergraduate science students; (4) laboratory exercise development by undergraduate science majors; and (5) off-campus short courses for faculty members.

Macalester College, St. Paul, Minnesota
$1,000,000 to support (1) junior and senior student-faculty research; travel to professional meetings and seminars for undergraduates; and minority access and retention through prefreshman laboratory rotations, freshman and sophomore year research, and a scientist-student mentoring program; (2) a strengthened science curriculum through the development of interdisciplinary, contextualized, and computer-integrated courses and laboratories; a new faculty appointment in developmental biology and an interdisciplinary science faculty colloquium; and (3) equipment for a computer learning center and chemistry laboratories, and equipment for loan to students in the prefreshman program.

Middlebury College, Middlebury, Vermont
$650,000 to support a major expansion of student research opportunities and other scientific activity, to include summer laboratory experiences with faculty members, travel to scientific meetings, and research during the prefreshman summer for students, including disadvantaged rural students and those from minority groups underrepresented in the sciences.

Mount Holyoke College, South Hadley, Massachusetts
$900,000 to support (1) the development of inquiry-based laboratories for introductory and intermediate biology courses, and renovation of existing facilities to enable inquiry-based experiments to be conducted; (2) student-faculty research collaborations, to include a summer research program of laboratory rotations and independent research for sophomores and juniors, interdisciplinary research collaborations among faculty and students, and year-round peer-mentoring activities designed to attract women to science, particularly those from underrepresented minority groups; and (3) major revision of the introductory biology courses and incorporation of molecular biology across the curriculum.

Nebraska Wesleyan University, Lincoln, Nebraska
$1,200,000 to support (1) laboratory equipment to implement new curricula in biochemistry, molecular biology, organic chemistry, and physics; computers for chemistry and biology laboratories and a computer resource center; and multimedia science classrooms; (2) summer research experiences for students from both the University and Philander Smith College, a historically black institution, and seminars and interdisciplinary laboratories for nonscience majors; (3) outreach to science teachers at rural high schools, providing science kits, curricular materials, and networked access to e-mail and the Internet; and (4) professional development opportunities for science faculty at the University and Philander Smith College.

Oakland University, Rochester, Michigan
$600,000 to support (1) directed research for undergraduates in faculty laboratories and seminars exploring the theme of biological communications; (2) modern equipment and computers for undergraduate laboratory instruction in cell biology, biochemistry, and molecular biology; (3) outreach activities for high school teachers from Pontiac city schools and school districts in which a majority of students are members of minority groups underrepresented in science, to include laboratory research and seminars in the biological sciences; and (4) on-campus workshops for faculty members and program participants in advanced techniques in areas not covered by current departmental expertise.

Oberlin College, Oberlin, Ohio
$600,000 to support (1) summer and academic-year research for undergraduates; (2) renovation of student research laboratories; equipment for chemistry, neuroscience, and psychobiology laboratories; and computers for physics; (3) an outreach effort to include curriculum development by teams of faculty, preservice science undergraduates, teachers, and a community-based educational organization; and (4) revision of precalculus courses, interdisciplinary and computational curriculum development, creation of a new course on health care issues and a new neuroscience course for nonmajors, and faculty development in psychoneuroimmunology.

Occidental College, Los Angeles, California
$800,000 to support (1) a prefreshman summer bridge to strengthen science and learning skills, summer and academic-year assistantships in research and teaching, student travel to scientific meetings and health professions interviews; (2) a faculty appointment in molecular evolution and interdisciplinary course development; (3) acquisition of computers to visualize biological and chemical structures and processes and for student use in gathering and analyzing research data; and (4) opportunities for faculty from Los Angeles area high schools and community colleges to participate in summer research in College laboratories.

Ohio Wesleyan University, Delaware, Ohio
$650,000 to support (1) equipment to enhance the research environment for students and infuse the curriculum with technology in multidisciplinary areas; (2) programs to increase student access to science, including summer research, faculty mentoring, and other activities; (3) a variety of outreach programs to include science programs for elementary school students and teachers and summer residential programs for middle and high school students; and (4) workshops and other faculty development opportunities to enable faculty to integrate computational science into the science curriculum.

Point Loma Nazarene College, San Diego, California
$750,000 to support (1) equipment to improve teaching laboratories and enhance students' research experiences in the sciences and start-up funds for supplies and equipment for new faculty; (2) an outreach program to introduce high school students to concepts in cell biology, biochemistry, and genetics and enhance their qualitative and quantitative skills; (3) summer research opportunities in molecular biology, genetics, chemistry, and other disciplines; and (4) development of new biology courses.

Pomona College, Claremont, California
$900,000 to support (1) renovation of and equipment for a computer modeling laboratory, equipment for investigative laboratories to include molecular biology and neuroscience, and start-up funding for a new faculty position; (2) a student research program, to include women and minorities underrepresented in the sciences; (3) a new tenure-track faculty position in molecular modeling aspects of biology and molecular biology, and a new course in molecular modeling and biological computing; and (4) an annual symposium for high school teachers and community college faculty members, with follow-up activities to include wet and computational laboratory development and undergraduate teaching assistantships for participants.

Reed College, Portland, Oregon
$700,000 to support (1) computing resources for science laboratories and courses to enrich the curriculum in areas such as molecular imaging that enhance students' quantitative skills; (2) summer and academic-year research opportunities for undergraduates, to provide stipends, supplies, and travel to national and regional scientific meetings, and support for a resource facility for basic science enhancement; and (3) outreach to a local elementary and middle school, to include teacher workshops offered by Reed faculty members, science equipment loans, and classroom activities by undergraduates.

Saint Olaf College, Northfield, Minnesota
$1,300,000 to support (1) the acquisition of computers, software, and other laboratory equipment to be integrated throughout the biology and chemistry curriculum; (2) a biology bridge course for prefreshmen selected through an early identification program, an environmental education program for rural and urban elementary and secondary schools, an enrichment program for science educators, K–12 teachers, and college faculty, and research for students traditionally underrepresented in the sciences; and (3) a summer research program to include laboratory training and symposia for undergraduates, including underrepresented students.

Smith College, Northampton, Massachusetts
$1,600,000 to support (1) a multimedia laboratory for an elementary school teaching classroom; equipment for undergraduate courses in physics, biocomputing, neuroscience, and biochemistry; and a confocal microscopy laboratory; (2) a summer research program primarily in interdisciplinary fields for science majors, a peer mentoring program to broaden student access to science, a visiting professorship, and a colloquium series; (3) precollege and outreach activities with a special focus on women's health issues, aimed at high schools and Native American community colleges; and (4) curriculum development in physics, a new program in biocomputing, and support for faculty development.

Spelman College, Atlanta, Georgia
$800,000 to support (1) curriculum development activities, to include integration of technology into the science curriculum, participation of visiting scientists in a seminar series, and faculty development activities; (2) summer laboratory research opportunities, seminars, mentoring, and other science experiences for local high school teachers and students, particularly those from schools with large minority enrollments; (3) student research experiences both on-campus and at other academic, government, and corporate research facilities, to include student travel to scientific meetings and presentations at an annual research symposium; and (4) computer-based laboratory equipment for data analysis and simulated experiments, and a visiting scientists/speakers program.

St. John's College, Annapolis, Maryland
$1,000,000 to support (1) renovations and equipment for teaching laboratories, including a core molecular biology laboratory and a plant tissue culture facility that will also be used for student-faculty research; (2) summer professional enrichment opportunities for faculty members to develop scientific knowledge and skills and to integrate that knowledge into the curriculum; (3) a partnership with a local Annapolis middle school with significant enrollment of underrepresented minority students, to include development of a mathematics and science curriculum, teacher training, materials development, and assessment and dissemination of the new approach; and (4) off-campus summer research opportunities for College students at research-intensive institutions including the Johns Hopkins University School of Medicine and the National Institutes of Health.

St. Mary's University, San Antonio, Texas
$600,000 to support (1) prefreshman laboratory training, peer tutors for freshman and sophomore biology, chemistry, and biochemistry majors, and an off-campus research program featuring seminars and academic counseling for undergraduates, including women and minorities underrepresented in the sciences; (2) curriculum development, to include a new course in cell biology, and faculty development activities; (3) computers and other equipment for biology, chemistry, and biochemistry courses; and (4) summer research opportunities at area laboratories for high school teachers and students, equipment for teachers, and research symposia for both teachers and students.

Swarthmore College, Swarthmore, Pennsylvania
$1,200,000 to support (1) an undergraduate research program, to include student travel to professional meetings, assistance in presenting and publishing research, and a lecture series; (2) renovations and equipment for a new evolutionary biology laboratory and equipment to update a psychobiology facility and a physical chemistry laboratory; (3) a new faculty appointment in evolutionary biology, and implementation and assessment of a new interdisciplinary honors program and release time for participating biology, chemistry, and physics faculty; and (4) summer research conducted by teams of students and teachers from local high schools, and academic counseling for high school students.

Tuskegee University, Tuskegee, Alabama

$600,000 to support (1) a science pathway program that includes prefreshman courses and laboratories, a freshman-year honors program and on- and off-campus research following the freshman year; (2) faculty development in educational technology and curriculum development, to include new and revised courses in cell biology; and (3) renovation and equipment of laboratories and a learning resource center.

University of Texas at San Antonio, San Antonio, Texas

$750,000 to support (1) purchase of equipment for neurobiology laboratories and computer equipment both for the laboratories and for middle and high school teachers; (2) development of neurobiology laboratories and development of curriculum for undergraduate-level courses; and (3) outreach programs for community colleges and summer workshops for middle and high school teachers.

Villanova University, Villanova, Pennsylvania

$1,600,000 to support (1) renovations and equipment for introductory biology laboratories, general chemistry courses, and a computing facility, and new curricula that emphasize quantitative approaches; (2) expansion of the Young Scholars outreach program in biology and mathematics, which is directed at high schools with substantial minority enrollments, and addition of a complementary mathematics and science teaching program for high school teachers from four urban school districts, to include equipment acquisitions and development of interdisciplinary instructional materials; (3) summer research opportunities for Villanova undergraduates and students from historically black institutions and other campuses, particularly those with substantial enrollments of underrepresented minority students; and (4) faculty workshops and release time for curriculum development.

Washington and Jefferson College, Washington, Pennsylvania

$600,000 to support (1) equipment for laboratories, to include cell biology, molecular biology, and biochemistry, and integration of computers and software into all biology courses; (2) on- and off-campus undergraduate research projects with college faculty members and other researchers; (3) mentoring by upper-class students and visiting scientists; (4) on- and off-campus faculty training and workshops, and appointment of a laboratory instructor/program coordinator; and (5) summer workshops, spring conferences, and classroom assistance for fifth- to ninth-grade teachers, and visits by public school students to College laboratories.

Wellesley College, Wellesley, Massachusetts

$1,500,000 to support (1) opportunities for students, including those from minority groups underrepresented in the sciences, to conduct on- and off-campus laboratory research, travel to scientific meetings, participate in honors seminars to strengthen their research skills, and work with faculty mentors; (2) new equipment acquisitions to enhance laboratory teaching and student research in such areas as nuclear magnetic resonance spectroscopy and biophysics; (3) a curriculum-wide initiative to strengthen interdisciplinary science education and the teaching of quantitative reasoning skills to science and nonscience majors; and (4) programs for precollege teachers and students to improve access to science, particularly for girls.

Wesleyan University South College, Middletown, Connecticut

$750,000 to support (1) faculty-mentored student research and a new first-year course to attract students to science, including women and students from underrepresented minority groups; (2) equipment acquisitions and laboratory renovations for courses in genetics, molecular biology, neuroscience, and structural biology, and computer upgrades to increase student access to the Internet and other resources; (3) start-up funding for new faculty appointments in cell biology and molecular biology and release time for curriculum development; and (4) continuation of an outreach program to science teachers in local secondary schools.

Western Maryland College, Westminster, Maryland

$700,000 to support (1) acquisition of microscopes for biology laboratories, renovations of student research facilities, and establishment of laboratories for emeritus scientists; (2) outreach to include curriculum and pedagogical development for middle school science teachers in Prince George's County, Maryland, and computers and microscopes for the schools; (3) an institute at which emeritus scientists will mentor student researchers; and (4) undergraduate research conducted by teams of students at various educational levels.

Whitman College, Walla Walla, Washington

$600,000 to support (1) the development of multimedia laboratories for introductory physical sciences and biology courses, to include renovations, acquisition of workstations and software, recruitment of a technical specialist, and purchase of physics equipment to interface with the multimedia workstations; (2) revision of introductory courses in biology, chemistry, and physics, and the appointment of a faculty biophysicist to create new courses and assist in the development of the multimedia laboratory; and (3) summer research experiences for students on campus in faculty laboratories and off campus in research settings.

Williams College, Williamstown, Massachusetts
$900,000 to support (1) equipment acquisitions for laboratories in introductory biology and biochemistry and for intermediate and upper-division courses in cell biology, developmental biology, molecular genetics, neuroscience, plant biology, and virology; (2) expansion of summer laboratory research opportunities for students, including those from underrepresented minority groups, to develop research skills and present their findings; (3) a new interdisciplinary seminar for nonscience majors; and (4) computers for local elementary schools linked to College and other science resources, science courses for elementary school teachers, and summer laboratory experiences for high school students.

Xavier University of Louisiana, New Orleans, Louisiana
$1,600,000 to support (1) opportunities for undergraduates underrepresented in the sciences, including summer bridge courses in biology and chemistry for prefreshmen, a peer-counseling center to provide tutoring and academic support, and stipends and workshops for undergraduates to improve retention of students in the sciences and mathematics; and (2) summer outreach programs in biology, chemistry, and mathematics for students from the seventh to twelfth grades, mini-grants and other activities for teachers in New Orleans public schools to develop their science and mathematics teaching, and national dissemination of program information to other institutions.

Precollege and Public Science Education

Since 1991 the Institute has developed several initiatives in precollege science education, principally to encourage students to choose scientific careers, to provide teachers with research opportunities and new teaching tools, and to address national concerns about the low level of scientific knowledge and interest in the general population. As of 1996, 93 institutions have received $21 million in support of precollege science education programs focusing on students (47 percent), teachers and curriculum (46 percent), and families and community groups (7 percent) (Figure 45).

The Institute's precollege initiatives are designed to stimulate the scientific community to work with teachers, school administrators, other educators, and students in all grades. The main objectives are to stimulate children's interest in science and to improve science education through revision of curricula, improvement of classroom practices, enhancement of teacher education (initial and continuing), and augmented teacher recruitment.

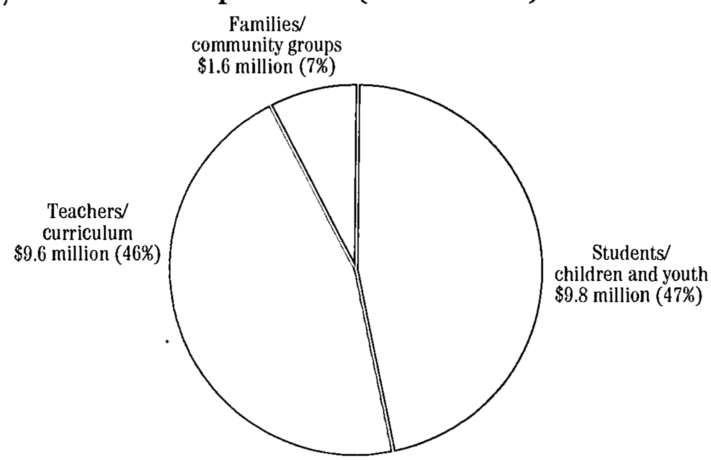
The commitment of the Institute to precollege science education has expanded in recent years. With a major focus on elementary school children, the Precollege and Public Science Education Program complements outreach activities funded through the Institute's undergraduate program, primarily at the middle and secondary school levels.

Precollege Program Directors Meeting

The directors of Institute-supported programs meet annually at HHMI headquarters in Chevy Chase,

Figure 45

Awards to 93 Science Museums[1] and Biomedical Research Institutions[2] by Program Component, 1992, 1993, and 1994 Competitions ($21 million)



[1]Includes science museums, aquaria, botanical gardens, and zoos.
[2]Includes medical schools, academic health centers, and independent research institutions

Maryland. Participants discuss their experiences in HHMI programs and consider broad policy issues related to precollege and public science education. Participants also have the opportunity to exchange curricular materials and demonstrate exhibits and educational technology developed with Institute support.

The fourth annual meeting of science museum program directors was held October 23–25, 1996.[1] In attendance were representatives of aquaria, botanical gardens, museums, zoos, medical schools, academic health centers, and independent research institutions. For the first time, representatives from other philanthropies with interests in precollege science education similar to those of the Institute were in attendance. The meeting focused on the role of educational technology in science education.

Educational technology—primarily computers and instructional software—is rapidly becoming a part of our institutions of learning. Not surprisingly, children seem the most adaptable, quickly getting online, mastering the language, and inventing new uses. In the meantime, the rest of us have to fathom the extent to which these new tools can strengthen, or weaken, an already delicate educational system.

For three days, program directors of the Institute's Precollege Science Education Program met to discuss their views of the role of technology in their home institutions, including its costs, benefits, and complexities, and to share information and experiences about what does and does not work.

An essential feature of much of the new educational technology is its ability to provide students with the time and resources to explore, often at their own pace. It can also provide a forum for exercises in iteration and reiteration of basic principles, and exposure to visual learning of an entirely new kind. Multimedia technology is especially promising in the development of science curricula for advanced placement high school and undergraduate students. The power of this technology is that it augments lectures and condenses the essentials of the course. Testing of the curriculum shows that students like the interactive nature of the CD-ROM products because of the hyperlinks, which allow for additional exploration.

The important message from many conference participants was that technology can be high or low; the critical factor is that it enrich the mix of learning experiences. For example, museums have for decades brought 20th-century learning to students in a meaningful way by providing the experience of place—an actual environment where the learning experience occurs. Technology—be it a diorama, walk-through heart, or computer—has always played a role. In some cases, the technology is exceedingly simple, for pragmatic or pedagogic reasons.

[1] *Making New Connections in Science Education: Casting a Wider Net.* Howard Hughes Medical Institute Office of Grants and Special Programs. 1997.

Educational technology changes the way we learn, asserted keynote speaker Linda Roberts of the U.S. Department of Education. It is no mistake, she claimed, that new learning techniques supported by cognitive-based methods and appropriate computer environments are part of many education reform activities. These techniques enable learners to communicate across barriers of time and space, engage in simulated activities that would not otherwise be possible, and facilitate the individualization of learning tasks.

Because technology changes the way we learn, educators must also change the kind of knowledge they are promoting as well as redefine the meaning of learning. In developing programs using educational technology, educators are struggling with how to balance pedagogy versus content. Some believe that there are principles of learning and that content should reflect the principles. However, content often drives the desire to learn. The key to success is in finding the balance.

Some educators believe that interactive educational technologies actually speed the learning of complex ideas, providing a more powerful educational system; others are less optimistic. During the two days of meetings, participants debated and discussed the value of technology in student-based learning and teacher development and grappled with issues about how to ensure access, evaluate outcomes, and introduce change into the curriculum.

Eligibility and Award Process

The precollege and public science education program awards funds through a variety of mechanisms. Most grants are made through national competitions, in which institutions are invited to submit proposals according to prescribed criteria.

In 1992 a national competition was held for children's and youth museums, natural history museums, and science and technology centers. In 1993 a similar competition added aquaria, botanical gardens, and zoos. For the 1994 competition for biomedical research institutions, applications were solicited from medical schools, academic health centers, and independent research laboratories. No national competitions were held in 1995.

In each year of a national competition, proposals are evaluated by an external panel of scientists, science educators, research and education administrators, and others with relevant expertise. The advisory panel's evaluations and recommendations are reviewed by Institute science and grants staffs. Recommendations are then made to the Trustees, who authorize funding.

In addition to national competitions, the Institute has provided support for selected science education programs at the national level that afford unique educational opportunities not offered through its national competitive programs.

The Institute also has an active local grants program focused on

Figure 46

Precollege Science Education Initiative for Museums, 1992 and 1993

- $10.65 million total to 51 institutions
- Five-year awards
- Program elements
  children and youth
  teachers
  families, youth organizations, and community groups
- Awards

1992	$6.4 million to 29 children's and youth museums, general science museums, natural history museums, and science and technology centers (162 competing)
1993	$4.25 million to 22 museums, aquaria, botanical gardens, and zoos (170 competing)

science education opportunities in the Washington, D.C., metropolitan area, particularly Montgomery County, Maryland, the home of its headquarters. Local awards are made at the discretion of Institute management in consultation with the Trustees.

Program Development, 1992–1996

Of the $21 million in precollege science education grants awarded since 1992, $10.65 million is being expended through the precollege science education initiative for museums and over $10.3 million through the initiative for biomedical research institutions.

In 1992 a total of $6.4 million was awarded to 29 science and children's museums for support of precollege science education activities. These involve primarily kindergarten through eighth-grade children (K–8) and their teachers and parents. The museum initiative supports linkages between science resource centers and elementary schools, promotes science enrichment activities for children and their parents and caregivers at home, and reaches into communities through youth organizations, churches, and other local institutions. An additional $4.25 million was awarded in 1993 for similar science education initiatives to 22 institutions, including aquaria, botanical gardens, arboreta, and zoos (Figure 46).

A major goal of the precollege science education effort is to provide opportunities for hands-on learning. Direct laboratory experiences and inquiry-based activities are now recognized as a necessary component of science education and preparation to teach science. Such learning serves several vital functions in intellectual development. It teaches the student to observe, hypothesize, theorize, and develop methods by which to generate knowledge. Hands-on research experiences promote the concept of biology as an experimental science, rather than just a subject to be studied through lectures and reading. Finally, the collection and interpretation of data are best taught by trial and error, with opportunities for analysis of results and modification of experimental design.

The use of laboratories in teaching biology is limited and has been declining nationally for many years. Some reasons for this are reductions in school resources for supplies, equipment, and laboratory space; lack of laboratory experience in teacher preparation; and the time-consuming demands of increasing curricular content. In response to this educational deficit, institutions of higher education are opening their doors to high school teachers and students, thus offering them both research experience in well-equipped and exciting environments and exposure to working scientists as mentors to students and partners to teachers.

Virtually every community with a medical school or research organization views it as a respected and economically important asset. The faculty and staff include trained professionals who can influence educational policies and practices, especially as they relate to preparing young people for careers in medicine and biological research. In addition, many medical schools are located in inner cities and thus offer opportunities to youth currently underserved in mathematics and the sciences. They have the potential to offer invaluable benefits to local students and teachers.

In June 1994 the Institute announced over $10.3 million in five-year awards to 42 medical schools, academic health centers, and independent research institutions for outreach programs to students and teachers in their local communities. These institutions will provide K–12 students and teachers with laboratory experiences, mentoring programs, teacher development, summer science camps, and classroom-based hands-on activities (Figure 47). This initiative encourages a larger role for practicing scientists in every aspect of education reform, from textbook development to teacher training.

Figure 47

Precollege Science Education Initiative for Biomedical Research Institutions, 1994

- $10.3 million total to 42 institutions
- Five-year awards
- Program elements

  student research or hands-on science opportunities

  teacher development, including scientist-teacher partnerships and research opportunities

  curriculum development and implementation, including development of science units and kits
- Awards

  $10.3 million to 29 medical schools, 7 academic health centers, and 6 independent research institutions (106 competing)

Summary of Precollege and Public Science Education Activities, 1992–1996

Through the science museum program, the Institute has awarded \$10.65 million to 51 institutions, including science museums, aquaria, botanical gardens, and zoos. Of this amount, approximately 53 percent goes for children's and youth activities, 33 percent to teachers and curriculum development, and 14 percent for science outreach to families and communities (Figure 48).

Of the \$10.3 million awarded to biomedical research institutions, approximately 41 percent goes for student activities, 46 percent for teacher development, and 13 percent for curriculum development (Figure 49).

Student Programs

Precollege science education grants are supporting programs designed to enhance young people's understanding of biology and related disciplines and their interest in these fields. The projects encourage girls to participate, and minorities underrepresented in the sciences. Of the \$21 million, nearly half is devoted solely to activities for children and youth. Among the approaches are those that encourage involvement of students, both rural and urban, in after-school and summer science activities, including educational programs that ease the transition of disadvantaged minority youth from elementary to secondary school. Many of the programs have a mentor component, where students are paired with older students or scientists for year-round or summer activities.

These initiatives are focused at elementary, middle, and secondary levels (Figure 50). Students involved in the science museum programs are likely to be very young; 77 percent are prekindergarten through grade 5. Students participating in the biomedical research institution programs are more likely to be older; 39 percent are in grades 6 through 8, and 32 percent are in grades 9 through 12. Over 155,000 students have engaged in these Institute-sponsored activities.

A number of the programs involve organized collaborations between grantee institutions and schools. Activities may take place at either site. Examples are field trips, classes, laboratory demonstrations, sponsorship of science clubs, and loans of materials and equipment (Figure 51). Another significant focus is on projects that involve students in a variety of research experiences, beginning in elementary school and continuing through the secondary school years.

Teacher Development

The Institute's precollege initiatives are intended, in part, to provide in-service training for teachers of biology and related disciplines. Most involve creation or distribution of instructional materials. Many support teacher development, with the primary focus on in-service initiatives. Several programs provide

Figure 48

Awards to 51 Institutions—Museums, Aquaria, Botanical Gardens, and Zoos—by Program Component, 1992 and 1993 Competitions ($10.65 million)

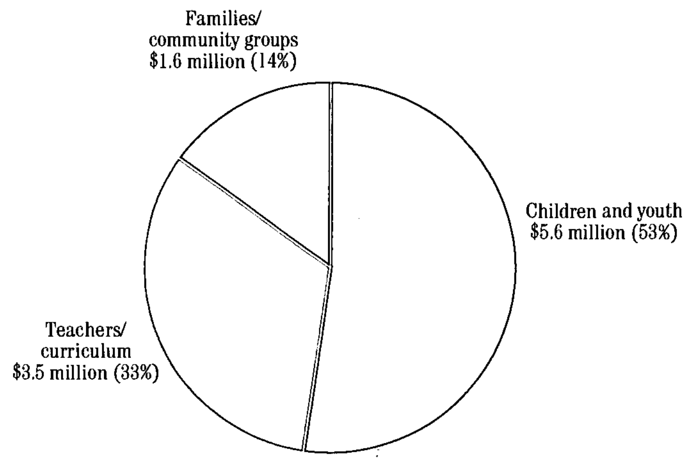


Figure 49

Awards to 42 Biomedical Research Institutions—Medical Schools, Academic Health Centers, and Independent Research Institutions—by Program Component, 1994 Competition ($10.3 million)

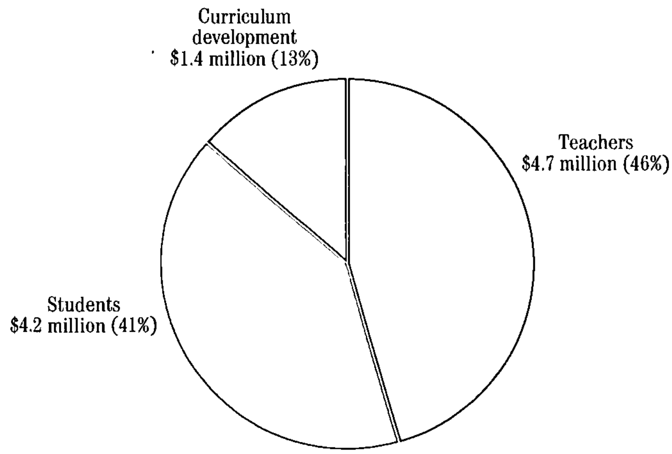
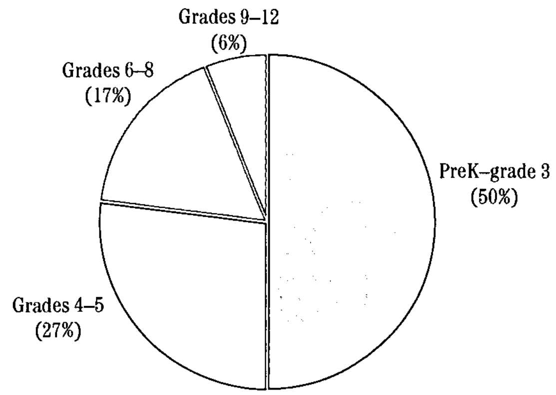


Figure 50

Student Participation in Precollege Programs, by Grade Level

Science Museum Initiative (1992–1996)



Biomedical Research Institution Initiative (1994–1996)

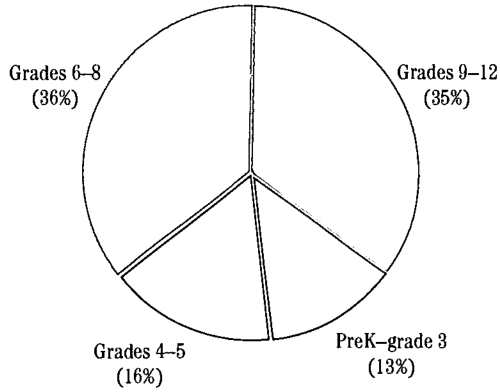


Figure 51

Student Activities, 1992–1996

Activity	Number of Students Participating
Visit to grantee institution	118,866
Classes	99,538
Outreach to schools	91,822
Field trips	9,557
Research	5.685
Product development	4,011
Summer science programs	3,227
Mentor programs	2,973
Science clubs	2,618
Explainer programs	478
Other	3,711

teachers with practical experience in modern biological research, allowing them to upgrade their knowledge and laboratory skills. Still others match teachers with scientists for year-round teaching and resource collaborations. Of the $21 million, $9.6 million is dedicated to teacher-related activities. More than 7,000 teachers have taken part in these Institute-sponsored professional activities (Figure 52).

Elementary school teachers are the primary beneficiaries. In the science museum programs, 75 percent of participating teachers have prekindergarten to 5th-grade classrooms (Figure 53). As would be expected, teachers participating at medical schools, hospitals, and research institutions are more likely to teach at the secondary level. Half of those teach 9th- through 12th-grade science.

Figure 52

Teacher and Student Participation in Precollege Programs, 1992–1996

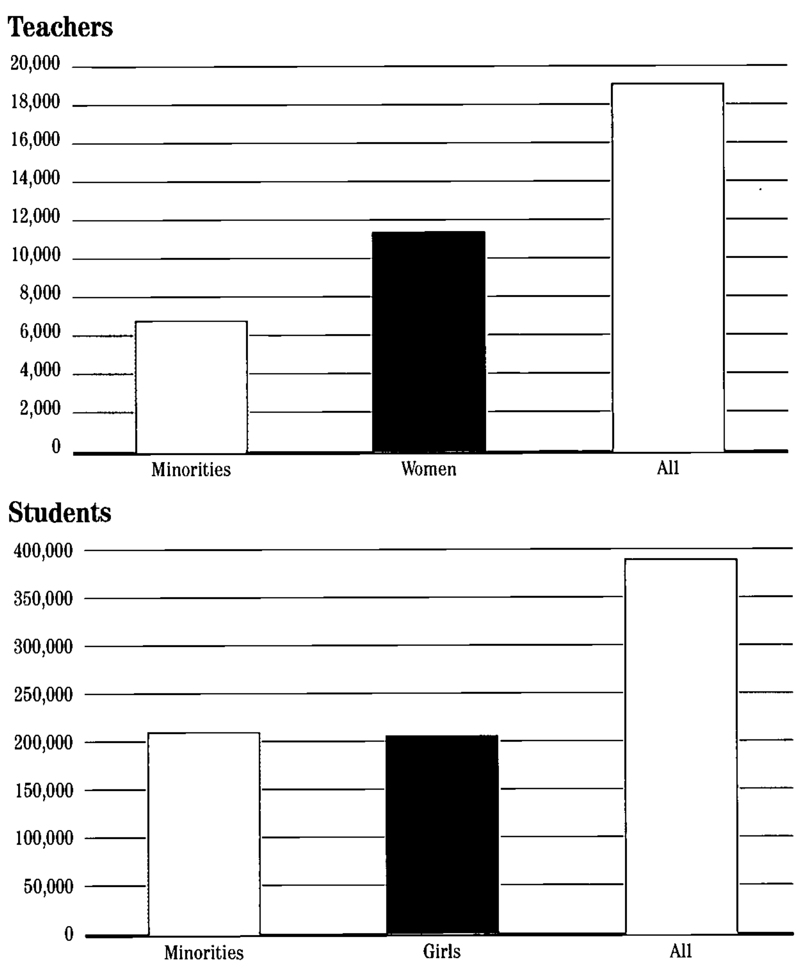
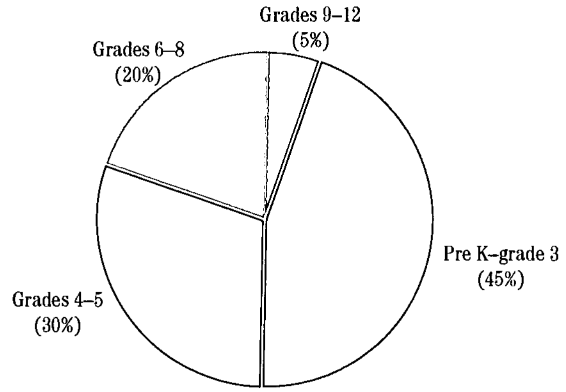


Figure 53

Teacher Participation in Precollege Programs, by Grade Level

Science Museum Initiative (1992–1996)



Biomedical Research Institution Initiative (1994–1996)

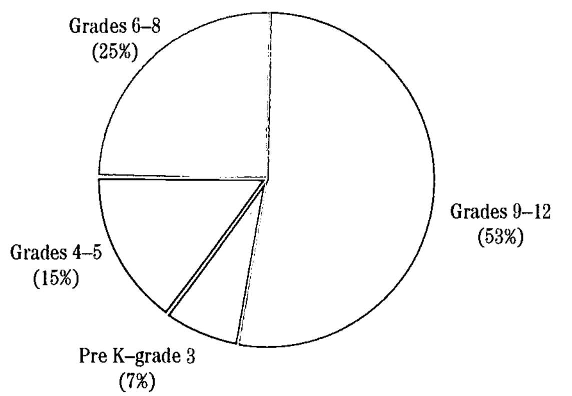


Figure 54

Teacher Development Activities, 1993–1996

Type of Activity	**Number of Participants**
In-service	2,976
Short sessions	2,746
Long sessions	1,089
Summer workshops	393
Pre-service	140
Other	152
Total	**7,496**

The types of programs offered to teachers include both in-service and pre-service activities, although the majority are offered to teachers already in the classroom. Professional development activities include one- or two-day workshops or one- or two-week summer institutes. During the summer of 1994, nearly 400 teachers took part in a summer workshop lasting a week or two (Figure 54).

Curriculum Development

Through support from the Institute grants, a significant number of institutions will develop inquiry-based instructional materials and kits, with an emphasis on distribution to educators working with limited resources in rural and urban environments. In many cases the grant will enable biology teachers to establish and maintain novel instructional tools to introduce students to a variety of biology topics. Programs include curriculum development, workshops and training sessions on use of the new curricula, and dissemination and evaluation activities (Figure 54, above).

The most common use of Institute funds for these purposes is for curriculum materials, which will be distributed to over 4 million students and teachers this year. Well-designed classroom activities and loan kits are also in development, as are videotapes, scripts, and guidebooks (Figure 55). There are also 53 traveling exhibits in the works, the vast majority coming from the museum community.

Family and Community-Oriented Programs

Recognizing that parental, peer, family, and community involvement in science education will foster young people's interest in science, the Institute designated family and community-oriented science education activities as an important component of the museum initiative. Of the $21

Figure 55

Educational Materials in Development or Use, 1993–1996

Type of Activity	Number in Development/Use	Number of Users
Curriculum materials	1,455	3,048,439
Videotapes	1,304	240,061
Traveling exhibits	53	279,654
Scripts	778	146,385
Guidebooks	108	78,813
Classroom activities	3,186	121,626
Loan kits	894	66,506
Other	2,757	31,334
Total	**10,535**	**4,012,818**

million, nearly $2 million is for family and community group activities. The grants are supporting a variety of exciting approaches that draw families, youth organizations, and community groups into the educational activities of museums and biomedical research institutions.

Some of the projects provide opportunities for parents and other child care providers (e.g., afterschool program directors, church groups, Girl and Boy Scout leaders) to be involved in learning science with children. These activities most often take place at the grantee institution, but nearly one-fourth of the family involvement takes place at an outreach facility such as a school or community center. Several grants support outreach efforts that bring science programs to rural families and youth groups with limited science education resources.

Figure 56

Regional Initiatives in Science Education of the National Research Council/National Academy of Sciences

Award

- $600,000
- Three-year term, 1994–1997

Objective

- Create a national network of scientists committed to precollege science education reform

Program Components

The RISE (regional initiatives in science education) project has two elements that reach different but overlapping audiences:

- Training workshops to involve scientists in K–12 education
  one- or two-day workshops at annual meetings of professional societies, information about legal issues and educational opportunities
- Regional groups to further ongoing interaction among participants
  experimental models of interaction among scientists, educators, community organizations, and schools; national policy formulation translated to strategies for local implementation

Other Precollege Program Activities

At the national level, the Institute supports selected science education programs that afford unique educational opportunities not offered through its competitive programs. In addition, the Institute has funded several precollege program activities in the Washington, D.C., metropolitan area.

Regional Initiatives in Science Education of the National Research Council/National Academy of Sciences

In June 1994 the Institute awarded $600,000 to the Commission on Life Sciences/National Research Council/National Academy of Sciences for a three-year grant to support Regional Initiatives in Science Education (RISE). This is a series of programs designed to create a national cadre of scientists equipped to participate effectively in system-wide reform of precollege science education (Figure 56). The grant finances personnel, faculty, travel, stipends, subsistence, supplies, equipment, and computer support.

The success of many of the precollege programs funded by the Institute and other organizations relies on the willing and able participation of scientists. Efforts to reform K–12 science education include revision of standards-based curricula and materials, teacher training and assessment, and change in the science education policies of schools and government agencies. Reform also involves changing the nature and level of educational collaboration between scientists and their communities. Through professional society workshops, regional experiments, and other approaches, RISE brings scientists and science resource institutions to the assistance of local schools and school districts engaged in the reform movement. Central to the efforts of RISE has been help to schools in undertaking the kinds of reforms advocated in the National Science Education Standards of the National Research Council (Figure 57).

As a project of the National Academy of Sciences, RISE will be able to access widely recognized scientists and bring their expertise to bear on the reform movement. In addition, with NAS coordinating the development of broad standards for science education, RISE participants will have ready access to individuals and groups involved in implementing the standards throughout the nation.

Woodrow Wilson National Fellowship Foundation National Leadership Program for Teachers

In 1996, the Institute renewed a grant to the Woodrow Wilson National Fellowship Foundation to fund summer institutes for high school biology teachers. The new award is for $2.4 million over four years, building on a previous grant

Figure 57

Regional Initiatives in Science Education: Promoting Science Education Reform

RISE activities assist scientists and science resource institutions in their efforts to undertake the kinds of reforms advocated in the National Research Council's *National Science Education Standards.* Principal reforms called for by the standards are

- adoption of curricula that emphasize inquiry
- adoption of instructional strategies that enable teachers to facilitate and to model scientific inquiry
- adoption of assessment strategies that measure student achievement in ways consistent with the Standards
- development of progressive K–12 science programs that reflect a continuum of learning outcomes appropriate for each level of child development.

The RISE program provides assistance in resource identification, leadership development, networking, and analysis at two regional experimental sites: Minneapolis, Minnesota, and Mercer County, New Jersey. The RISE sites stimulate the local science community, including teachers and professional scientists, to work together to identify needs and resources.

Figure 58

Woodrow Wilson National Fellowship Foundation, National Leadership Program for Teachers

Award

- $1.6 million
- Three-year term, 1993–1996

1996 Summer Biology Institute at Princeton University

- Four-week institute
- Theme: Living Computers? Neurobiology at All Levels of Organization
  - animal behavior
  - the nervous system
  - neurotransmitters and hormones
  - gene regulation
  - embryological development
- 49 high school teachers selected in national competition
- Faculty:
  - Lin Aanonsen, Neuroscience Program, Macalester College
  - Bruce Alberts, President, National Academy of Sciences
  - John Alcock, Department of Zoology, Arizona State University
  - Bonnie Bassler, Department of Molecular Biology, Princeton University
  - Wayne Bowen, National Institutes of Health
  - Donald Cronkite, Department of Biology, Hope College
  - Charles Drewes, Department of Zoology, Iowa State University
  - Frank Hinerman, Mt. Lebanon Senior HIgh School, Pittsburgh, Pennsylvania
  - Robert Ho, Department of Molecular Biology, Princeton University
  - Jane Obbink, Lincoln Southeast High School, Lincoln, Nebraska
  - Eric Wieschaus, Department of Molecular Biology, Princeton University

1996 One-Week Summer Outreach Institutes

- 175 teachers
- 11 sites in 7 states for teacher training
- Master teachers selected from 4-week summer institutes

made in 1993 for $1.6 million over three years. An intensive four-week institute is offered on the Princeton University campus for 50 teachers selected through a national competition, and regional one-week outreach institutes are conducted by teams of master teachers at colleges and universities, teacher centers, and science museums nationwide (Figure 58). The new award will also provide support for the establishment of a Woodrow Wilson National Fellowship Foundation World Wide Web site for teachers on the Internet.

Each summer the four-week Princeton institute is taught by a national faculty from liberal arts colleges and research universities. In planning it, the foundation appoints an advisory network of scientists and teacher educators. Many serve as faculty during the summer session.

Each day of the four-week institute includes lecture and laboratory components. Lectures update the teachers' knowledge of their field. The labs include field site visits, computer applications, and curriculum development projects. The participating teachers develop curricula based on the institute's theme. These teachers disseminate the curricula throughout the country via TORCH (teacher outreach) institutes, as do teams of master teachers who lead the one-week regional institutes.

The goals of the program are to strengthen the content mastery and pedagogic skills of the teacher workforce in biological sciences, to expand and maintain a national network of talented biology teachers who are prepared to teach other teachers, to serve them as a resource, and to enhance the status and visibility of the teaching profession by affirming the central role of the teacher as an active agent of education reform.

Choice of topics for an institute is essential, since this professional development program is content driven. While similar programs feature annual variations on a relatively narrow topic, the Woodrow Wilson summer institutes choose a new topic each year. This is done for a number of reasons. Alumni from previous years receive and work with materials produced at all the institutes; each year an increasingly varied body of enrichment activities is available for classroom enhancement; and the outreach activities assume a slightly different perspective each year, so an ongoing participation is encouraged.

Populations to Molecules: Heredity at All Levels was the topic for the first year (1994). In 1995 the institute topic was Evolution: A Context for Biology. In 1996 the theme was Living Computers? Neurobiology at All Levels of Organization. The 1996 theme was chosen because neurobiology is not commonly taught in high school biology. However, new resources for teaching this topic in high school became available recently, developed by the National Association of Biology Teachers and the American Psychological Association, providing some starting points for the Woodrow Wilson faculty. The first week of the Institute focused on animal behavior and laboratory and field exercises using crickets, beetles, and damsel flies. The second week moved from behavior of whole animals to the study of nervous systems, particularly invertebrates easily found, such as worms. The third week exposed teachers to neuropharmacology, neurophysiology, and neurotransmitters. Laboratory exercises relied on a bacterial model of intercellular communication. The final week involved a series of lectures and studies of developmental neurobiology, including the nervous systems in flies and zebrafish.

The 49 teachers taking part in the summer of 1995 represented 28 states and the West Indies. The majority teach in public schools, and experience ranges from 4 to over 30 years. Most teach biology, but some also teach other science subjects and mathematics.

The one-week summer TORCH institutes, which carry the experiences of the Princeton institute into the field, were conducted at 11 sites in the summer of 1996 and were attended by 175 teachers. In addition, teacher-originated in-service projects reach thousands more across the country. In the year following their Princeton institute experience, teachers lead in-service activities involving an average of 15 peers. Teachers can also request Institute support grants for follow-up activities.

Washington, D.C., Metropolitan Area Programs

In 1997 the Institute entered the eighth year of an active program to support science education efforts in the Washington, D.C., metropolitan area, home of HHMI headquarters. This year cumulative support for local grants surpassed $4 million. (Figure 59). Each year the Institute's local grants involved nearly 3,300 area students and 1,300 teachers. In addition, the Institute annually supports Maryland Science Week activities through the Maryland Science Center in Baltimore. By affording unique opportunities for students and teachers to gain hands-on experience in the science classroom and laboratory, the Institute's local education initiatives address national concerns about the state of science education.

Figure 59

Summary of Washington, D.C., Metropolitan Area Grants

Year(s)	Science Education Grants	Total Awarded†
1990–1999*	Howard Hughes Medical Institute Summer Research Fellowship Program at the National Institutes of Health	$760,000
1990–1997*	Montgomery County Public Schools Student and Teacher Intern Program at the National Intitutes of Health	1,332,000
1990–1993*	Cold Spring Harbor Biotechnology Program with the Montgomery County Public Schools	219,500
1994–1999*	Montgomery County Public Schools Elementary Science Education	640,000
1993–1994	Edison Career Center Biotechnology Program	14,000
1993–1998*	Edison Career Center Middle School Biotechnology Summer Focus Program	85,000
1993–1999*	Chesapeake Bay Foundation/ Montgomery County Public Schools	598,000
1996–1999	Audubon Naturalist Society/ Montgomery County Public Schools	37,000
1992–1995*	Maryland Science Week	35,000
1990–1995*	Carnegie Institution of Washington First Light Program	65,000
Year	**Other Grants**	**Total Awarded†**
1991	American Association for the Advancement of Science	5,000
1988–1990	University of Maryland Education Center	225,000
1989–1995*	Washington Area United Way	200,000
	Total	**$4,215,500**

*Multiple awards

†Cumulative amounts paid and/or committed for caleandar years shown

Local Partnerships

With an abundance of scientific and educational resources already established in the Washington area, students and teachers are at a unique advantage. The programs funded by the Institute take advantage of local scientific resources such as the laboratories of the National Institutes of Health, the classrooms of local colleges and universities, the living collections of the National Zoo and National Aquarium, the vast waters of the Chesapeake Bay, and the well-established programs and expertise of the local Audubon Naturalist Society. Several Institute-supported programs in the Washington, D.C., area are mature enough to have proven track records. One, now in its seventh year, provides research experience at the National Institutes of Health for about 40 area students each summer. Some entered while in high school and are now in medical school or pursuing graduate study in the biological sciences.

Another program enables selected Montgomery County students and teachers to join research teams at NIH or the Food and Drug Administration during the summer and academic year. Teacher graduates of this initiative have gone on to revise their laboratory courses, develop new curricula, and start science clubs and other extracurricular activities for students. Students in the program present their research findings each spring to teachers, parents, and scientist mentors.

A program offered to Montgomery County students and teachers by the Chesapeake Bay Foundation provides hands-on science and environmental studies of America's largest estuary. A summer science camp at the Thomas Edison High School for Technology in Wheaton, Maryland, opens new horizons in molecular biology and biotechnology for area middle school girls. A teacher development program offered by the Audubon Naturalist Society provides local teachers with curricula and resources to conduct science education programs in their own schoolyard. Nearly 4,000 science kits have been introduced in Montgomery County elementary schools as an aid to revamping science education.

Howard Hughes Medical Institute Holiday Lectures on Science

In 1993 the Institute initiated a series of holiday lectures on science for high school students. The lectures are built on traditions established in 1827 by the British scientist Michael Faraday and on a science lecture series offered more recently by Rockefeller University. The Institute is strongly committed to enhancing science education nationally, and the holiday lectures, held for two days in the conference center at Institute headquarters in Chevy Chase, Maryland, engage speakers known to be effective in communicating their scientific work to the general public and in reaching out to students at the precollege level. Approximately 190 students from 80 high schools in the Washington, D.C., area attend the lectures annually. Principals and science department heads in each of the schools nominate student attendees on the basis of a demonstrated interest in science.

Figure 60

Howard Hughes Medical Institute Holiday Lectures on Science, 1993–1996

- December 20–21, 1993

  Stephen Burley, M.D., D.Phil., The Rockefeller University

  John Kuriyan, Ph.D., The Rockefeller University

  Da Vinci and Darwin in the Molecules of Life
  The speakers explored relationships between modern structural biology and the work of Leonardo da Vinci and Charles Darwin, who helped establish the intellectual foundation for the biological sciences.

- December 19–20, 1994

  Shirley M. Tilghman, Ph.D., Princeton University

  Robert L. Nussbaum, M.D., National Institutes of Health

  Genes, Gender, and Genetic Disorders
  Dr. Tilghman explained the latest findings on how gender is determined in humans and other mammals, and Dr. Nussbaum discussed how mutations and chromosome disorders affect the genes involved in this process and lead to clinical disorders.

- December 18–19, 1995

  Thomas Cech, Ph.D., University of Colorado, Boulder

  The Double Life of RNA
  The discovery that RNA can play a dual role in the cell, serving both as messenger and catalyst, was discussed and illustrated; new therapeutic agents based on RNA's dual role were suggested; and a novel theory involving RNA was offered to explain the origin of life on earth.

- December 9–10, 1996

  Philippa Marrack, Ph.D., and John W. Kappler, Ph.D., National Jewish Center for Immunology and Respiratory Medicine, Denver, Colorado

  The Immune System–Friend and Foe
  Vertebrates defend themselves against infectious organisms through receptors on the surfaces of lymphocyte cells. As each lymphocyte develops, it randomly expresses only one of trillions of possible receptors. When an infection occurs, lymphocytes can multiply rapidly and mount a defense. However, the body must avoid being attacked by its own immune system. How these mechanisms of self defense and self recognition occur is the focus of these lectures.

The December 1997 lectures will mark the fifth year of the series (Figure 60) and will be presented by Drs. James A. Hudspeth and Jeremy H. Nathans. The title is Sense and Sensitivity: Neuronal Alliances for Sight and Sound. This year's lecture series is supported by derivative materials that will be distributed to 10,000 teachers around the country. In addition, the Institute will again broadcast the lectures, using advanced satellite and computer technologies, with a view to further encouraging interest in science among students, nationally and internationally.

For the 1996 holiday lectures, Drs. John W. Kappler and Philippa Marrack, HHMI Investigators and members of the National Jewish Center for Immunology and Respiratory Medicine in Denver, Colorado, presented "The Immune System—Friend and Foe." Televised live across the United States and Canada, the Kappler-Marrack lectures reached an audience of 7,000 junior and senior high schools via satellite and were rebroadcast to an additional 10,000 schools by the Classroom Channel. As such, they reached an estimated 800,000 students and teachers. The present chapter traces briefly the careers of Drs. Marrack and Kappler and the experiments they described in the 1996 holiday lectures.

The 1996 Lectures: "The Immune System—Friend and Foe"
Meet the Presenters

If asked what trait would be most useful to a budding scientist, many people would probably say "being really, really smart." But immunologists Philippa Marrack and John Kappler say that an excess of brains is not necessarily what you need. Instead, determination, flexibility, patience, working well with your peers—and luck—are all as useful,

Figure 61
Philippa Marrack and John Kappler

they suggest, as raw brain power in building a successful scientific career.

Marrack and Kappler know more than most about what it takes to succeed in science—and about how to get along with laboratory partners. Married since 1974, they have enjoyed a uniquely productive personal and professional partnership for more than two decades. During their careers, they have produced a steady stream of advances in our understanding of how the immune system operates, punctuated by a few major discoveries that have earned them a global reputation.

Marrack cites three traits that have been helpful to her—traits that she says many good biologists have. First, she says, you need to be alert, and able to hear what your results—especially unexpected results—tell you. "You have to be able to pay attention to the unexpected data," she says. "If you can't, you'll miss the most important findings."

But beyond intellectual flexibility, Marrack adds, you need both tenacity and a special kind of patience—the ability to find satisfaction in the smallest details while slowly building a much bigger picture. "In science, you have to know what the most important question is, and be willing to do whatever it takes to answer that question. John and I have always had a clear idea of what we wanted to find out, and we've pursued it ruthlessly." But really big discoveries happen rarely, if at all, she reflects. "For most of your daily scientific life, you have to be satisfied with little things, small satisfactions. Just the fact that the gel ran straight, or that the cell cultures seem healthy for a change, counts as a small triumph."

Kappler agrees, but adds that another important trait is the ability to forge productive scientific collaborations. "Almost nobody succeeds in this business all alone, and I owe a lot of my success to the people I've worked with." Kappler also says that the whims of fate play a role in moving a scientist out to the cutting edge. "Serendipity plays an awfully big role in most scientific careers, and even then, only if you're in the right place at the right time and collaborating with good people. We sometimes don't like to admit it, but to make discoveries you have to be lucky."

School Days

"Chance favors the prepared mind," Louis Pasteur's oft-quoted dictum, well applies to the careers of Marrack and Kappler. If they've been lucky, it's because they earned their good fortune. They met at the University of California–San Diego, in 1971, where they were postdoctoral researchers working on immune cell culture systems in Richard Dutton's laboratory. This stint was Kappler's first plunge into immunology.

After graduating in 1961 from a science and engineering–oriented high school in Baltimore, Maryland, Kappler went to Lehigh University to study engineering. He soon realized, however, that scientific research, especially biochemistry, was his real love. After taking his B.S. in chemistry from Lehigh, he went to Brandeis University to pursue a Ph.D. There he studied how the attachment of specific chemical groups to DNA (methylation) changes as cells move through the growth cycle.

Kappler says he spent most of his time in graduate school learning how not to do science. "Like most graduate students, I came in with all these great ideas about what I would do, and I slogged away for a long time trying to get some kind of sensible results, without getting anywhere," he recalls. "Then something clicked, and I started to think more clearly about how to approach the problem. I branched out and found something that worked, probably producing 80 percent of the data for my thesis in my last six months of graduate school."

Marrack, meanwhile, had already taken up the study of the immune system as a graduate student. Born in England, she went to an all-girls boarding school before moving on to Cambridge University. "My high school was more intellectual than many other girls' schools of the time," she says. "We weren't just being trained to wear fancy gloves and run church bazaars, although, I must admit, it was close. My teachers didn't really know how to deal with a woman who was interested in science, so they shipped me off to various places to have extra instruction. When I went to University, I took all science courses because that was what I was good at."

From there, she just continued to pursue her scientific education without a clear idea of where it would lead. "At the start I didn't really know there were people who spent their whole lives in research," Marrack continues. "In my last year at University, I met the man who became my Ph.D. thesis adviser, and he persuaded me to come study with him. My father's uncle, John Marrack, was a famous immunologist in the 1930s, and my future adviser (I later learned) thought it would be neat to have a descendant of this curmudgeonly character working in his lab. So I started to study T cells then, and I've been at it ever since."

Kappler and Marrack both recall that they went to San Diego as much for the climate as for the intellectual opportunity. In the laboratory where they met, each independently characterized immune cells in culture and unraveled the complex interactions that lead to specific immune defenses. Marrack had intended to return to England at the end of her postdoctoral work, but changed her plans and instead joined Kappler in Rochester, New York, where he had landed a job as an assistant professor of microbiology at the University of Rochester.

Building a Partnership

The first few years in Rochester set a tone for their partnership that continues today. When they first arrived, only Kappler had a faculty position. Marrack, with a Ph.D. from Cambridge and three years of postdoctoral training, was officially a technician working in his lab. "But from the very beginning," Kappler says, "it was clear to both of us, and to anyone who worked with us, that our lab was a complete partnership—we worked together." Also, they decided that all their scientific papers and, whenever possible, grant applications would be joint endeavors. "We figured it didn't matter who did what—whether it was making the supper or running the gel, we both contributed," he says.

Marrack quickly took steps to establish her own scientific credentials. In her second year at Rochester, she won a prestigious research grant from the American Heart Association and began teaching a graduate course in immunology. But most important perhaps, she credits her husband for having the good sense to support her. "John never got in the way—he didn't blanket my achievements. Anyone could see we were a pair of scientists and not a guy and someone working for him."

The first problems the couple took on in their new laboratory were extensions of their postdoctoral projects. They continued to characterize the interactions that occur between immune cells—T cells, which mature in the thymus, and B cells, which mature in the bone marrow and produce antibodies. They showed that there were many specific factors, called cytokines, that are released by helper T cells and exert profound effects on their B cell targets. They also showed that various cytokines act together and produce effects far different than when they act alone.

Eventually Marrack and Kappler began to focus on how T cells recognize specific antigens. Immunologists at the time knew that the body fields an incredibly broad array of T cells, each bearing receptors capable of binding a different but highly specific chemical antigen. They knew that T cells (unlike B cells) have to recognize their antigen displayed on another cell's surface before they can be activated. And they knew that cell surface proteins encoded by certain genes—those of the major histocompatibility complex, or MHC—were intimately involved in antigen recognition.

"The burning question at the time was how antigen recognition occurs," says Kappler. "Were there separate receptors on the T cell for antigen and MHC protein, or was there just one receptor for both? Could each T cell recognize only one specific antigen, or many? Why didn't T cells bind antigens normally present in the body? Structurally and biochemically, what were the T cell receptors like? Those were questions we took on then, and we've been working on them ever since."

One of the technical difficulties is that immune cells taken from an animal live only for a few weeks in tissue culture. In the mid-1970s, researchers learned to fuse normal B cells from mice with cells from mouse myeloma, a cancer in which mutated B cells divide indefinitely. The resulting *hybridoma* cells make whatever antibody the B cell encoded, and can live indefinitely in culture. Moreover, clones from this culture will produce only a single type of antibody, with exquisite affinity for a particular antigen. These *mono-*

clonal antibodies are immensely useful as raw material for studying antibody structure and function.

In the late 1970s Marrack and Kappler, working with Lee Harwell, a technician in their lab, developed a method of making T cell hybridomas. "It was really Lee's idea, because he was in charge of harvesting mouse T cells for our studies of cytokines," recalls Marrack. "He wanted to adapt B cell hybridoma technology to make immortal T cells, so he'd never have to kill another mouse."

"Lee was a determined character, and he worked for a whole year in a corner of the lab, getting plenty of hybrids but no secretion of the T cell factors we needed." Perhaps, the researchers reasoned, the T cell hybridomas had to be stimulated to secrete the factors. In the next experiment, Lee added concanavalin A, a potent stimulator of T cells. "And there it was," recalls Kappler— "the hybridomas made cytokines in abundance."

Then it occurred to the researchers that adding a specific antigen to a mix of T cell hybridomas should stimulate only those hybrids with receptors for that antigen. This should result in a permanent T cell population with a defined binding capability—in short, monoclonal T cells. But following up on that idea had to wait a bit.

Kappler and Marrack had meanwhile added two children to their family—Jim in 1974 and Katy in 1976. If having children didn't slow them down, it certainly made them much busier. Marrack's parents emigrated from England in 1978 to help care for their grandchildren. Both Marrack and Kappler say this allowed them to do much more in the laboratory than would otherwise have been possible.

The couple had also been looking for a place where both could be full-fledged faculty. Then fate intervened. "A friend called and told us to come look at Denver, where he was, and we never looked back," says Kappler. "There were lots of good people, with plenty of energy, and they gave us each a job we couldn't refuse." Specifically, the offer came from the National Jewish Center for Immunology and Respiratory Medicine, a research institution, and the University of Colorado Health Sciences Center, which encompasses a medical school and graduate programs in several biomedical sciences.

T Cells: Function and Origin

They set up shop in Denver in 1980. The first experiment was to try to stimulate the hybrid T cells with specific antigens. Happily, it worked like a charm, allowing them to grow many liters of well-characterized T cells with the same antigen specificity. With these defined cultures in hand, they set out to purify and characterize the cell's antigen receptor. They injected the hybridoma cells back into rats and mice, then screened the blood serum of the inoculated animals for antibodies that could either stimulate or block T cell activation in culture. An antibody that stimulated activation would likely do so by binding to the T cell receptor (TCR), while one that blocked T cell activation would barricade the antigen-binding site.

After a great deal of tedious screening, Marrack and Kappler found two mouse antibodies that bound the TCR. They used these to help with TCR purification, which they conducted in collaboration with their colleague Ralph Kubo, a protein chemist. Around the same time in the mid-1980s, a technical revolution was sweeping the biomedical labs as the powerful techniques of gene cloning and molecular biology became widely available. Through the work of several investigators, the complete sequence of the TCR soon became known. "Immunologists had been arguing about the chemical nature of the TCR for a decade, and suddenly the controversy was over," Kappler says. "Within two months, our lab and two others had purified and characterized the TCR." All the results together showed that the TCR was only vaguely similar to an antibody molecule.

The chemical nature of the TCR, however, was only half the story. It was still unclear what the receptor actually bound on the antigen-presenting cells. In a series of experiments, Rick Shimonkevitz, one of Kappler and Marrack's graduate students, filled in the rest of the story of how the TCR, antigens, and the MHC intertwine. "Rick's work finally clarified a whole bunch of fuzzy thinking and gave us a new paradigm," says Kappler. "Antigens were taken inside the presenting cells, broken into fragments, complexed with MHC proteins, and finally shipped back out to the cell surface for display."

Clonal Elimination and Self-Tolerance

"The first few years in Denver were really our turning point from being basically good scientists doing a good job to doing something that was really out at the edge," says Kappler. "But many of our successes wouldn't have happened without our collaborators. We really were in the right place at the right time." This right time, however, was not just a brief interlude but a long span that continues to this day.

Marrack and Kappler next turned their laboratory's attention to the question of how the immune system can single out invaders to attack. How does it manage to create a repertoire of T cells that recognize antigens from every potential pathogen under the sun without making T cells that attack the body's healthy tissues?

It was clear that the MHC proteins were intimately involved in marking cells as self or non-self. Indeed, MHC proteins were first noticed because they are extraordinarily potent activators of the immune response. The immune system will quickly destroy tissue transplanted from one animal to another with different MHC variants, even if the two animals are closely related (thus the term histocompatibility). But if MHC molecules are such good targets, why doesn't the body attack its own? What prevents that from happening?

In 1959 Nobel laureate Joshua Lederberg had proposed that any developing T cell that can recognize the body's MHC proteins is somehow eliminated in the thymus. Lederberg's idea of clonal elimination was one of several competing theories to explain self-tolerance. Others suggested that self-reactive T cells are just inactivated, not eliminated, or that the body never makes them in the first place. Direct proof for any of these theories was still lacking in the mid-1980s.

Marrack and Kappler, though, now had the tools to follow specific T cells as they passed through development in the thymus. One of their monoclonal antibodies, they discovered, bound to a particular region of the TCR. They also found that TCRs containing this region reacted strongly to a particular MHC molecule. Surprisingly, however, when the MHC molecule was present in strains of adult mice, mature T cells containing this TCR region were absent. By using the appropriate fluorescent-labeled monoclonal antibody, the investigators were able to identify immature T cells in the thymus that did contain this region. They also saw that these cell clones disappeared as the T cells matured in the thymus. Clonal elimination had finally been observed.

The Edge of the Envelope

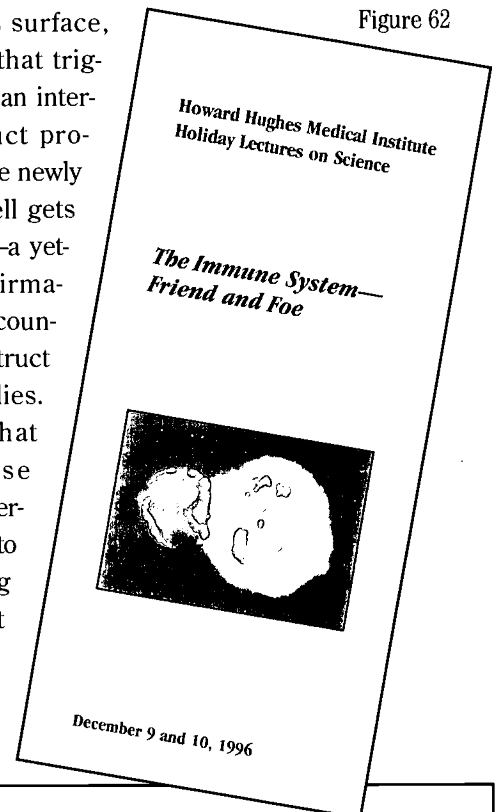
Since their breakthrough work on clonal elimination, Marrack and Kappler have continued to pursue the ins and outs of immune recognition of foreign antigens and the development of self-tolerance. But their research paths have diverged somewhat. "In the last five years or so, our work has taken a different flavor," says Marrack. "Our projects still often converge, but we generally have separate programs now."

Kappler has returned to his early predilection toward physics and physical chemistry and is working on biophysical characterizations of important immune system molecules. His projects have included the use of x-ray crystallography to determine the structure of the complete TCR-antigen-MHC protein complex. Success in this line of work often hinges on finding just the right conditions for growing high-quality crystals of the protein under study. "It is a very empirical process, with no guarantee of success, and I've been dusting off a lot of my old books on kinetics and biophysics," says Kappler. "You pretty much need to have the heart of a riverboat gambler," he adds—and judging by his enthusiastic tone, he apparently has.

Marrack, meanwhile, has returned to whole-animal studies after many years of investigating immune system cells in culture. She is finding important differences between the immune system operating in an intact animal and the immune cells in a Petri dish. "We showed years ago that the body makes a vast array of T cells and that most self-reactive ones die in the thymus," says Marrack. "But a few that can self-react sneak through—somewhere between 1 in 1,000 or 1 in 10,000. Somehow the system has to clobber these cells in order to prevent autoimmune disease, while allowing T cells that recognize pathogens to do their job."

Her research now is centered on understanding the complex fail-safe system that holds the remaining self-reactive cells in check. "If you just put antigen on T cells in a culture dish, they divide and grow," says Marrack. "But a few years ago we found that in an intact mouse, the T cells that recognize an antigen divide a few times and then just die. This was totally unexpected." Pursuing this phenomenon further, Marrack showed that *in vivo,* a T cell that meets its particular antigen immediately puts several new proteins on its surface, including one that triggers apoptosis, an internal self-destruct program. Unless the newly stimulated T cell gets another signal—a yet-unknown confirmation code that counteracts the destruct sequence—it dies. "We believe that mammals use these same generic mechanisms to tell an activating T cell that instead of dying it must continue to divide."

Figure 62



Howard Hughes Medical Institute
Holiday Lectures on Science

Monday, December 9, and
Tuesday, December 10, 1996

10:00 a.m.–12:30 p.m.

HHMI Conference Center
4000 Jones Bridge Road
Chevy Chase, MD 20815-6789

The 1996 Howard Hughes Medical Institute Holiday Lectures on Science for high school students, fourth in an annual series, will be delivered by John W. Kappler, Ph.D., and Philippa Marrack, Ph.D., Howard Hughes Medical Institute investigators and members of the Department of Medicine at the National Jewish Center for Immunology and Respiratory Medicine, Denver. Dr. Kappler and Dr. Marrack are also professors at the University of Colorado Health Sciences Center in Denver.

Monday, December 9

How Immune Cells Create Trillions of Receptors from a Few Hundred Parts
John W. Kappler
10:00 a.m.–11:00 a.m.

White blood cells of the type called lymphocytes are able to recognize almost any kind of foreign material that enters the body, including bacteria, viruses (such as HIV), and man-made chemicals that did not exist when the immune system was evolving. Lymphocytes are divided into two principal groups, termed B cells and T cells. Both have the ability to identify a wide array of intruders because each bears on its surface a unique receptor, one created by random combinations of relatively few components. Much as random choices from a restaurant menu can lead to meals with a huge number of variations, random combinations of components can lead to trillions of different receptors. The human body therefore has at least a trillion ways of recognizing that something foreign has invaded.

How the Immune System Detects Invaders
Philippa Marrack
11:30 a.m.–12:30 p.m.

The immune system recognizes invaders in a complex way. The two lymphocyte groups use different strategies. B cells can attack the intruder directly. T cells require assistance from B cells or other white blood cells that ingest and digest foreign invaders. Protein fragments from the processed invader reappear on the surface of these cells, bnund in specialized grooves of a complex of proteins. This complex, known as the MHC (major histocompatibility complex) proteins, presents the invader fragments to T cells. The T cell receptors recognize the bound protein complex and initiate a cascade of events, enlisting the B cell army as well as other T cells. This system allows lymphocytes to identify and destroy cells in which viruses or bacteria are hidden and multiplying.

Tuesday, December 10

How the Host Avoids 'Friendly Fire'
John W. Kappler
10:00 a.m.–12:30 p.m.

Normally these trillions of lymphocytes do not attack their host. To prevent such attacks, lymphocytes bearing receptors that might react with host tissues are selectively destroyed during their development. Cells that escape this screen treat host molecules as invaders, causing serious autoimmune (self-destructive) diseases such as juvenile diabetes, rheumatoid arthritis, and lupus erythematosis.

Stalking the Elusive Pathogen
Philippa Marrack
11:30 a.m.–12:30 p.m.

Some organisms have evolved ways of evading nr subverting the body's defenses. The malaria parasite, for example, changes its coat proteins to stay one step ahead of the host's immune cells. Herpes viruses become almost undetectable to lymphocytes. The AIDS virus destroys a subset of T cells that are essential for a successful immune response. Thus the immune system fights off many but not all infections. By learning more about how such pathogens work, new means may be found to thwart them.

But, one might ask, how does the immune system avoid activating the few self-reactive cells in the presence of infection? "Now we've come to the edge of the envelope," Marrack answers. "Since the body constantly filters any self-reactive clones that escape the thymus, I suppose it's unlikely that you'd have a self-reactive cell at the same time and place as an infection, but I'm not sure. And there are doubtless other backup mechanisms that we don't know about."

Marrack and Kappler intend to pursue these and other questions about the immune system for the rest of their careers. Their children are now grown, but all those dinner table conversations about T cell recognition of MHC-antigen complexes and other esoteric scientific subjects seem to have rubbed off. Jim is a first-year graduate student in neurobiology at Rockefeller University in New York City, and Katy is a junior at Brown, deciding between a career in science or politics.

After talking to Kappler and Marrack, it becomes abundantly clear that these sociable people definitely do not fit the popular caricature of shy or unimaginative scientists. "Your whole day is spent interacting with people in your own lab, and in other labs," says Marrack. "Making and maintaining successful partnerships is a major part of your work."

Howard Hughes Medical Institute Home Page

The area of the HHMI Web site currently under the most intense development involves the HHMI Holiday Lectures on Science <http://www.hhmi.org/lectures/>. Visitors to these pages can choose to participate in the 1997 lectures, which will be made available through satellite transmission and cable television. Research summaries of recent investigations by Drs. Marrack and Kappler, presenters of the 1996 lectures, are also available, as are the lectures that were given in 1993, 1994, and 1995. Those who missed the 1995 lectures "The Double Life of RNA" by Nobel laureate Thomas R. Cech may order a free videotaped copy on line.

For viewing on line and for downloading, the Holiday Lecture area of the HHMI Web site makes available resources and teaching material suitable for classroom reading and discussion. High- and low-bandwidth paths are available. Users equipped to view the high-bandwidth path will be able to enjoy multimedia resources, such as a virtual laboratory viable through the Shockwave plug-in for Netscape Navigator and Microsoft Internet Explorer. Interesting and important links to Web sites featuring general science and genetics information are also available. These range from Access Excellence, which offers a resource center and bulletin board area, to Virtual Fly Lab, a dry laboratory to test the rules of genetic inheritance.

The Research Resources program aids research and educational organizations that serve as teaching facilities and unique national resource laboratories. The size and scope of the Research Resources program was significantly expanded in 1995 with the launching of the Research Resources Program for Medical Schools. In January 1996 grants totaling $80 million over four years were awarded to 30 medical schools to strengthen their research infrastructure and support the recruitment of outstanding faculty in the early stages of their careers.

Also in 1995 the Institute awarded four-year grants totaling $3.1 million to the Cold Spring Harbor Laboratory at Cold Spring Harbor, New York, and the Marine Biological Laboratory at Woods Hole, Massachusetts, to support advanced education and training programs for graduate students, postgraduate fellows, and research scientists. In addition, a four-year grant of $2 million was awarded to the Jackson Laboratory at Bar Harbor, Maine, to support and expand its unique facility for the maintenance and distribution of genetically altered mice.

Research Resources Program for Medical Schools

The Research Resources Program for Medical Schools was initiated in recognition of the profound challenges facing academic medical centers in the United States as a result of major structural changes in the health care system and slow growth in federal support for biomedical research. In January 1996 the Institute awarded grants totaling $80 million over four years to 30 medical schools to enhance their research capabilities.

Most biomedical research is carried out in medical schools and their affiliated teaching hospitals; more than half of NIH extramural research grants go to medical schools.[1] Academic medical centers are also major providers of patient care, and revenues from that source have traditionally contributed to the schools' educational and research activities. However, patient care revenues have diminished as pressures mount to hold down medical costs.

At the same time, constraints on federal support for biomedical research and training have become more severe. At a time when the pool of biomedical scientists is growing and scientific opportunity is unprecedented, the rate of increase in research funds has been declining and competition for available funds has intensified. The rising costs of conducting research add to the pressures on limited resources.

Much of the high-quality research that occurs in medical schools is funded internally, at least initially. A recent study by the Association of American Medical Colleges estimated that in 1992–1993, academic medical centers used approximately $816 million in clinical revenues to support research.[2]

[1]Pardes H. The future of medical schools and teaching hospitals in the era of managed care. *Acad Med* 1997 Feb; 72(2):97–102.

[2]Jones RF and Sanderson S. Clinical revenues used to support the academic mission of medical schools, 1992–93. *Acad Med* 1996 Mar; 71:300–307.

Figure 63

Research Resources Program for Medical Schools

Program Components

- □ New faculty start-up
- □ Core facilities or major equipment
- □ Minor renovations or updating of research laboratories
- □ Pilot research projects
- □ Unexpected requirements or emergency project support

Goal

- □ To provide medical schools with resources needed to sustain their mission in research

Awards

- □ $20 million annually in total grants
- □ Four-year awards to 30 institutions
- □ Awards range from $2.2 million to $4 million

The acquisition of preliminary data, crucial to effective competition for a research grant, is not eligible for federal funding. This places both young investigators and established investigators with innovative ideas at a competitive disadvantage.

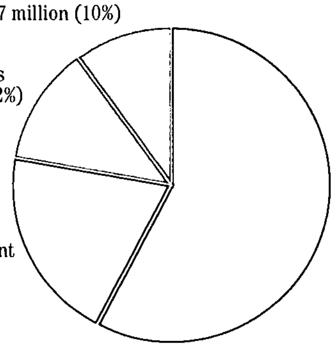
Funds to renovate or modernize research laboratories have also become scarcer. The advancing age of many biomedical research facilities threatens research quality. Strains on the infrastructure that supports the research enterprise have increased, making it more difficult for institutions to provide important research resources such as transgenic facilities, shared instrumentation, and electronic communications networks.

In response to these multiple pressures, the Institute initiated the Research Resources Program for Medical Schools to provide resources that medical schools needed to sustain their mission in research (Figure 63). The 30 awardees were selected from 117 institutions that responded to the Institute's invitation to submit proposals. Awardees were chosen on the basis of reviews by an external panel of distinguished biomedical scientists and scientific administrators, and the final determinations were made by the Institute's management and Trustees.

Applicant institutions were encouraged to propose junior faculty start-up, establishment or

Figure 64

Awards to 30 Medical Schools by Program Component, 1995 Competition ($80 million)



improvement of core facilities, purchase of major equipment, minor renovation or updating of research laboratories, pilot research projects, support for unexpected requirements, and emergency funding for projects. Institutions also had the option of designing additional program components to meet local needs and opportunities.

Individual awards ranged from $2.2 million to $4 million over a four-year period. Among the awardee institutions are 17 public and 13 private medical schools in 21 states. Figure 64 shows the distribution of awards by program component.

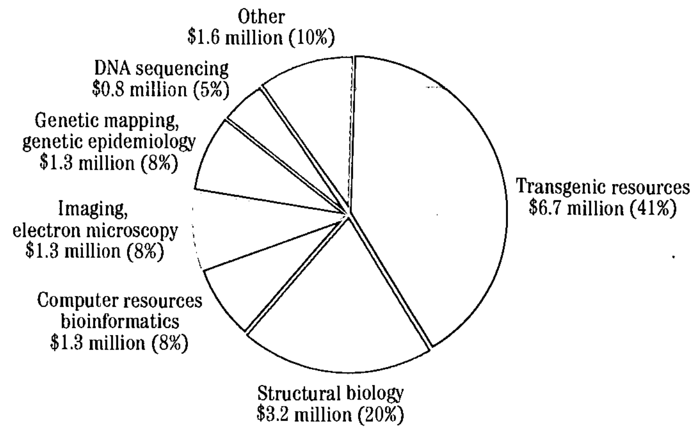
A total of $46.7 million, 58 percent of the funds awarded, is supporting start-up packages for new faculty. Of the 30 funded institutions, 29 plan to use all or part of their grants to provide start-up funds for a total of 207 new faculty. These awards provide crucial assistance for new faculty members to quickly establish strong research programs that will be competitive in the quest for external funding.

A total of $16.2 million, 20 percent of the funds awarded, is supporting the improvement or establishment of core research facilities or major equipment. Of this amount, $6.7 million, or 41 percent, is aiding in the establishment of central resources for transgenic research. Approximately $3 million, or 20 percent, is going toward facilities and equipment to support structural biology, including x-ray crystallography and nuclear magnetic resonance imaging. The balance is being used to establish or improve facilities for such activities as computing and bioinformatics, electron microscopy, genetic epidemiology, and DNA sequencing (Figure 65).

A total of $9.4 million, or 12 percent of the funds awarded, is supporting approximately 250 pilot research projects. About $7.7

Figure 65

Types of Core Facilities Supported ($16.2 million)



million, or 10 percent, is to provide short-term bridge funding for meritorious research projects and to support minor renovation projects, the purchase of shared equipment, faculty enrichment activities, junior faculty travel to scientific meetings, other research-related activities, contingencies, and program administration.

Cold Spring Harbor Laboratory

In 1995 the Institute awarded a four-year grant of $1.1 million to the Cold Spring Harbor Laboratory to continue support of its expanded program of postgraduate courses (Figure 66). The grant is supporting nine lecture and laboratory courses in molecular genetics, neurobiology, and structural biology during the period 1996–1999. Funds are provided for equipment and supplies, instructors and guest lecturers, student scholarships, and support personnel.

The quality and scope of Cold Spring Harbor's postgraduate program are known worldwide. The laboratory is an international center for research and training in biology, especially genetics. It serves as a schoolhouse for modern biology, annually hosting major conferences, seminars, workshops, and courses. Participants in the postgraduate program supported by the Institute include graduate students, postdoctoral fellows, and established scientists at major universities and research centers.

Cold Spring Harbor's postgraduate courses meet a special need for training in new and highly specialized interdisciplinary subjects. These courses provide intensive study of the most recent developments and techniques, preparing students to enter directly into research. To ensure up-to-date coverage of current research work, Cold Spring Harbor brings together a workshop staff from many laboratories around the world and supplements it with seminar speakers.

The Hughes Teaching Laboratories, integral to the neuroscience teaching and research facility, were constructed with Institute support. Since the summer of 1991, they have been used for courses in molecular embryology, molecular cloning, molecular approaches to ion channel expression and function, imaging structure and function in the nervous system, developmental neurobiology, the visual system, neurobiology of human neurological disease, and the biology of memory.

Eleven courses were offered during the summer and fall of 1995 and the spring of 1996 (Figure 67). A total of 172 course participants were accepted from 427 applicants. The participants, including 74 who were awarded Institute-funded partial scholarships, came from the United States and 22 other countries—Argentina, Australia, Belgium, Brazil, Canada, Finland, France, Germany, Greece, India, Israel, Italy, Japan, Korea, Malaysia, the Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, and the United Kingdom. Instructors, assistant instructors, and seminar presenters came from the United States, Argentina, Canada, Denmark, Germany, Spain, Sweden, and the United Kingdom.

Marine Biological Laboratory

In 1995 a four-year grant of $2 million was awarded to the Marine Biologi-

Figure 66

Cold Spring Harbor Laboratory

Program Summary

- 4-year grant of $1.1 million awarded in 1995
- Provides continued support for expanded program of postgraduate courses
- 9 lecture and laboratory courses will be supported in 1996–1999

Figure 67

Cold Spring Harbor Laboratory Courses Supported by the Howard Hughes Medical Institute, 1996

Summer 1995 lecture course:

- Brain mapping
- Structure, function, and development of the visual system
- Developmental neurobiology
- Neurobiology of human neurological disease: mechanisms of degeneration

Summer 1995 laboratory courses:

- Molecular approaches to ion channel expression and function
- Molecular cloning of neural genes
- Neurobiology of *Drosophila*
- Imaging structure and function of the nervous system

Fall 1995 laboratory courses:

- Macromolecular crystallography
- Phage display of combinatorial antibody libraries

Spring 1996 laboratory course:

- Early development of *Xenopus laevis*

Figure 68

Marine Biological Laboratory

Program Summary

- 4-year grant of $2 million awarded in 1995
- Provides continued support for education and training programs in basic biology
- 10 courses will be supported annually in the period 1996–1999

cal Laboratory to continue support of its education and training programs in basic biology for graduate students, postdoctoral fellows, and research scientists (Figure 68). The grant is supporting 10 courses in fields such as neurobiology and molecular evolution during the period 1996–1999. Funds are provided for equipment and supplies, instructors and guest lecturers, student scholarships, and support personnel.

Students are selected for these advanced, intensive laboratory courses on the basis of their academic accomplishments and their potential for future scientific productivity in biological or biomedical research. Faculty are selected for their ability as teachers, their standing in their fields, and the way in which their expertise fits into the course as a whole. The ratio of faculty to students is often one to one.

The laboratory has served as a center for research and teaching in basic biology since 1888. Each summer, investigators and advanced students come to work and study, often using marine organisms from the surrounding waters. Educational and research programs are closely intertwined. The Marine Biological Laboratory/Woods Hole Oceanographic Institute (MBL/WHOI) Library, one of the world's most comprehensive repositories of biomedical and marine biological information, one of the world's most comprehensive repositories of biomedical and marine biological information, is available 24 hours a day to support the education and research programs.

Eight courses were offered during the summer of 1996 (Figure 69). A total of 210 course participants were accepted from 512 applicants. The participants came from the United States and 19 other countries—Australia, Belgium, Canada, Chile, Denmark, Germany, India, Israel, Italy, Japan, Kenya, the Netherlands, Norway, South Africa, Spain, Sweden, Switzerland, the United Kingdom, and Venezuela. Faculty and guest lecturers came from the United States, Canada, France, Germany, Japan, Israel, Mexico, Switzerland, and the United Kingdom.

The Institute's earlier grant provided $1 million to support program development at the MBL/WHOI

Library, including electronic information storage and retrieval and management of scientific research and education.

Jackson Laboratory

In 1995 the Institute awarded a four-year grant of $2 million to the Jackson Laboratory to support and develop its Induced Mutant Resource (IMR), a unique facility—established in 1992—that is the premier world resource for special strains of genetically unique mice (Figure 70). This facility imports, cryopreserves, maintains, and distributes to the biomedical research community important transgenic, chemically induced, and targeted mutant strains.

The mice are produced in research laboratories worldwide. Once accepted to the IMR program, the Jackson Laboratory maintains strains in a genetically consistent, disease-free state for distribution at modest cost to the international research community. These mice are valuable for biomedical research because their genetic defects are models for human disease or facilitate the study of fundamental biological processes.

This grant reflects the Institute's recognition of the increasing importance of transgenic and targeted mice in biomedical research. The Institute made an earlier three-year award of $1.2 million to support development of the IMR.

In 1995–1996 the IMR accepted 122 strains, 32 more than had been

Figure 69

Marine Biological Laboratory Courses Supported by the Howard Hughes Medical Institute, 1996

- Cellular neurobiology and development of the leech
- Embryology
- Methods in computational neuroscience
- Microbial diversity
- Molecular evolution
- Neural systems and behavior
- Neurobiology
- Physiology

Figure 70

The Jackson Laboratory

Program Summary

- 4-year grant of $2 million awarded in 1995
- Supports development and expansion of the Induced Mutant Resource

Induced Mutant Resource

- Unique repository of genetically altered mice (produced by gene targeting, gene transfer, and other methods) that serve as models of human disease and basic biological processes

Resource Services

- Importation
- Cryopreservation
- Maintenance
- Distribution

Figure 71

The Jackson Laboratory Induced Mutant Resource: Examples of Activities Supported During 1996

□ Cryopreservation of strains

Final-phase cryopreservation of 21 strains and first-phase cryopreservation of 4 strains has been completed. An additional 17 strains are being processed.

□ Cryopreservation of mouse sperm

Sperm cryopreservation will expand the IMR's ability to import strains by permitting the inexpensive archiving of strains that are not expected to be widely distributed but are considered important enough to be preserved for future use. High fertilization rates have been achieved in the past with frozen and thawed hybrid sperm. However, only about 20 percent of the sperm survive the freezing process, and research is being carried out to identify the locus of injury.

□ Genetic typing

Genetic typing is required to identify carrier animals (heterozygotes) for strains being backcrossed onto a defined genetic background and to identify heterozygotes for strains where the homozygous mutants are not viable. Currently, 142 of the 299 accepted strains require genetic typing.

projected. Use of the facility continues to grow dramatically. Institute investigators are both donors to the resource and heavy users. As of June 1, 1996, 297 strains had been distributed, of which 67 (23 percent) were contributed by Institute investigators. From its inception to August 1, 1996, the IMR accepted a total of 299 mutant stocks and is currently adding about eight strains per month.

The Institute's support of the IMR relieves the mutant's initial developer of the time-consuming and costly task of making the strain available to other researchers. The Jackson Laboratory, as a central resource, maintains the mouse line whether or not the scientist who originated the strain continues to use it.

The IMR also undertakes genetic development of mouse stocks to improve their value for research. Such development activities include transferring mutant genes or transgenes to defined genetic backgrounds and combining transgenes or targeted mutations to create new mouse models for research. Figure 71 lists some of the IMR activities that were supported by the Institute grant during 1996.

International Programs

The international scope of modern biomedical research and the contributions of scientists outside the United States to fundamental knowledge relevant to the Institute's research activities led the Institute in 1991 to launch an initiative to support foreign scientists who are conducting research abroad. In four rounds of awards over the last six years, International Research Scholar grants totaling $53 million have been awarded to support the work of more than 190 researchers in 19 countries (Figure 72). Also since 1991, the Institute has funded a productive joint effort of the U.S. National Academy of Sciences and the Mexican Academia Investigación Científica. In 1995 this program was expanded and renewed for four years.

International Research Scholars Program

International Research Scholars awards provide support for five years to promising biomedical scientists who have contributed significantly to fundamental biomedical research—to the understanding of basic biological processes or disease mechanisms. These are outstanding scientists whose research careers are still developing. Awardees must hold a full-time academic appointment at a university, medical school, research institution, or other nonprofit scientific organization in their home country and must not have significant administrative responsibilities.

The grants not only provide for the scientist's laboratory—for equipment, personnel, supplies, and travel—but

Figure 72

Countries Where International Research Scholars Are Being Supported

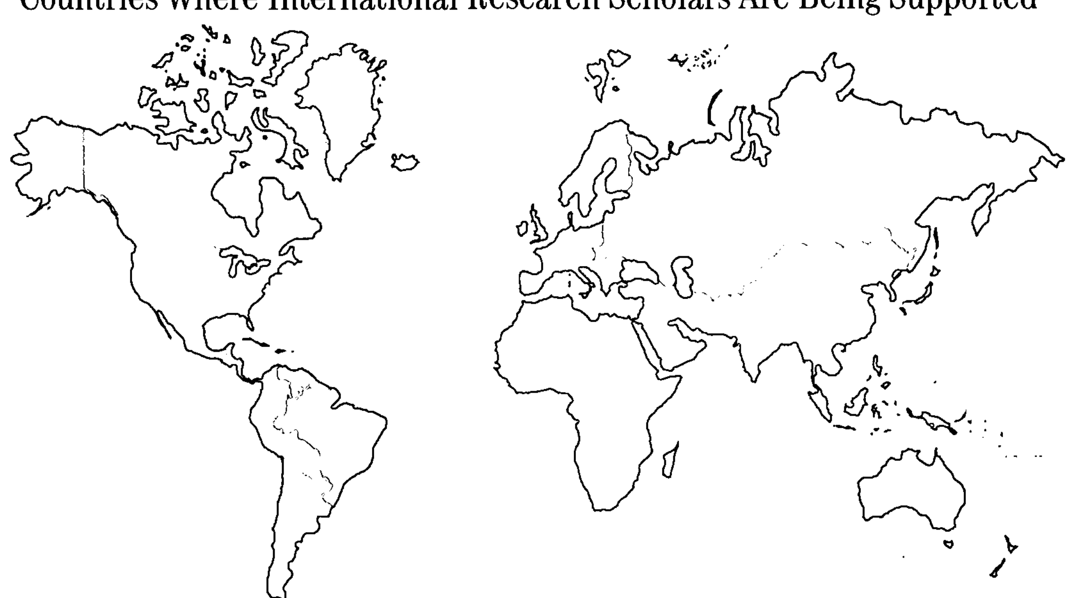


Figure 73

International Research Scholars, New Awards, 1997 Canada and Selected Countries in Latin America

Selected Countries

- **Argentina**
  9 scientists
  8 institutions
  $2.4 million
- **Brazil**
  7 scientists
  6 institutions
  $2.1 million
- **Canada**
  20 scientists
  9 institutions
  $6.7 million
- **Chile**
  3 scientists
  2 institutions
  $800,000
- **Mexico**
  7 scientists
  6 institutions
  $2.2 million
- **Venezuela**
  1 scientist
  1 institution
  $0.3 million

Grant Terms

- Five-year term
- Up to $80,000 annually
  equipment
  personnel
  shared resources[1]
  supplies
  travel
  indirect costs[2]

Eligibility Criteria

- Significant contribution to fundamental biomedical research
- Publication in English-language, peer-reviewed scientific journals
- Career still developing
- No major administrative responsibilities
- Full-time academic or research appointment at a nonprofit institution in selected country
- Not a U.S. citizen or permanent resident

[1]*In Latin American countries only.*

[2]*Ten percent of the award is to be allocated to the Scholar's host institution for indirect costs.*

also contribute to science education by funding trainees' stipends and travel and providing equipment and supplies for their research. Moreover, in recognition of the importance of an intellectual environment and adequate resources for scientific work, a portion of the award in certain countries provides shared resources for the Scholar's department.

1996 Competition: Canada and Selected Countries in Latin America

The fourth International Research Scholars initiative supports the work of outstanding scientists in Canada and five Latin American countries that lead the region in scientific research—Argentina, Brazil, Chile, Mexico, and Venezuela. Forty-seven grants were announced in February 1997. The Scholars were each awarded up to $80,000 annually for five years to support research at their home institutions (Figure 73).

The selected Scholars are noted both for their achievements to date and their strong potential to make significant research contributions in the future. Not only are they advancing fundamental knowledge, but their laboratories serve as international resources in their fields. In addition, many of the awards will bring cutting-edge research techniques to the Scholars' countries.

Nomination Process and Eligibility. Scientists were invited to apply for these grants. The process began with the Institute's invitation to institutions in eligible countries to nominate up to three of their scientists. Nominees were then invited to submit formal applications. The application included background information about the nominee, a research plan and budget, a curriculum vitae, and reprints of three papers that represented the nominee's most important research contributions and that had been published within the previous five years in international, peer-reviewed, English-language scientific journals.

Selection Process. Approximately 500 applications were received. After several rounds of internal screening, the most promising applications were judged by external readers. Those that rated highest were reviewed by a 20-member external panel chaired by Dr. David Sabatini of New York University School of Medicine. In addition to prominent peers in various biomedical research fields, this review panel included investigators and members of the Institute's Medical Advisory and Scientific Review Boards.

The external review panel evaluated the proposals and ranked the candidates. These priority rankings were then reviewed by an Institute internal scientific panel. On the basis of these assessments and the overall objectives of the international program, the Institute's management recommended awards to the Institute Trustees, who authorized funding of the 47 five-year awards.

Summary of International Program Activities 1991–1996

In three previous international competitions, a total of $53 million was awarded in 137 five-year grants (including three group awards). Support for individual Scholars ranged between $22,000 and $100,000 annually.

In 1991, 20 awards were presented to 24 scientists from Canada and Mexico, which as the immediate neighbors of the United States were selected as the participating countries for the first International Research Scholars competition. In the second competition in 1992, 28 awards went to 29 scientists in Australia, New Zealand, and the United Kingdom. In the third competition in 1995, awards went to 90 scientists and 58 collaborating scientists in the Baltics, Central Europe, and the former Soviet Union (Figure 74).

Figure 74

International Research Scholars, Continuing Awards, 1991–1995

Spring 1991 Awards

- Canada
  11 grants for 14 scientists
  7 institutions
  $5.8 million
- Mexico
  10 grants for 10 scientists
  4 institutions
  $5 million

Fall 1992 Awards

- Australia
  5 grants for 5 scientists
  4 institutions
  $2.4 million
- New Zealand
  2 grants for 2 scientists
  2 institutions
  $975,000
- United Kingdom
  21 grants for 22 scientists
  12 institutions
  $10 million

Summer 1995 Awards

- Belarus
  1 collaborative grant
  1 institution
  $125,000
- Czech Republic
  6 individual and 6 collaborative grants
  7 institutions
  $1.8 million
- Estonia
  2 individual grants
  2 institutions
  $300,000
- Hungary
  5 individual and 9 collaborative grants
  10 institutions
  $2.2 million
- Latvia
  1 collaborative grant
  1 institution
  $125,000
- Lithuania
  2 individual and 1 collaborative grants
  3 institutions
  $425,000
- Poland
  3 individual and 9 collaborative grants
  9 institutions
  $1.7 million
- Russia
  7 individual and 26 collaborative grants
  21 institutions
  $5.1 million
- Slovak Republic
  3 individual and 3 collaborative grants
  4 institutions
  $725,000
- Ukraine
  1 individual and 2 collaborative grants
  3 institutions
  $495,000

Grant Terms

- Five-year term
- up to $35,000 annually[1]
  equipment
  personnel[2]
  supplies
  travel
  indirect costs

[1] *In the first and third competitions, 22 percent of each grant is allocated to the Scholar's department for shared resources.*

[2] *Technicians, graduate students, and postdoctoral associates. In Mexico and the countries participating in the summer 1995 awards, the grants may also provide Scholars with annual salary supplements.*

Program Impact

The Institute's International Research Scholars program has had a major impact, as evidenced by the numbers and quality of the Scholars' scientific publications and presentations. In addition, the awards have helped to provide stipends and travel funds for postdoctoral associates and graduate students.

In Mexico, the Baltics, Central Europe, and the former Soviet Union, the awards provide for shared department resources to help renew and expand scientific infrastructure. These funds can be used to purchase equipment, computers, chemicals, journal subscriptions, stipends, and travel, which must be accessible to other scientists and students in the Scholar's department.

Impact of 1995 Grants

According to the August 1996 issue of *Science*, the third-round grants have provided a lifeline for scientists from the former Soviet bloc. "[W]ith government funds drying up in many countries and scientists' salaries often less than those of manual workers, [the International Research Scholar grants] are having an impact," the journal reported.

"Without collaboration with Western institutes, it is virtually impossible to do serious research," Russian senior researcher and International Research Scholar Sergei Nedospasov told the *Chronicle of Higher Education* in July 1996. Nedospasov, who is employed at the V.A. Engelhardt Institute of Molecular Biology in Moscow, said that "in biomedical research, 90 percent of what was Soviet science has either collapsed or cannot continue in the modern sense."

"The predictability and stability of the five-year Institute grants are a boon," Nedospasov told *Science*. The awards are providing the consistent support needed to advance understanding of basic biological processes and disease mechanisms.

In addition, the grants are having a multiplier effect, helping awardees garner other funds. Michael Novák of the Slovak Academy of Sciences of Bratislava says that obtaining an International Research Scholar grant helped him win government funds for a new Institute of Neuroimmunology at the Academy. Czech molecular geneticist Jitka Forstová believes that having been awarded an International Research Scholar grant helped her prevail in stiff, nationwide competitions for Czech government funds to build university research infrastructure.

International Research Scholars Meeting in Prague

Under the auspices of Czech president Vaclav Havel, the first meeting of the Institute's International Research Scholars from the Baltics, Central Europe, and the former Soviet Union was held June 23–26, 1996, in Prague. Eighty-six of the 90 International Research Scholars and 18 of 58 collaborating scientists were present to exchange ideas, discuss research, and develop ties. This was the Scholars' and collabo-

Figure 75

1996 Meeting of International Research Scholars

Program Synopsis

Howard Hughes Medical Institute
Office of Grants and Special Programs
1996 Meeting of Scholars from the Baltics, Central Europe, and the Former Soviet Union
Hotel Forum, Prague, Czech Republic

Sunday, June 23, 1996

Welcoming Remarks

Joseph G. Perpich, M.D., J.D., Vice President for Grants and Special Programs
Jiri Forejt, M.D., Ph.D., Chairman, Organizing Committee
Opening Address
Shared Horizons: The Institute's National and International Role
Purnell W. Choppin, M.D., President

Monday, June 24, 1996

Scholars' Presentations—Scheduled Talks

Neural Plasticity
Neurobiology
Protein–Nucleic Acid Interactions
Structure I: Protein Folding and Dynamics
Scholars' Presentations—Posters
Regulation of Transcription
Genome Characterization
Cell Surface Membranes
Molecular Interactions
Biotechniques

Concert at Prague Castle

Tuesday, June 25, 1996

Scholars' Presentations—Scheduled Talks

Mechanism of Protein Action
Oncogenes
Genetic and Physiological Responses
Macromolecular Interactions and Responses
Gene Regulation
Receptor Activation/Signal Transduction
Protein-Membrane Interactions
Recombination

Wednesday, June 26, 1996

Scholars' Presentations—Scheduled Talks

Structure II: Crystallography
Mitochondrial Systems
Gene Mapping

Visit to Local Research Institutes and/or Tour of Prague rating scientists' first opportunity to interact as a group (Figure 75).

Following the opening reception, Institute president Dr. Purnell W. Choppin welcomed the participants and distinguished guests, who included Rudolf Zahradnik, President of the Academy of Sciences of the Czech Republic; Petr Blahus, Vice Chancellor of Charles University; and Professor Vaclav Paces, President of the Czech Society for Biochemistry and Molecular Biology.

During the three-day meeting, the participants discussed their work of the past year, visited local research laboratories, and toured the historic city. Their scientific presentations included 68 talks and 18 posters that covered a wide range of topics, including circadian cycles, neural plasticity, genetic regulation, signal transduction, and receptor biology. The broad array of topics was remarked upon by many of the scientists, who enjoyed the opportunity to learn about each other's fields.

The level of science at the meeting was also a source of comment. "I go to a lot of scientific meetings and I think the quality at this one was very high," said Mikhael Tukalo of the Institute of Molecular Biology and Genetics in Kiev, Ukraine. "The presentations were very professional." Edmund Lin of Harvard Medical School, who is collaborating with Ruslan Grishanin of the Belozersky Institute of Physico-Chemical Biology in Moscow, said, "Scientifically, this meeting is on a level with the ones I attend back in the States."

The meeting was an opportunity for Scholars to benefit from discussions with their peers and reestablish the network of scientific communication that was disrupted by recent political and economic changes in the selected countries. Participants commented on the need for such meetings to help sustain and advance fundamental biomedical research. Additional conferences, both formal and informal, are planned to continue this exchange.

Other International Program Activities

U.S. and Mexican National Academies

In 1995 the Institute approved a second four-year grant to the U.S. National Academy of Sciences (NAS) ($795,000) and a second four-year grant to the Mexican Academia de la Investigacíon Cientifíca (AIC) ($100,000). These new awards are enabling the continuation of work begun in 1991 to continue promoting stronger scientific ties and the exchange of scientific and technical information between the United States and Latin America.

The grants support biomedical research education programs conducted by the two scientific academies in cooperation with their counterparts in Argentina, Brazil, Chile, and Venezuela. Programs offered include symposia and lectures on cutting-edge topics in biology and biomedical science, which involve international participants and visiting faculty, and laboratory-and-lecture courses in selected Latin American countries. These

Figure 76

Joint Activities of U.S. and Mexican Science Academies Held in Latin America, 1991–1997

- Symposium on Biomedical Research Frontiers
  - 1992 Molecular Biology of Parasites
  - 1994 Human Genome Research
  - 1996 First Latin American Symposium on Bioethics on the Human Genome
  - 1997 Human Genome Research (planned—location to be determined)
- Annual Laboratory Course
  - 1991 Methods in Computational Neuroscience
    Dr. James Bower, California Institute of Technology
    Dr. Jose Vargas, The Center for Advanced Studies of the National Polytechnic Institute
  - 1992 The Molecular Cloning of Neural Genes
    Dr. James Boulter, Salk Institute for Biological Studies
    Dr. Ricardo Tapia, National Autonomous University of Mexico
  - 1993 Molecular Biology of Parasite Gene Expression
    Dr. John Swindle, University of Tennessee, Knoxville
    Dr. Juan Pedro Laclette, National Autonomous University of Mexico
  - 1994 Transfection and Genetic Expression of Parasites
    Dr. John Swindle, University of Tennessee, Knoxville
    Dr. Esther Orozco, The Center for Advanced Studies of the National Polytechnic Institute
  - 1995 Macromolecular Crystallography
    Dr. Gary Gilliland, Center of Advanced Research in Biotechnology, Maryland
    Dr. Marcia Newcomer, Vanderbilt University School of Medicine
  - 1996 Transfection and Genetic Expression of Parasites (Argentina)
    Dr. John Swindle, University of Tennessee, Knoxville
    Dr. George Newport, University of California, San Francisco
  - 1997 Molecular Approaches to Ion Channel Structure and Function
    Dr. Todd Scheuer, University of Washington, Seattle
    Dr. Arturo Ponce, The Center for Advanced Studies of the National Polytechnic Institute
- Visiting Lectureships
  - 1993 Structural Biology
  - 1994 Structural Biology
  - 1994 Human Genome Research

courses are modeled after those of the Marine Biological Laboratory and the Cold Spring Harbor Laboratory, which also receive Institute support (see chapter on Research Resources). Joint activities of the U.S. and Mexican Science Academies are listed in Figure 76.

The courses, symposia, and visiting lectures funded by the first NAS-AIC grant had a significant impact on scientific relations between the United States and Mexico. Students who attended the courses had a unique opportunity to learn state-of-the-art techniques from outstanding scientists. The visiting lectureships permitted U.S. scientists to spend short periods in Mexico, resulting in the strengthening of scientific ties.

The 1996 course Transfection and Expression in Parasites was held December 4–19 at the Institute for Biotechnology Investigation (IIB), National University of General San Martin, Buenos Aires, Argentina. This intensive, highly competitive course attracted 45 applicants from Latin American countries. Ultimately, 16 graduate and postdoctoral students were selected to participate. The three key criteria used in selecting candidates were the applicants' experience and current research, the probability that they would use the new techniques taught in the course, and their intent to teach these techniques to others at their institutions.

The course emphasized DNA-mediated transformation as a powerful technique for the study of parasitic organisms. Laboratory work focused on different aspects of gene expression—including transcription, messenger RNA processing, and mRNA stability—using the trypanosome as a model organism. Use of the technique with other organisms was described by guest lecturers in daily seminars.

The course was directed by Dr. John Swindle of the Seattle Biomedical Institute and Dr. George Newport of the University of California, San Francisco. The local host and organizer was Dr. Albert Carlos Frasch, director of the IIB and a 1997 HHMI International Research Scholar.

During 1997 one course and two symposia are being held. The course, Molecular Approaches to Ion Channel Structure and Function, was held April 20–May 5 at CINVESTAV in Mexico City. It was hosted by Dr. Marcelino Cerelijido of CINVESTAV and directed by Dr. Todd Scheuer of the University of Washington, Seattle. A conference entitled Human Genome Research: Implications for Health in Latin America will be held in Mexico in November, and a Frontiers of Biology symposium involving young scientists from the United States and Latin America is being planned for December.

Figure 77 lists the Scholars named in the 1996 competition, their institutions, and their research topics.

Figure 77

International Research Scholars, 1996 Competition
Canada and Selected Countries in Latin America

□ Argentina

Alfredo Oscar Cáceres, M.D., Ph.D.
Independent Researcher, National Council of Scientific and Technical Research; Head, Neurobiology Group, Mercedes and Martin Ferreyra Institute for Medical Research, Córdoba, Argentina
Microtubule-associated proteins and the development of a neuronal morphology

Ana Belen Elgoyhen, Ph.D.
Assistant Scientist, Molecular Neurobiology, Pharmacological Research Institute, National Council of Scientific and Technical Research, Buenos Aires, Argentina
Nicotinic receptors in auditory physiology

Alberto Carlos Clemente Frasch, D.M.D., Ph.D.
Career Research, Institute for Research in Biotechnology, University of General San Martin, National Research Council, Buenos Aires, Argentina
Two-domain parasite antigens in the pathogenesis of Chagas' disease

Hugo José Fernando Maccioni, Ph.D.
Professor, Department of Biological Chemistry, Faculty of Chemical Sciences, National University of Córdoba; Principal Investigator, National Council of Scientific and Technical Research, Buenos Aires, Argentina
Regulation of ganglioside synthesis in the central nervous system

Luis Segundo Mayorga, Ph.D.
Independent Researcher and Assistant Professor, Institute of Histology and Embryology, Faculty of Medical Sciences, National University of Cuyo, Mendoza, Argentina
Mechanism of intracellular transport along the phagocytic pathway

Armando José Parodi, Ph.D.
Staff Scientist, Laboratory of Glycobiology, Institute for Biochemistry Research, Campomar Foundation; Professor of Biochemistry, Institute for Biochemical Research, School of Sciences, University of Buenos Aires; Career Investigator, National Council of Scientific and Technical Research, Buenos Aires, Argentina
Quality control of glycoprotein folding

Alberto Luis Rosa, M.D., Ph.D.
Assistant Professor, Department of Biological Chemistry, University of Córdoba; Career Investigator, National Council of Scientific and Technical Research, Córdoba, Argentina
DNA methylation and mutation in Neurospora crassa

Marcelo Rubinstein, Ph.D.
Staff Scientist, Institute of Genetic Engineering and Molecular Biology, National Council of Science and Technology; Assistant Professor, Department of Biological Chemistry, School of Exact and Natural Sciences, University of Buenos Aires, Buenos Aires, Argentina
Functional role of D2-like dopamine receptors by targeted mutagenesis into the mouse genome

Fernando Carlos Soncini, Ph.D.
Researcher, Department of Microbiology, National University of Rosario, Rosario, Argentina; Research Associate, Department of Molecular Microbiology, Washington University School of Medicine, Saint Louis, Missouri
The regulation of virulence functions in Salmonella typhimurium

□ Brazil

Sérgio T. Ferreira, Ph.D.
Associate Professor, Department of Biochemistry, Institute of Biomedical Sciences, Federal University of Rio de Janeiro, Brazil
Energetics, dynamics, and structural basis of deterministic behavior of proteins

Jorge Kalil, M.D., D.Sc.
Associate Professor, School of Medicine, and Director, Laboratory of Immunology, Heart Institute, School of Medicine, University of São Paulo, São Paulo, Brazil
Immunopathogenesis of human post-infectious autoimmune disease

Lucia Mendonça-Previato, D.Sc.
Professor, Department of General Microbiology, Microbiology Institute, Federal University, Rio de Janeiro; Member, Advisory Committee in Microbiology, National Research Council, Brasilia, Brazil
Studies on sialoglycoproteins and trans-*sialidase system in* Trypanosoma cruzi *virulence*

Figure 77 (*continued*)

International Research Scholars, 1996 Competition Canada and Selected Countries in Latin America

Glaucius Oliva, Ph.D.
Associate Professor, Laboratory of Protein Crystallography and Structural Biology, Department of Physics and Informatics, University of São Paulo, São Carlos, Brazil
Structural biology of medically important proteins: crystallography, molecular modeling, and drug design

Maria Rita Passos-Bueno, Ph.D.
Assistant Professor of Genetics, Department of Biology, Institute of Biosciences, University of São Paulo, São Paulo, Brazil
Mapping, cloning, and characterization of genes important for human development

Jerson Lima Silva, M.D., Ph.D.
Chairman, Department of Biochemistry, Institute of Biomedical Sciences, Federal University of Rio de Janeiro, Brazil
Energy linkage as the basis for macromolecular recognition: protein folding, protein-nucleic acid interactions, and virus assembly

Fernando C. Reinach, Ph.D.
Professor of Biochemistry, Department of Biochemistry, Institute of Chemistry, University of São Paulo, São Paulo, Brazil; Visiting Associate Professor, Department of Cell Biology, Cornell University Medical College, New York, N.Y.
Control of muscle contraction: the molecular mechanism of the Tn/Tmy 'switch'

□ Canada

Vanessa Jane Auld, Ph.D.
Assistant Professor, Department of Zoology, University of British Columbia, Vancouver
Analysis of glial genes and their roles in nervous system development

Robert Christopher Bleackley, Ph.D.
Professor, Department of Biochemistry, University of Alberta, Edmonton
Identification and characterization of proteins that interact with the cytotoxic cell proteinases, the granzymes

Barton Brett Finlay, Ph.D.
Associate Professor, Departments of Biotechnology, Biochemistry and Molecular Biology, and Microbiology and Immunology, University of British Columbia, Vancouver
Interactions of enteropathogenic Escherichia coli *(EPEC) and* Salmonella typhimurium *with host cells*

Jack Fred Greenblatt, Ph.D.
Professor, Banting and Best Department of Medical Research, Faculty of Medicine, University of Toronto
Elongation control mechanisms in transcription

Sergio Grinstein, Ph.D.
Professor, Department of Biochemistry, Research Institute, Hospital for Sick Children–University of Toronto
Regulation of pH and ionic concentration in compartments of the secretory pathway

Philippe Gros, Ph.D.
Professor, Department of Biochemistry; Member, Cancer Center, and Member, Center for Host Resistance, McGill University, Montreal
P-glycoprotein: lipid translocation and mechanism of drug transport

Mitsuhiko Ikura, Ph.D.
Senior Scientist, Division of Molecular/Structural Biology, Ontario Cancer Institute, Toronto; Assistant Professor, Department of Medical Biophysics, University of Toronto; Professor (joint appointment) Center for Tsukuba Advanced Research Alliance, University of Tsukuba, Japan
Structural basis for information transfer in cells

Lewis E. Kay, Ph.D.
Professor, Department of Medical Genetics, University of Toronto
Development of NMR methods to study protein structure and dynamics: Application to signal transduction proteins containing SH2 and SH3 domains

Robert George Korneluk, Ph.D.
Professor, Departments of Pediatrics and of Microbiology and Immunology, Faculty of Medicine, University of Ottawa; Director, Molecular Genetics Laboratory, Children's Hospital of Eastern Ontario, Ottawa
Characterization of a novel gene family encoding apoptotic inhibitor proteins

Roderick Rowan McInnes, M.D., Ph.D.
Senior Scientist, and Director, Developmental Biology Program, Hospital for Sick Children; Professor, Department of Pediatrics and Molecular and Medical Genetics, University of Toronto
The genetics of mammalian retinal development and photoreceptor structure

Figure 77 (*continued*)

International Research Scholars, 1996 Competition
Canada and Selected Countries in Latin America

Tim R. Mosmann, Ph.D.
Professor, Department of Medical Microbiology and Immunology, University of Alberta, Edmonton
Immunoregulation by T cell subsets and their cytokines

Michael Anthony Parniak, Ph.D.
Staff Investigator, Lady Davis Institute for Medical Research, Sir Mortimer B. Davis–Jewish General Hospital; Associate Professor, Department of Medicine, Division of Experimental Medicine, and McGill AIDS Center, McGill University, Montreal; and Adjunct Associate Professor, Department of Chemistry, University of Waterloo, Waterloo, Ontario
Structure-function studies of drug resistant HIV reverse transcriptase

Anthony James Pawson, Ph.D.
Senior Scientist, Samuel Lunenfeld Research Institute, Mount Sinai Hospital, Toronto; Professor, Department of Molecular and Medical Genetics, University of Toronto
Tyrosine kinase signaling in the nervous system

Richard Anthony Rachubinski, Ph.D.
Professor, Department of Anatomy and Cell Biology, and Professor (cross appointment) Department of Biochemistry, University of Alberta, Edmonton
Translocation machineries for peroxisomal matrix proteins

Randy John Read, Ph.D.
Associate Professor, Department of Medical Microbiology and Immunology, University of Alberta, Edmonton
Protein crystallography and pathogenesis

Janet Rossant, Ph.D.
Senior Scientist, Program in Development and Fetal Health, Samuel Lunenfeld Research Institute, Mount Sinai Hospital, Toronto; Professor, Department of Molecular and Medical Genetics, and Professor, Department of Obstetrics/Gynecology, University of Toronto
Patterning the neural axis in the mouse embryo

Nahum Sonenberg, Ph.D.
Professor, Department of Biochemistry, Faculty of Medicine, McGill University, Montreal
Regulation of translation and cell growth by repressors of mRNA 5' cap-binding protein

Peter Henry St. George-Hyslop, M.D., D.Sc.
Assistant Professor, Department of Medicine, Division of Neurology, and Director, Center for Research in Neurodegenerative Disease, University of Toronto
Vertebrate and invertebrate presenilin genes in neurodegeneration

Lap-Chee Tsui, Ph.D.
Senior Scientist, Sellers Chair in Cystic Fibrosis, Department of Genetics, The Hospital for Sick Children, Toronto; University Professor, Department of Molecular and Medical Genetics, and Professor, Institute of Medical Science, University of Toronto
Molecular genetics of cystic fibrosis and other diseases

James R. Woodgett, Ph.D.
Associate Professor/Senior Scientist, Division of Cellular and Molecular Biology, Ontario Cancer Institute, Toronto
Roles of stress-activated protein kinase pathways in development

□ Chile

Enrique Brandan, Ph.D.
Associate Professor, Department of Cell and Molecular Biology, Faculty of Biological Sciences, Catholic University of Chile, Santiago, Chile
Function of proteoglycans during skeletal muscle differentiation

Pedro Labarca, Ph.D.
Professor, Biophysics Section, Santiago Center for Scientific Studies; Associate Professor, Faculty of Sciences, Department of Biology, University of Chile, Santiago, Chile
Electrophysiological correlates to short-term memory in Drosophila

Francisco Sepulveda, Ph.D.
Professor, Faculty of Medicine, Santiago Center for Scientific Studies, University of Chile, Santiago, Chile
Cloning and functional expression of intestinal epithelium chloride channels of the ClC family

Figure 77 (*continued*)

International Research Scholars, 1996 Competition
Canada and Selected Countries in Latin America

□ Mexico

Carlos Federico Arias, Ph.D.
Professor, Department of Genetics and Molecular Physiology, Institute of Biotechnology, National Autonomous University of Mexico, Cuernavaca, Mexico
Molecular biology of rotavirus replication

Carmen Clapp, Ph.D.
Associate Professor, Neurobiology Center, National Autonomous University of Mexico, Mexico City, Mexico
Autocrine and endocrine regulation of angiogenesis by prolactin gene products

Gerardo Gamba, M.D., Ph.D.
Titular Researcher, Department of Nephrology and Mineral Metabolism, Salvador Zubirán National Institute of Nutrition; Professor of Human Physiology, National University of Mexico School of Medicine, Mexico City
Regulatory role of the C-terminal domain in the electroneutral Na-(K)-Cl cotransporters

Luis Rafael Herrera-Estrella, Ph.D.
Professor and Head, Plant Genetic Engineering Department, Center for Research and Advanced Studies, Irapuato, Mexico
Molecular dissection and functional analysis of light-responsive elements from plants

Fernando Lopez-Castillas, M.D., Ph.D.
Titular Researcher (Level B), Institute of Cellular Physiology, National Autonomous University of Mexico, Mexico City
Betaglycan regulatory and therapeutic roles in TGF-β induced nephropathies

Esther Orozco, Ph.D.
Professor (Level E), Department of Experimental Pathology, Center for Research and Advanced Studies of the National Polytechnic Institute; Professor, Molecular Biomedicine Program, National Polytechnic Institute, Mexico City
Genome organization and gene expression regulation in Entamoeba histolytica: *variability, virulence, and multi-drug resistance*

Lourival Domingos Possani, Ph.D.
Professor, Department of Molecular Recognition and Structural Biology, Institute of Biotechnology, National Autonomous University of Mexico, Cuernavaca; Professor of Biochemistry, Department of Biochemistry, Medical School, National Autonomous University of Mexico, Mexico City
Chemical and functional characterization of scorpion toxins

□ Venezuela

Raúl A. Padrón, Ph.D.
Senior Investigator, Structural Biology Laboratory, Biophysics and Biochemistry Center, Venezuelan Institute for Scientific Research, Caracas, Venezuela
Structural biology of muscle contraction and its regulation

HHMI's Office of Grants and Special Programs is committed to a comprehensive assessment effort as an integral part of its grants activities. To further this assessment effort, the Institute has undertaken periodic surveys of private-sector support for science education. In 1995, in connection with a workshop on the training of physician scientists and assessment of their career outcomes, HHMI conducted a survey of research training programs for physicians in the public and private sectors.[1] (See Program Assessment chapter of *Grants for Science Education, 1996.*)

In 1996 HHMI surveyed foundation support for undergraduate and precollege science education.[2] A report of a survey of predoctoral and postdoctoral research training programs in the public and private sectors is under way.

In addition to evaluating its own programs, HHMI encourages grantees to conduct program assessments and provides opportunities for assessment information to be shared among grantees and funding organizations. Assessment activities by both foundations and grantees were the focus of the 1996 undergraduate and precollege program directors meetings.

[1] Office of Grants and Special Programs, Howard Hughes Medical Institute, 1997. *Training of Physician Scientists and Assessment of Career Outcomes.*

[2] Office of Grants and Special Programs, Howard Hughes Medical Institute, 1997. *Assessment Strategies for Science Education: Undergraduate and Precollege Programs.*

This chapter reviews current support and assessment of science education activities, with particular focus on undergraduate and precollege programs. Amounts of funds reported are approximate and report years vary. To the extent possible, data are the most recent available. When appropriate, however, data for 1994 were used to provide comparability. Because each organization, agency, and information source defines and categorizes support for science education differently, total amounts reported are not readily compared.

Overview of Private and Public Funding for Science Education and Training

HHMI Support

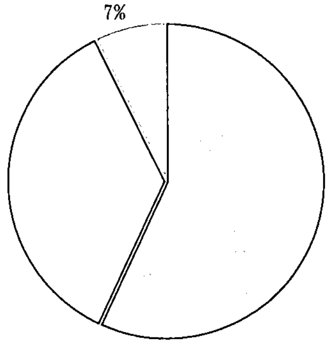
HHMI contributes to science education through both its grants program and its medical research organization (MRO) program. The HHMI grants program has awarded about $608 million since its inception.

In 1994 the program made grant payments totaling $52.5 million. Of that amount, $49.7 million supported domestic science education programs and $2.8 million supported research by scientists abroad. The funds for science education were distributed as follows: undergraduate, $28.5 million (57 percent); graduate, $17.6 million (36 percent); and precollege and public science education, $3.6 million (7 percent) (Figure 78).

Also in 1994, HHMI's MRO program provided $6.5 million for grad-

Figure 78

Distribution of HHMI Grant Support for Science Education by Education Level, 1994



Total: $49.7 million[1]

[1]International program support, $2.8 million in 1994, is not included.

Source: Internal HHMI document

uate education at institutions that host HHMI investigators. In addition, the MRO program supported several hundred postdoctoral associates working in investigators' laboratories.

Other Private Support

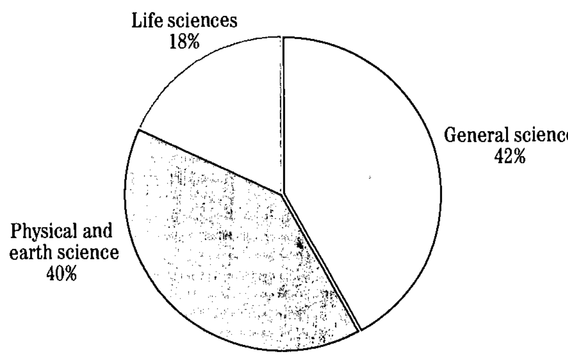
According to the 1996 file of the Foundation Center's Foundation Grants Index, total foundation giving to science education in 1994 was $85.8 million. The index includes grants of $10,000 or more awarded to organizations by approximately 800 large and 200 smaller foundations. For community foundations, only discretionary grants are included. Grants to individuals, and science education grants awarded by HHMI are also excluded.

Foundation grants for science education in 1994 were distributed as follows: general science, $36.6 million (42 percent); physical and earth science, $34 million (40 percent); and life science, $15.2 million (18 percent) (Figure 79). For a more detailed analysis of foundation support for science education, see HHMI's publication (1997) *Assessment Strategies for Science Education: Undergraduate and Precollege Programs.*

Figure 80 shows total private grant support for *life sciences* education in 1994, including both HHMI and foundation support as reported in the *Foundation Grants Index.* HHMI expended $49.7 million (77 percent of the total), and foundations expended $15.2 million (23 percent).

Figure 79

Distribution of Foundation Support for Science Education by Major Science Field, 1994

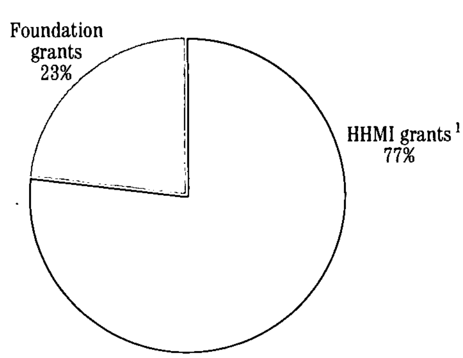


Total: $85.8 million

Source: Foundation Giving *(1996 Edition), The Foundation Center, New York*

Figure 80

Combined Grant Support for Science Education in the Life Sciences by HHMI and Foundations, 1994



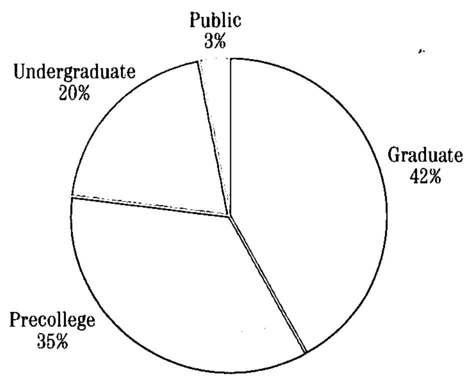
Total: $65 million

[1] *International program support, $2.8 million in 1994, is not included.*

Source: Foundation Giving *(1996 Edition) and internal HHMI document*

Figure 81

Distribution of Federal Support for Science Education by Education Level, 1993



Total: Approximately $2.5 billion

Source: Federal Coordinating Council for Science, Engineering, and Technology

Public Support

In 1993, the last year for which aggregate federal figures are available, the annual federal commitment of dollars specifically for science and mathematics education was approximately $2.5 billion.[3] These funds were distributed as follows: 42 percent for graduate education, 35 percent for precollege education, 20 percent for undergraduate education, and 3 percent for public understanding of science (Figure 81).

The principal federal agencies supporting science education are the National Institutes of Health (NIH) and the National Science Foundation (NSF).

National Institutes of Health. NIH spent about $373 million on biomedical science training programs in 1994. Its training budget has remained relatively constant in real terms since the mid-1970s. NIH provides training support through both fellowship awards to individuals and training grants to institutions. Training programs are available at several levels, including medical student, predoctoral, postdoctoral, and young faculty.

National Science Foundation. NSF spent about $569 million on support of education and human resources in 1994. These programs focus on elementary, secondary, and informal education; undergraduate and graduate education; research

[3]Federal Coordinating Council for Science, Engineering, and Technology, June 1993. *The Federal Investment in Science, Mathematics, Engineering and Technology Education: Where Now? What Next?*

development; and human resource development to increase the participation in science and engineering of minorities, women and girls, and persons with disabilities. Support for an experimental program to stimulate research in historically less competitive states is also included within this budget category.

Other Federal Support. The U.S. Department of Education provides more than $12 billion in support for postsecondary education. However, a large proportion of these funds are for student loans and other financial assistance. It is not possible to quantify the support directed toward students pursuing educational opportunities in science and mathematics. Other federal agencies involved in supporting science education include the National Aeronautics and Space Administration and the U.S. Departments of Agriculture, Energy, and Defense.

Assessment of Science Education Programs

Both public and private funders of science education have an interest in assessing the impact of the programs they support. The National Research Council and the Educational Testing Service, among other organizations, have made significant contributions to an ongoing dialogue on such issues as how to define assessment, what kinds of assessment measures are appropriate, and how best to obtain meaningful assessment data.

There is increasing recognition that assessment methodologies must be appropriate to the outcomes to be measured. Thus, varied approaches and multiple data-collection methods are valid and necessary. Much valuable work has been and is being done to develop new assessment tools that more adequately measure problem-solving skills and mastery of complex material.

HHMI Data Archive: An Invaluable Assessment Tool

Ready access to comprehensive, comparable program data is prerequisite to program assessment. For this reason, the basis of HHMI's efforts to assess its grants programs is a central data archive that contains, in a standard format, comprehensive information from all grant competitions, outcome information from grantees, and selected national education data.

To allow assessment across years and programs, terminology and format have been standardized for institutions, scientific fields, names, degrees, and other variables. With packaged standard reports and the ability to design ad hoc queries that reach any data element, the archive is now an important source of cross-cutting program assessment analyses. It is possible, for example, to add to the assessment of undergraduate institutions the educational origins of awardees in HHMI's fellowship programs. The ability to filter for a type of institution, research field, award outcome, or underrepresented minority status adds greatly to the archive's power as an analytic tool.

The archive is continually updated as new information becomes available, and the data can readily be retrieved for assessment purposes. The archive is also a key link with related assessment projects.

Assessment of Research Training for Physician Scientists

HHMI Assessment Initiatives. For the past seven years, HHMI has funded the Association of American Medical Colleges (AAMC) in a long-term project to assess the outcome of HHMI's research training programs for medical students and physicians. HHMI also uses surveys to track the career progress of program alumni. By spring 1997, HHMI will have in place a secure system using the World Wide Web to survey alumni of the three fellowship programs and to generate directories of fellows.

HHMI-AAMC Assessment Project. The assessment project monitors career outcomes of medical students and physicians who participate in HHMI fellowships, in comparison with outcomes of other groups of physicians.

The project uses existing national databases and measures several key indicators of research involvement. To ensure comparison with their peers, fellows are grouped into cohorts by year of receipt of the M.D. degree. Comparison groups (which include unsuccessful applicants for the fellowships and participants in other research training programs) are tracked in parallel with the fellows.

The databases are maintained and updated regularly by the AAMC, the National Institutes of Health, and the National Research Council of the National Academy of Sciences. HHMI has obtained permission from these agencies to use the data.

Monitored outcomes include receipt of the Ph.D. degree, years of postgraduate clinical training, NIH support of postdoctoral research training, NIH research grant applications and awards, and appointment to a medical school faculty. Demographic variables such as age, sex, and racial or ethnic group are also recorded. A sample of outcome data is shown in Figure 82. It is important to note that these data are meant to be illustrative of the analyses that are possible, but the numbers are too small to allow conclusions to be drawn. Several more years are necessary before fellows will have progressed in sufficient numbers to allow meaningful analyses of career outcomes.

Although NIH is a major source of research grants, and medical schools are the principal source of faculty appointments, neither of these measures is comprehensive. Other federal agencies and voluntary health associations are also important sources of research support. Fellows may obtain academic appointments outside medical schools or conduct research in private medical research institutions or the pharmaceutical and biotechnolo-

Figure 82

Physician Scientist Career Outcomes: Postdoctoral Support and Research Grants from NIH All 1991 M.D. Graduates of U.S. Medical Schools

	1991 M.D. Graduates	NIH Postdoctoral Fellows and Trainees*		NIH Research Grant Applicants*		NIH Research Grant Awardees*	
	Total	Number	% of Total	Number	% of Total	Number	% of Total
HHMI Medical Student Fellowship Program*							
Fellows	16	1	6	0	0	0	0
Non-award applicants	10	0	0	0	0	0	0
M.D./Ph.D. programs	261	57	22	21	8	14	5
All other M.D. graduates	15,150	308	2	36	0.2	10	0.1
Totals	15,437	366	2	57	0.4	24	0.2
HHMI Physician Postdoctoral Fellowship Program*							
Fellows	11	2	18	3	27	1	9

**HHMI Fellowship programs include fellows and nonaward applicants from the inception of the programs (1989 for Medical Student, 1990 for Physician Postdoctoral) through the 1995 competitions. NIH Postdoctoral Fellows and Trainees includes data through fiscal year 1994. NIH Research Grant Applicants and Awardees include data through fiscal year 1995. NIH career development awards (Physician Scientist and Clinical Investigator) are tallied here among research grants.*

gy industries. Existing databases do not capture this information. To cover these gaps, HHMI is exploring participation by other funders (e.g., voluntary health agencies) in the assessment project. More directly, HHMI is also tracking the careers of former fellows through directories.

HHMI Directories of Fellows. Directories published by HHMI represent survey-based assessment of the fellowships. In the past, a survey form was sent periodically to each current and former fellow, and the information thus obtained was published in a directory of fellows. Updating the directories periodically enables HHMI to keep track of fellows' current professional appointments, education, and research achievements. However, this is very labor intensive. To facilitate information input and minimize the need to research current addresses, the directory function is being moved to the World Wide Web. Certain information will remain private, for use by HHMI only, but selected data will be published on the Web and in print as directories of fellows.

Other Public and Private Assessment Initiatives

National Institutes of Health. Assessment of NIH research training and career programs for physicians suggests that the time, duration, and quality of early research experiences influence the outcome of postdoctoral research training. For example, medical school research experience is strongly associated with postgraduate research involvement.

A survey of full-time medical school faculty conducted for NIH by Quantum Research Corporation found that those who received some Public Health Service training support were more likely to be principal investigators in 1993 than faculty who had received no PHS training support.

Although the causal linkages between research training and outcomes are not yet fully understood, it appears that the training grant mechanism is less successful than the fellowship program in preparing M.D. trainees to apply for NIH grants. Program officers at NIH believe this is probably attributable to differences in the career levels of trainees versus fellows.

NIH is in the process of implementing a three-phase assessment of research training programs, comprising an evaluation of existing data, a survey of former fellows and trainees, and development of longitudinal databases using information collected every two years from a sample of trainees and fellows.

Private-Sector Programs. Several privately funded research training programs for physician scientists, including the Stanley J. Sarnoff Endowment for Cardiovascular Science, the Cancer Research Fund of the Damon Runyon–Walter Winchell Foundation, and the Lucille P. Markey Charitable Trust, track the careers of their program alumni through surveys and, in some cases, national databases. Information obtained through these tracking programs indicates that a significant percentage of alumni (80 percent for Markey, 67 percent for Sarnoff) have obtained academic appointments to date.

Assessment of Undergraduate Science Education Programs

Student Tracking and Other Assessments

The purpose of HHMI's Undergraduate Biological Sciences Education Program is to strengthen the national quality of undergraduate science education and provide research opportunities for students, including women and minorities historically underrepresented in the sciences. As such, appropriate assessment activities span the spectrum from formal testing to tracking students through their undergraduate years and beyond. Programs offered by grantee institutions include student research opportunities, initiatives to broaden access to science, faculty recruitment, curriculum development, and outreach to precollege institutions.

Activities supported by the undergraduate program have been shown to be key determinants of whether students are attracted to and retained in scientific fields through the undergraduate years and beyond. Laboratory research experiences, access to enthusiastic faculty mentors, and exciting courses taught with modern equipment and facilities have all been cited as pivotal factors in students' decisions to persist in the sciences. A significant number of students successful in science and mathematics have also credited stimulating precollege curricula, laboratory experiences and other special opportunities, and the personal interest of a teacher as crucial to their early interest in science.

Program Directors Meetings: A Forum for Discussing Assessment

Assessment has been a topic of discussion at every undergraduate program meeting since 1991 and was the overarching theme of the 1996 meeting. 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.[4]

Assessment can provide useful information to educators, students, and the communities in which they interact. 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.

At recent undergraduate program directors meetings, participants have described evaluation activities under way at their institutions. These include tracking of 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.

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 data essential for determining what works and what does not and when program interventions can most affect the science education continuum from grade school through graduate school. Standards developed by the Nation-

[4] Office of Grants and Special Programs, Howard Hughes Medical Institute, 1997. *Tracking Science Pathways: A Report of the 1996 Meeting of HHMI Undergraduate Program Directors.*

al Research Council for precollege science education could suggest useful assessment strategies to college-level science educators.

HHMI Assessment Initiatives

To collect data on which to base future assessment studies, HHMI's undergraduate program staff has developed a system that enables grantee institutions to submit annual program information over the World Wide Web. Each grantee has access to an electronic report form on a dedicated, secure site on HHMI's home page. Data on student research participation, new faculty appointments, precollege teacher and student involvement, and other program activities can be submitted and directly loaded into HHMI's archival database. This system, introduced in spring 1997, replaces printed forms and diskettes.

As part of the Web-based reporting system, HHMI is requesting information on each student who participated in HHMI-supported laboratory research. In 1996, the first year this information was requested, data were submitted on over 3,500 students who engaged in HHMI-supported research during that year. This information will enable HHMI to link with other existing databases, such as the Association of American Medical College's Student Applicant Information Management Systems, the National Science Foundation's Comprehensive Index of Fellows, the National Institutes of Health's Trainee and Fellow File, and HHMI's own fellowship databases. The intent is to track HHMI-supported students as they complete their undergraduate education, enter graduate or medical school, and embark on careers.

HHMI is also collecting information on faculty members who have been appointed with HHMI funds. Currently, about 290 such faculty members have been appointed; many of these individuals are now competing for NIH and NSF grants and are approaching tenure review. Following them over the long term should provide valuable information about the factors that shape their careers as scientists and educators. The feasibility of collecting long-term tracking information on the precollege teachers and students involved in outreach programs supported by the undergraduate program is being explored.

Selected Initiatives by HHMI Undergraduate Grantees

There is as yet no broad consensus in the science education community concerning issues such as how to define assessment, what kinds of assessment measures are appropriate, and how best to obtain meaningful assessment data. Many science educators feel that clearly defined objectives, well-planned methodologies, and measurable outcomes, while necessary preconditions for good assessment, are insufficient because they fail to account adequately for intangible benefits such as changing student attitudes toward science and the prevailing level of science literacy among the general public.

The initiatives summarized below exemplify the wide range of assessment strategies that can be effective and the importance of tailoring strategies to specific goals and objectives of the program being assessed (one size does not fit all). A more comprehensive report could have included many more examples of valid approaches to program assessment. Inclusion of the examples below does not imply that these approaches are in any way superior to others not mentioned. Equally, exclusion of other examples does not imply that those approaches lack validity.

Wellesley College. 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 science majors and persistence in a science career path, Wellesley College, with funding from the Alfred P. Sloan Foundation, launched the Pathways for Women in the Sciences project in 1991.

The project includes three studies: a longitudinal study of the Wellesley class entering in 1991, a retrospective study of alumnae who graduated in the classes of 1983–1991, and a retrospective study of alumnae who graduated in the classes of 1968–1982. The undergraduate study represents one of the few longitudinal analyses of persistence in science.

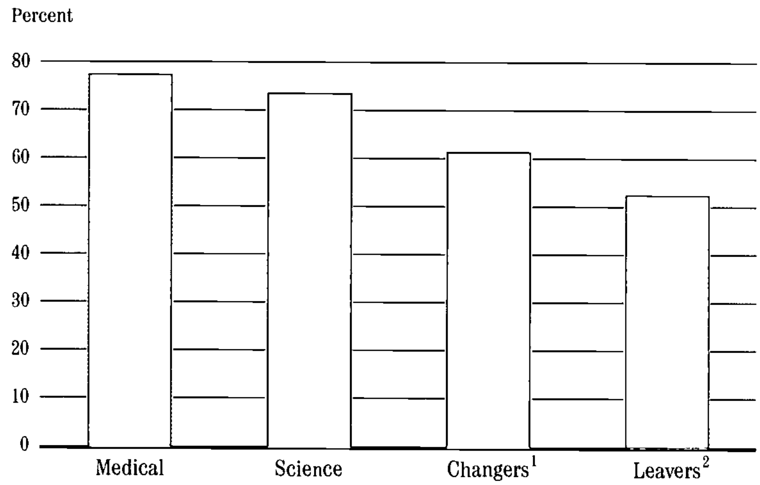
Issued in 1993, *Pathways for Women in the Sciences: The Wellesley Report, Part I* describes the first two years of undergraduate study as well as the early career experiences of the more recent graduating classes. The second report describes persistence in science majors for the longitudinal cohort and persistence in science careers for all alumnae classes surveyed. Findings from *The Wellesley Report, Part II,* published in June 1997, are excerpted here (with the permission of Wellesley College):

- Interest in pursuing science or mathematics majors is developed before college. Very few students major in these subjects if they have not expressed an interest in them at orientation.
- Students initially interested in science who switch to another field most commonly say that they are not rejecting science but have become interested in the other field. They also say that laboratories take too much time.
- Students who prefer subjects where the material has multiple interpretations are more likely to switch from science, whereas students who prefer precise answers tend to stay.
- Premedical students persist in science and mathematics majors at higher rates than students who major in pure science.
- The freshman year is the riskiest period for losing students from science. Although premedical students are less likely than pure science students to leave at the end of the first year, they are more likely than pure science stu-

Figure 83

Wellesley College's Longitudinal Study of 1,142 Women in the Sciences

Alumni with research experience outside the classroom



[1] Changed from science to another area subsequent to college graduation.

[2] Left science in their undergraduate years.

Source: The Wellesley Report, Parts I and II, 1993 and 1997

dents to leave at the end of the second year.

- Other factors related to persistence include having completed more years of high school science and mathematics, having a higher grade point average during the freshman and sophomore years, and placing low importance on materialistic career factors.
- In focus groups, students pursuing science place considerable importance on undergraduate research experiences and individual contact with faculty members who serve as mentors.

The alumnae analysis 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.) Findings from this analysis include the following:

- More than 40 percent of the study cohort (345 women) had left science by the time of data collection. A quarter of science graduates leave the field at graduation, and a further 2–5 percent leave each year during years 1 though 11 after graduation. 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, three-fifths of the women who had a mentor were retained, compared with half of the women

who did not have a mentor. More than half of all women in science careers said they would not be where they are today if they had not had a mentor. No differences were found between women who had a male mentor and women who had a female mentor. Graduates in the physical and life sciences were most likely to credit their persistence to their mentor.

- Participation in undergraduate research is also associated with retention in science. At the end of year 11, three-fifths of the women who engaged in undergraduate research are retained compared with slightly more than half of the women who did not engage in such research (Figure 83).

These data are significant for HHMI's undergraduate biological sciences education program, which is currently providing more than 25,000 undergraduates with mentored research experiences. More than half of these undergraduates are women and a quarter are from minority groups underrepresented in the sciences.

University of California—Los Angeles. At UCLA, physical and life scientists are collaborating with cognitive scientists and psychologists to assess the university's institution-wide effort to implement technology-based education. Faculty members involved in the collaborative effort say this is one of four such initiatives of this scale that are under way in American higher education. Issues being studied include the effectiveness of distance learning in the sciences, the most effective ways to use computers in the classroom to enhance understanding of scientific concepts, and gender differences in students' responses to computer-based science courses (women tend to like these courses better than men do).

Dr. Orville Chapman, a professor of chemistry who is involved in the HHMI-supported undergraduate program at UCLA, collaborated with a faculty member in the university's psychology department, an expert in perception, to reorganize an organic chemistry course. Test scores among students taking the reorganized course increased by about 50 percent.

The university also developed a four-course, self-paced, interdisciplinary life sciences curriculum and a battery of measures to assess student performance under the curriculum. 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 mastery of theoretical and practical course material. Those involved hope that this project will produce findings that are relevant to the assessment of undergraduate program initiatives on faculty and curriculum development.

National Research Council. In 1995 HHMI awarded a four-year grant of $800,000 to the Committee on Undergraduate Science Education (CUSE) of the National

Research Council, National Academy of Sciences, to support the development of an Internet-accessible database on undergraduate science education and a national review of science education technologies.

The database was publicly released in December 1995. It contains information on more than 800 courses, programs, and organizations relating to undergraduate science education, including HHMI-supported programs. Thus, information about HHMI's undergraduate programs is being disseminated to greater numbers of precollege teachers; college and university administrators, faculty, and students; and state and national policy makers. The CUSE Web page <http://www2.nas.edu/cuselib/index.html> is linked to the HHMI home page.

The review of science education technology will result in an official National Research Council report, which is expected to be published in 1998. Topics that will be addressed in the review include quality control in educational software development, an assessment by scientific discipline of the need for educational software, and issues of equity in access to educational technology.

Assessment of Undergraduate Programs by the National Science Foundation

NSF's Directorate for Education and Human Resources has a five-year plan to evaluate the agency's science, mathematics, engineering, and technology education initiatives. Evaluations and impact studies are performed by outside organizations under competitively awarded contracts.

The directorate published the *User-Friendly Handbook for Project Evaluation,* a practical guide to conducting project evaluation for recipients of NSF science education grants. The handbook emphasizes techniques for obtaining significant outcome information.

The directorate commissioned and in 1996 published the results of a review of the state of undergraduate science, mathematics, engineering, and technology education in the United States. A significant finding of the year-long review was that important and measurable improvements have been achieved in the past decade. Curricular and pedagogical improvements documented in the report include the following, all of which are priorities of HHMI's undergraduate biological sciences education program:

- incorporating new knowledge into lower-level courses more rapidly and more thoroughly
- organizing courses or course modules to address real-world problems
- focusing on scientific processes at least as much as on the transmission of facts
- emphasizing active learning experiences and peer-learning techniques
- exposing students to interdisciplinary connections and multidisciplinary perspectives
- incorporating computer-based learning approaches, multimedia

materials, digital libraries, and other technologies into curricula

- developing students' cognitive and communication skills and ability to work in teams

The report's central recommendation is to build on the progress that has been made to ensure that all undergraduates (including nonscience majors and groups traditionally underrepresented in science, such as women, minorities, and persons with disabilities) have access to excellent science, mathematics, engineering, and technology education and have opportunities to be involved in scientific inquiry.

Assessment of Precollege Science Education Programs

HHMI's precollege initiatives are designed to stimulate the scientific and museum communities to work with teachers, school administrators, other educators, and students at all grade levels. The main objectives are to stimulate children's interest in and understanding of science and to improve science education through revision of curricula and classroom practices, enhancement of teacher education (initial and continuing), augmented teacher recruitment, and family and community involvement in the learning process. Assessment of different approaches to these objectives is vital to HHMI in developing its strategy and formulating dynamic initiatives in precollege education.

Because of the diverse nature of precollege activities and the wide range in educational and learning levels of participants (from prekindergarten children to high school biology teachers), no single approach to assessment can suffice. Standard educational assessment tools are available for evaluating well-defined populations, but determining outcomes becomes progressively more difficult in less formal settings.

National Research Council Standards. New science education standards published by the National Research Council[5] hold considerable potential to help institutions grappling with assessment. The standards stress the need to use an assortment of variables that rely on diverse data-collection methods rather than the more traditional sampling of one variable by a single method. The standards suggest that science achievement—ability to inquire, scientific understanding of the natural world, comprehension of the nature and utility of science—be assessed by using multiple methods such as performance and portfolios of the students' work as well as conventional tests. The standards also emphasize the measurement of opportunity to learn. Assessment data can provide feedback to teachers, students, and parents on the effectiveness of programs.

Professional Development for Teachers. Teacher development activities are widely offered by HHMI grantees in both the undergraduate and precollege programs.

[5] National Academy Press, Washington, DC, 1996. *National Science Education Standards*.

According to the National Center for Education Statistics, about 1.7 million K–12 teachers in the United States teach science. Those who can take advantage of opportunities for professional development and who have access to state-of-the-art science curriculum resources will play an important role in science education reform. Biomedical research institutions, colleges and universities, and museums provide teachers with such opportunities and resources through internships, educational collaborations, and school-based support.

Role of Museums and Other Informal Science Education Institutions. Anecdotal and empirical evidence supports the value of hands-on, inquiry-based learning for young students, research experiences for older students, and strong family and community support for all youths in developing an interest in science. Informal science education programs, such as those offered by museums, aquaria, botanical gardens, and zoos, are most likely to reach young students, especially those in elementary school.

A recent survey of informal science education centers conducted for the Association of Science-Technology Centers demonstrated that informal science education serves as an invisible infrastructure that supports science teaching reform in local schools.[6] Figure 84 shows the estimated percentage of science museums and related institutions in the United States that provide various forms of support for school-based science teaching.

The question of what are appropriate criteria for assessing or evaluating informal science education activities—such as those that occur in science museums—is the focus of continuing debate. Most institutions use indirect measures of effectiveness, such as total attendance; the length of the school waiting list; the popularity of a new exhibit; and progress in attracting new members, partners, and sponsors. More rigorous criteria for successful outcomes—such as improved test scores and numbers of science majors or Ph.D.'s—are more difficult to obtain because of the long time-frame involved and the lack of a well-defined, accessible study population.

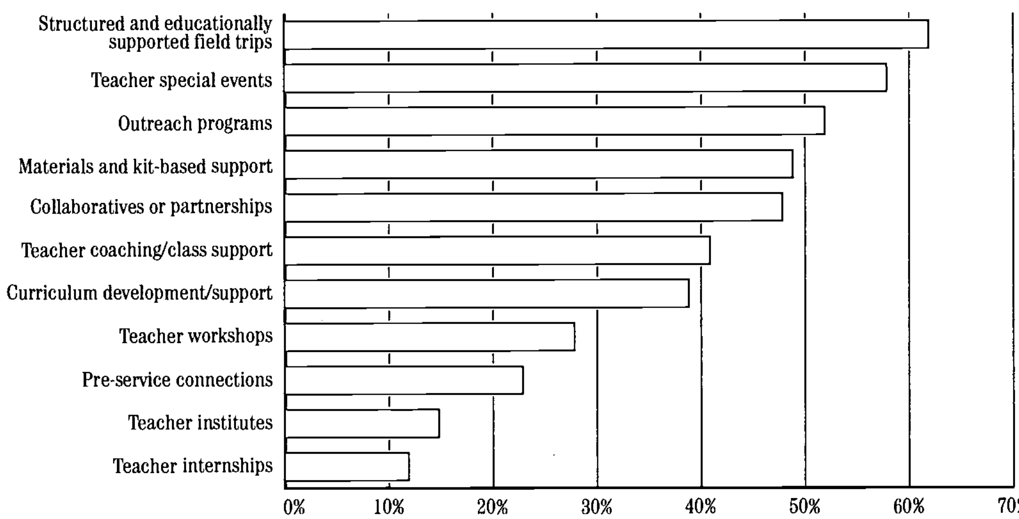
As noted above, these initiatives exemplify the wide range of assessment strategies that can be effective and the importance of tailoring strategies to the objectives of programs assessed. Many more examples of valid approaches to program assessment could be cited.

HHMI-funded museums include pioneers in informal science education such as the San Francisco Exploratorium, Franklin Institute in Philadelphia, Children's Museum in Boston, Lawrence Hall of Science in Berkeley, Chicago Museum of Science and Industry, and New York Hall of Science. These institutions have led the way in evaluation efforts and have provided assess-

[6] Inverness Research Associates for the Association of Science-Technology Centers, Washington, DC, 1996. *An Invisible Infrastructure: Institutions of Informal Science Education.*

Figure 84

Estimated Percentage of Science Museums and Related Institutions in the U.S. that Provide Support for School-Based Science Teaching, by Type of Activity



Source: Inverness Research Associates for the Association of Science-Technology Centers, 1996.

ment templates that are being used and adapted by other museums, biomedical research institutions, and colleges and universities engaged in K–12 precollege outreach. Their efforts were highlighted at the 1996 HHMI precollege program directors meeting. These and other initiatives to assess precollege and informal science education programs are described below.

Initiatives by Universities and Biomedical Research Institutions

Cornell University. The Cornell Institute for Biology Teachers, a professional development program that is a partnership between Cornell University and teachers' organizations in upstate New York, conducts a variety of ongoing assessment activities. Classroom laboratory materials developed jointly by teachers and Cornell faculty are tested in classrooms for a year, and components that do not prove useful are eliminated. Other forms of program assessment include extensive use of questionnaires, teacher interviews, and instructors at summer institutes.

Ongoing assessment of the Cornell program has included

- pre- and posttesting of the 170 participating teachers to gain information about the relative value of the laboratories and experiments, the affordability of laboratories for classroom use, and the effectiveness of program materials, particularly those required by the New York State biology syllabus

- monitoring of electronic network use (by April 1996 more than 35,000 calls had been logged among teachers and between teachers and Cornell faculty, for a total of more than 5,000 hours on-line)
- tracking the use of a science kit lending library (by April 1996, 48 kits had served more than 5,000 students at 60 schools; the same equipment was used by about 260 teachers for 17 in-service workshops).

California Institute of Technology. Caltech scientists collaborated with teachers and faculty of the Claremont Graduate School to develop a preservice teacher-training program in biology and physics, based on cooperative learning techniques. Students were graded on 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 students and faculty.

Evaluation of this aspect of the Caltech program included

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

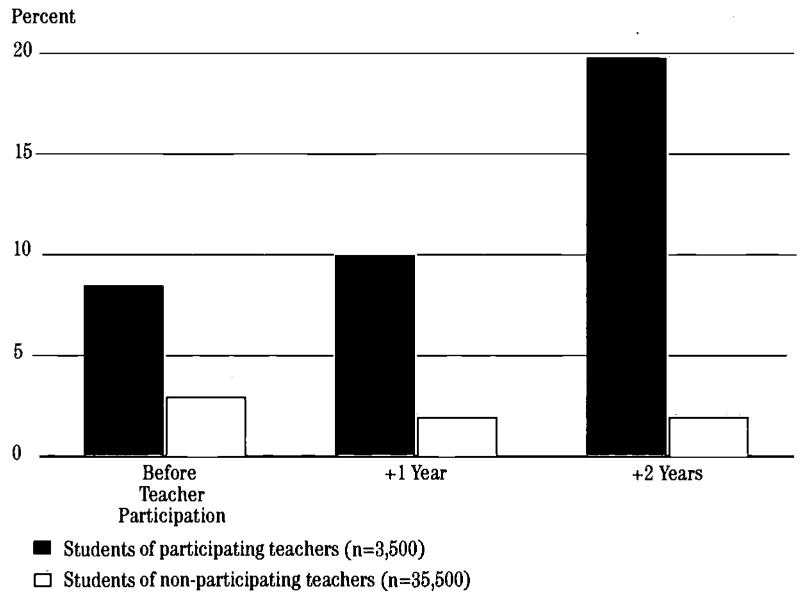
Columbia University School of Medicine. Dr. Samuel Silverstein, director of Columbia University's summer research program for secondary school science teachers, has collected data on the program's impact on students. Student performance data were obtained for the year before a teacher's entry into the program and for the years after the teacher's first and second summers in the program. A control group comprised students of nonparticipating science teachers at the same schools during the same period.

Data were obtained on about 39,000 students (3,500 in the classes of participating teachers and 35,500 controls). Students of teachers participating in the Columbia program were 3 times as likely as controls to undertake Westinghouse-type science projects and 3.5 times as likely to participate in a science club (Figure 85). Moreover, student attendance in the science classes of participating teachers rose markedly. Further data collection and analysis will provide information about how long these positive effects last

Figure 85

Precollege Student Participation in Science Clubs or Other Extracurricular Activities After Outreach to Teachers

Student Participation



Source: Internal HHMI document

and whether students' performance on standardized tests improves.

Planning is under way for a multisite collaborative study of student outcomes in six of the largest scientific work experience programs for teachers, including two programs supported by HHMI at Columbia University and the Fred Hutchinson Cancer Research Center.

Initiatives by Museums and Other Informal Providers

Museum of Science and Industry, Chicago. The museum employed professional evaluators to assess its Mystery at the Museum program, a hands-on exhibit designed for 5th- to 8th-grade students. Purposes of the two-year multimethod evaluation were to assess the program's impact on teachers and students and to guide improvements in all aspects of the program.

Evaluation instruments included pre- and postvisit questionnaires, a critical review of the program and the associated teachers' workshop and teaching materials, open-ended interviews with student participants, follow-up school visits, and teacher questionnaires. These instruments were refined during the evaluation process to identify the most effective way of measuring the program's impact.

The pre- and postvisit questionnaires were not found to be sensitive or well-matched to the teachers' and students' brief experience of the exhibit, and use of this instrument was discontinued after preliminary testing. The critical review resulted in a variety of changes to both the exhibit and the supporting materials. Interviews with student participants also led to program adjustments.

In open-ended questionnaires completed by student participants at their schools two to three weeks after the museum visit, more than 60 percent of students gave unprompted responses that indicated they understood and recalled the three concepts that formed the basis of the exhibit. This level of response from children several weeks after a one-time exposure to the program was considered positive and significant.

In a follow-up test, the students who had visited the exhibit used appropriate key words twice as often and used less appropriate key words half as often as the students who had not visited the exhibit.

Responses to the teacher questionnaire confirmed that teachers used and benefited from the workshop and classroom materials that supported the exhibit. This questionnaire also revealed that the Mystery Lab activities (which focused on biomedical and forensic imaging) were the only human biology units taught in the classroom of more than 40 percent of respondents.

New York Hall of Science. In 1993 the New York Hall of Science received an HHMI grant to train 7th-grade life science teachers in microbiology and provide materials, equipment, and ongoing resource and curricular support systems. By enhancing instruction in microbiology (recently added to the state's 7th-grade curriculum), the New York Hall of Science intends to build a critical mass of life science teachers who can bring about systematic reform of life science instruction in the New York City schools. Strategies to achieve this goal include teacher workshops, provision of kits for microbiology laboratory and classroom activities, and microscope and equipment rentals.

A recent formative evaluation of the outreach program revealed encouraging preliminary changes in the way teachers viewed their ability to teach microbiology. After taking the workshops and using the kits, 56 percent found that they were well prepared to teach microbiology in their classes, 25 percent believed they were completely prepared, and 19 percent felt they were adequately prepared. More importantly, 92 percent of the teachers reported an increase in student enthusiasm for life science classes and a marked increase in student interest in microbiology in general.

Conclusions

For over a decade much has been heard about the dismal state of science education in the United States, the lack of a scientifically literate public, and the need to train scientists and engineers to become internationally competitive. Few dispute these claims. The big question is, How? How do we improve curriculum, equip the classroom, and provide teachers with appropriate teaching skills and adequate resources? How do we maintain our children's interest in science in a fast-moving, high-tech world with competing demands? How do we know which training pathway will lead to a successful and productive scientific career?

HHMI, together with other organizations in the philanthropic community and with federal agencies, has made a substantial commitment to science education at all levels. The HHMI grants program is the nation's major privately funded initiative to improve the performance of U.S. students in science. By many national measures, these efforts appear to be having a positive effect, particularly among the youngest students.

After a decade of reform in the way science is taught, there are early signs that positive change has occurred nationwide. Children at the elementary level are spending more time learning science, teachers are spending more time teaching it, and more students are staying in science courses well into high school. At the undergraduate level, enrollments in life science courses are at an all-time high. At the graduate level, students who are provided high-caliber fellowships have an advantage in the competition for research positions and dollars.

Certain types of programs make a positive difference in science learning at all levels: resourceful teacher development programs; student-guided learning and research opportunities; community-based science education; innovative new curricula; and productive, meaningful partnerships among schools, colleges, universities, scientific organizations, and local communities.

Ongoing assessment of science education initiatives is crucial to the reform process because it helps to identify effective approaches. Delineating the characteristics of successful programs enables such programs to be duplicated in other settings.

At the undergraduate level, assessment activities include tracking of the course choices and test scores of students who have participated in science education programs and research experiences, evaluation of the career choices of women and minorities underrepresented in the sciences, observational studies of classrooms in which innovative curricula and educational technologies are used, surveys to assess changes in attitudes about science, and evaluations of curricular innovations. The results of these studies emphasize the importance of student research, good teaching, and positive mentors and role models in a student's decision to pursue science at the undergraduate level.

Assessment at the precollege level is more complex because of the diverse nature of the educational activities and the wide learning range of the participants (from preschool children to high school biology teachers). No single approach can suffice. However, new science education standards from the National Research Council provide some help for institutions seeking the best means to measure the impact of their programs. Both numeric and anecdotal data attest to the value of hands-on, inquiry-based learning for young students, research experiences for older students, and strong family and community support for all youths in stimulating an interest in the sciences. Direct and indirect support of K–12 teachers is also a crucial element of precollege programs that recognizes these teachers' influence in introducing science to young children.

Bruce Alberts, president of the National Academy of Sciences and keynote speaker at the 1995 HHMI precollege program directors meeting, has spoken of the need for a "wise and stable platform for the continued improvement of science education." After 10 years of providing support at all educational levels, HHMI has embraced this ideal. HHMI's commitment to a wide range of programs offered by a diverse set of institutions has cast a vast net of science education opportunities. These programs complement and enhance those supported by foundations and the public sector and have become an important part of the nation's education infrastructure.

Policies and Procedures for Grant Applications

Grants and fellowships awarded by the Howard Hughes Medical Institute are administered by its Office of Grants and Special Programs. The awards are made under specific initiatives that have individual objectives and guidelines.

In brief, graduate fellowships, grants for undergraduate and precollege science education, grants for research resources for medical schools, and grants for research in selected countries abroad are awarded on the basis of applications or proposals reviewed by outside panels of scientists and educators. The panels' evaluations are reviewed by an internal committee, which makes recommendations to the Institute's Trustees for authorization of funding. The Trustees and Institute management annually review current grants policies, initiatives, and possible directions for program development.

The Institute does not award grants for research in the United States. It does not award institutional training grants or support conferences or publications. Funds for pilot research projects are available only through institutional grants made to medical schools under the Institute's research resources program. Policies and procedures for each of the program areas are described below.

The Institute Grant-Making Process

Institute grants and fellowships support science education at all levels in the United States and its territories. The six main program areas are graduate, undergraduate, and precollege science education, research resources, local and special programs, and the international program (Figure 86). The research resources

Figure 86

The Grants Cycle

	Graduate	Undergraduate	Precollege	Research Resources	Local (Special)	International	Program Assessement
Announcement	Broad	Limited			None	Broad	None
Application	Open competition	Invitation only			Ad hoc	Nomination or open competition	Invitation only
External review	External review panels of 15–20 members from academia, government, and industry (review panels convened by NRC for the predoctoral fellowship program)						
Internal review	Management and Trustees						
Payments	$21.3	$30.9	$2.8	$21.1	$0.8	$9.3	$0.2
Assessment	Annual financial reports and grantee meetings						Surveys

The HHMI grant-making process varies somewhat from program to program (top). Operations, however, are broadly similar in each phase of the grants cycle (left, descending). A call for applications, for example, is made in all programs except Program Assessment, though some target different types of institutions or different regions from one competition to another. The Payments row shows totals for fiscal 1996 in millions, adding to $86.4 million.

and international programs also support research.

Most of the fellowship or awards competitions are announced publicly at the start of the grant cycle. Program announcements give information on the objectives, eligibility requirements, and application process, and provide appropriate application forms. All of the fellowships under the graduate programs are offered in open competition, while the institution-based grants (undergraduate, precollege, and research resources for medical schools) go to specific types of institutions that are invited to apply. The local initiative and some resource awards are by invitation only, and the international awards are limited to scientists in selected regions of the world.

For the graduate fellowship programs, applications are due several months after announcement. The applications typically request verification of eligibility, a research plan, letters of recommendation, and a mentor's statement of training plans. Additional materials, such as educational transcripts, may be required. The completed applications are examined by the grants staff to ensure completeness and eligibility. An exception is the predoctoral fellowship program, for which, in view of the large number of applicants (about 1,400 annually), the National Research Council manages the review under an Institute award.

For the undergraduate, precollege, research resources for medical schools, and international programs, proposal deadlines follow the announcement by several months. Executive summaries, narrative descriptions of the proposed program, and budget summaries and detail are required. Institutions must also submit institutional and departmental data and, as appropriate, letters of commitment from collaborating institutions.

For the graduate, undergraduate, precollege, research resources, and international programs, applications and proposals are assigned for review and evaluation to external panels of distinguished scientists and educators in academia, government, and industry. Selection of the reviewers, usually no more than 20 per competition, is based on professional credentials and expertise in a field germane to the program area.

An internal review committee then considers the panel evaluations. The committee, in turn, makes recommendations to the Institute Trustees, who authorize funding of the specific awards. For the fellowships, however, authorization is made through the fiscal-year program budget. The Trustees do not authorize the specific awards in these cases.

Following the Trustees' authorization, grants are announced to the awardees and the press. Awardee institutions are then asked to sign a *Terms and Conditions* document and to name a fellowship officer or program director. For the undergraduate, precollege, research resources, and international programs, awardees must also develop a budget to be approved by the Institute. As an adjunct to *Terms and*

Conditions, an information booklet setting forth detailed policies and procedures is issued annually for each program.

Payments are sent to institutional grantees annually and to the fellowship institutions biannually. For the institutional grants, expenditures must conform to the approved budgets and to policies and procedures set forth in *Terms and Conditions* and the information booklet for each program. For the fellowships, the information booklets specify the policies on appropriate uses of funds and allocation of awards for various purposes.

Grant recipients are required to submit program and financial reports using forms provided by the Institute. These reports inform the staff of grant-funded activities and expenditures during the reporting year and are used extensively for internal and external Institute reports. In addition, annual meetings for each program convene fellows or program directors at the Institute headquarters in Chevy Chase to meet one another and invited guests, to hear presentations, and to exchange information and ideas. The international research awardees participate each year in an Institute-sponsored scientific meeting.

As part of its ongoing assessment efforts, the Grants office issues directories of fellows and programs, meeting reports, and special reports on science education and funding. For general information about the grants program, the Institute has a home page on the World Wide Web, with direct links to the grants sites. The universal resource locator (URL) is <http://www.hhmi.org>. URLs for the individual programs are listed at the end of each section below.

Graduate Education in the Biological Sciences

The Institute supports graduate education through fellowships to individual students and physicians. As mentioned above, it does not award institutional training grants. There are three graduate fellowship programs.

The URL for general information about the fellowship programs is <http://www.hhmi.org/fellowships>.

Predoctoral Fellowships in Biological Sciences

The predoctoral fellowships provide support for up to five years of full-time study toward the Ph.D. or Sc.D. degree in specific areas of the biological sciences. They are awarded to individual students through an international competition. Processing and review of the applications are managed by the Fellowship Office of the National Research Council/National Academy of Sciences. The application deadline is in mid-November each year, and awards are announced by early April.

The URL for the predoctoral fellowships in biological sciences program is <http://www.hhmi.org/grants/graduate/predoc/start.htm>.

Research Training Fellowships for Medical Students

The medical student fellowships enable students enrolled in U.S. medical schools to undertake a year of full-time fundamental research. Awards are based on a national competition. The application deadline is early December each year, and awards are announced by early April.

The URL for the research training fellowships for medical students program is <http://www.hhmi.org/fellowships/>.

Postdoctoral Research Fellowships for Physicians

The postdoctoral fellowships provide support for three years of full-time research for physicians. To be eligible, they must have completed at least two years of postgraduate clinical training and no more than two years of postdoctoral research training by the start of the fellowship. Awards are based on an international competition. The application deadline is in early December each year, and awards are announced by the end of June.

The URL for the postdoctoral research fellowships for physicians program is <http://www.hhmi.org/fellowships/>.

Undergraduate Biological Sciences Education Program

The undergraduate program supports initiatives on the part of colleges and universities to strengthen the quality of undergraduate teaching and learning in the biological sciences and other fields (including chemistry, physics, and mathematics) as they relate to biology. Grants awarded for undergraduate science education provide broad funding for science departments to create programs that enrich undergraduate teaching and attract and retain students in science, including women and members of minority groups underrepresented in scientific fields.

The program supports opportunities for students to explore science through stimulating, hands-on research in on- and off-campus laboratories. It also supports laboratory training, prefreshman bridging programs, opportunities for students to present their research, and other experiences to deepen understanding and appreciation of science for majors and nonmajors.

Another program emphasis is on helping science departments maintain the vigor of their programs by building the undergraduate science infrastructure through support of equipment acquisitions and laboratory renovations. Colleges and universities also receive support to strengthen their electronic and communication infrastructure for science education, and to create or adapt software for science teaching.

The Institute also provides support for the appointment of new faculty members in the biological and related sciences, and for scientific and professional development activities for mid-career and senior faculty members. In addition, it supports efforts by science departments to integrate the biological sciences curriculum, forge new links between biology and the physical sciences and mathematics, and develop programs for science students who may pursue nonscience careers.

An important objective of the undergraduate program is to aid science departments to develop initiatives on behalf of science education in elementary and secondary schools and two- and four-year colleges, through a range of science outreach activities for teachers and students. In addition, the Institute fosters programs that encourage science majors to pursue teaching careers or that strengthen the scientific training of prospective elementary and secondary teachers.

Institutions are invited to compete for undergraduate grants on the basis of their records of having graduated students who went on to medical school or to earn doctoral degrees in biology or related fields. This assessment is based on data from the Association of American Medical Colleges, the National Research Council, and the U.S. Department of Education. In conducting its invitation assessments, the Institute may take into account institutions' records of graduating students from minority groups underrepresented in the sciences who have gone on to medical school or to earn biological or related doctorates.

The Institute does not provide scholarships or other forms of financial assistance directly to undergraduates. The colleges and universities receiving undergraduate grants are responsible for selecting students and awarding them Institute support for laboratory research and other educational opportunities in the sciences.

There will be no undergraduate program competition in 1997.

The URL for the undergraduate biological sciences education program is <http://www.hhmi.org/undergraduate/>.

Precollege and Public Science Education

Through this grants program, the Institute explores avenues of support for precollege and public science education. Initiatives are designed to address the level of scientific knowledge and interest of both school children and adults.

The Institute's precollege initiatives are designed to stimulate the scientific community to work with teachers, school administrators, other educators, and students at all grade levels. The main objectives are to stimulate children's interest in science and improve science education through revision of curricula, improvement of classroom practices, enhancement of teacher education (initial and continuing), and augmented teacher recruitment.

There will be no precollege program competition in 1997

Awards to children's museums, general science and natural history museums, and science and technology centers support science education programs for children and youth, their teachers and families, and community organizations. Competitors were selected after consultation with numerous experts in the field. Reviewers took into consideration existing relationships with educational organizations, as well as experience in conducting high-quality science education programs at the precollege level. Grants were awarded in 1992 and 1993 for five-year periods. The 1993 competition was the first to include aquaria, botanical gardens, arboreta, and zoos.

An initiative for biomedical research institutions is another Institute effort in precollege science education. It enables science-rich institutions to work in collaboration with schools, youth organizations, and community groups. The objective is to develop educational activities that focus specifically on biology or that integrate biology with other scientific fields. It builds on the unique resources that biomedical research institutions can offer in untraditional ways to stimulate interest in science, particularly among young people. In the 1994 competition for five-year awards, selection of invited institutions was made after consultation with the Association of American Medical Colleges, Association of Academic Health Centers, Association of Independent Research Institutions, and several databases.

1997 Competition

The 1997 competition will support science museums, aquaria, botanical gardens, and zoos to work in collaboration with other science resource centers, schools, youth organizations, and community groups. The purpose is to develop precollege education projects that focus specifically on the life sciences and, where appropriate, integrate the life sciences with other disciplines such as chemistry, physics, and mathematics. It is intended to build on the unique capabilities of these institutions in making science attractive and interesting to children and in strengthening the science literacy of the general population. Among the overall objectives of the initiative are the following:

- to enhance precollege education in biology and related fields
- to develop programs rich in scientific content that incorporate teaching methods appropriate to the subject matter and the populations to be served
- to increase interest in science education and research careers among women and minorities underrepresented in the sciences.

Washington, D.C., Metropolitan Area Grants

The Institute's Washington, D.C., metropolitan area grants address national concerns regarding the state of science education. They provide unique opportunities at the local level for students and teachers to gain hands-on experiences in the science classroom and research laboratory. The primary recipients are public school students and teachers of Montgomery County, Maryland, though some awards may benefit those in adjacent areas. The Institute works closely with school officials and local research institutions in developing the projects. Although the Institute will consider unsolicited requests, the grants are intended to support objectives through predefined science education programs in the local community.

The URL for the Washington, D.C., metropolitan area grants is <http://www.org/local/>.

Research Resources

This program provides support to research and educational institutions in the United States that serve as national resource laboratories and teaching facilities, including those supplying unique biological stocks and materials. The Institute limits the grants to organizations whose activities not only serve the biomedical research community as a whole, but also coincide with specific Institute interests.

A new initiative announced in 1995, the Research Resources Program for Medical Schools, represents a major expansion of the scope and size of the Institute's support of research institutions. The primary objective is to foster the research activities of medical schools by strengthening their research infrastructure and promoting the early careers of their basic and clinical science faculties. Awards to 30 U.S. medical schools were announced in January 1996.

There will be no research resources program competition in 1997.

The URL for the research resources program is <http://www.hhmi.org/research_resources>.

International Program

The important contribution of scientists abroad to advances in biomedical science stimulated the Institute to launch in 1991 a limited program of international research grants. Small and experimental, the program is limited to selected countries.

International Research Scholars Program

The International Research Scholars Program first offered grants for research in Canada and Mexico. The second round, announced in 1992, went to scientists in Australia, the United Kingdom, and New Zealand. In 1994 a competition was held for scientists in the following 10 countries of the Baltics, Central Europe, and the former Soviet Union: Belarus, Czech Republic, Estonia, Hungary, Latvia, Lithuania, Poland, Russia, the Slovak Republic, and Ukraine. Awards were made in mid-1995.

Awards to scientists in Argentina, Brazil, Canada, Chile, Mexico, and Venezuela were announced in February 1997.

The Research Scholar awards support research expenses, with considerable flexibility, for a term of five years. The recipients are promising scientists who have made significant contributions to fundamental biomedical research and whose careers are still developing. They must hold appropriate full-time academic or research appointments, and may not be citizens or permanent residents of the United States.

In some competitions, nominations of candidates are requested from officials of leading biomedical organizations in the eligible countries and from Institute investigators, review boards, and advisers. Eligible nominees are evaluated by a large panel of scientists with appropriate expertise, and those rated highest are invited to submit a brief research proposal. For the competition involving the Baltics, Central Europe, and the former Soviet Union, an open invitation was issued to the scientific community to submit applications. Future competitions will be announced.

Other International Activities

The Institute has also made an international program grant for joint activities by the U.S. National Academy of Sciences and the Mexican Academia de la Investigación Científica. Few additional awards are anticipated. Applications should only be submitted after consultation with the grants program management.

The URL for the international program is <http://www.hhmi.org/international/>.

Unsolicited Proposals

Although the Institute will consider unsolicited requests, grants are intended to support specific objectives through well-defined programs. Thus, the Institute will only be able to fund a small fraction of unsolicited proposals. The grants program does not support research projects in the United States. Rather, the Institute directly employs independent investigators in its collaborative laboratories at leading universities, research hospitals, and academic medical centers.

Initial correspondence to the Institute concerning support for science education should be a brief letter outlining (1) the specific need and the approach proposed, (2) the institution's special capabilities for implementation, (3) the qualifications of the proposed director, (4) the general plan of action to meet the objectives, and (5) the estimated budget, timetable, and existing funds for the project.

Further information on the Institute's research programs, copies of the annual report, and other publications are available from the Office of Communications at <http://www./hhmi.org/communic/>.

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)

Research Training Fellowships for Medical Students, Continued Award Application (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 (biennial)

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

Assessing Science Pathways, 1996

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 (annual)

Local

Meeting of the Montgomery County Public Schools Student and Teacher Interns at the National Institutes of Health, Student and Teacher Internship Program (brochure, annual)

Program Directories

Graduate Science Education Program

Directory of Predoctoral Fellows (annual)

Directory of Medical Student Fellows (annual)

Directory of Physician Postdoctoral Fellows (annual)

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.

Publications on the HHMI Grants Program may be requested from

Howard Hughes Medical Institute
Office of Grants and Special Programs
4000 Jones Bridge Road
Chevy Chase, MD 20815-6789
(fax) 301-215-8888
(e-mail) grantvpr@hq.hhmi.org

Howard Hughes Medical Institute

Trustees

Officers

Purnell W. Choppin, M.D.
President

Stephen M. Cohen
Vice President and
Chief Financial Officer

W. Maxwell Cowan, M.D., Ph.D.
Vice President and
Chief Scientific Officer

Joan S. Leonard, Esq.
Vice President and
General Counsel

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

C. F. Wolfe
Vice President and
Chief Investment Officer

Principal Staff Members

Craig A. Alexander, Esq.
Deputy General Counsel

Stephen A. Barkanic
Grants Program Officer

W. Emmett Barkley, Ph.D.
Director of Laboratory Safety

David A. Clayton, Ph.D.
Senior Scientific Officer

Winfred J. Clingenpeel
Director of Purchasing

Jill G. Conley, Ph.D.
Grants Program Officer

Barbara Filner, Ph.D.
Grants Program Officer

James R. Gavin III, M.D., Ph.D.
Senior Scientific Officer

Donald H. Harter, M.D.
Senior Scientific Officer and Director, HHMI-NIH Research Scholars Program

Heidi E. Henning, Esq.
Associate General Counsel

Edward H. Klees, Esq.
Associate General Counsel

Robert B. Kuhn III
Director of Human Resources

Dennis WC. Liu, Ph.D.
Grants Program Officer

Margaret Feczko May, Esq.
Associate General Counsel

Robert H. McGhee
Director of Research Facilities Planning

Alan E. Mowbray
Director of Management Services

Robert C. Mullins
Director of Internal Audit

Edward J. Palmerino
Assistant Controller

Susan S. Plotnick
Assistant Treasurer

Robert A. Potter
Director of Communications

Ellen B. Safir
Managing Director–Investments

Mark W. Smith
Controller

Lauren Talner Spiliotes, Esq.
Associate General Counsel

Daniel M. Szente
Managing Director–Equity

Claire H. Winestock, Ph.D.
Senior Scientific Officer

Office of Grants and Special Programs

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

Stephen A. Barkanic
Program Officer
Undergraduate Science Education Program

Jill G. Conley, Ph.D.
Precollege Science Education Program
International Program

Barbara Filner, Ph.D.
Program Officer
Graduate Science Education Program

Dennis WC. Liu, Ph.D.
Program Officer
Public Science Education Program
Research Resources and Information Programs

Maryrose Franko, Ph.D.
Program Analyst
Graduate Science Education Program

Gertrude B. Kelly
Editor
Grants Publications

Maria Koszalka
Program Analyst
Undergraduate Science Education Program

Mary McCormick, Ph.D.
Program Analyst
Graduate Science Education Program

Jean E. Schroeder, Ph.D.
Program Analyst
Precollege Science Education Program
International Program

Patricia Soochan
Program Analyst
Undergraduate Science Education Program

Tim Taylor, Ph.D.
Program Analyst
Graduate Science Education Program

Tony Tse
Program Analyst
Precollege Science Education Program
International Program

Rose A. Napper
Executive Assistant

Patricia A. Anderson
Senior Secretary

Jamie H. Gresty
Senior Secretary

Monica O'Day
Senior Secretary

Moscow Office

Laura M. Kennedy
Program Coordinator
Baltics, Central Europe, and Former Soviet Union Initiative

Howard Hughes Medical Institute

Office of Grants and Special Programs
4000 Jones Bridge Road
Chevy Chase, MD 20815-6789
http://www.hhmi.org/grants/

09-97-021-6K

SE060883

ERIC

U.S. Department of Education
Office of Educational Research and Improvement (OERI)
National Library of Education (NLE)
Educational Resources Information Center (ERIC)

REPRODUCTION RELEASE

(Specific Document)

I. DOCUMENT IDENTIFICATION:

Title: GRANTS FOR SCIENCE EDUCATION 1997

Author(s):

Corporate Source: HOWARD HUGHES MEDICAL INSTITUTE

Publication Date: Sept. 1997

II. REPRODUCTION RELEASE:

In order to disseminate as widely as possible timely and significant materials of interest to the educational community, documents announced in the monthly abstract journal of the ERIC system, *Resources in Education* (RIE), are usually made available to users in microfiche, reproduced paper copy, and electronic media, and sold through the ERIC Document Reproduction Service (EDRS). Credit is given to the source of each document, and, if reproduction release is granted, one of the following notices is affixed to the document.

If permission is granted to reproduce and disseminate the identified document, please CHECK ONE of the following three options and sign at the bottom of the page.

The sample sticker shown below will be affixed to all Level 1 documents	The sample sticker shown below will be affixed to all Level 2A documents	The sample sticker shown below will be affixed to all Level 2B documents
PERMISSION TO REPRODUCE AND DISSEMINATE THIS MATERIAL HAS BEEN GRANTED BY ______ Sample ______ TO THE EDUCATIONAL RESOURCES INFORMATION CENTER (ERIC) 1	PERMISSION TO REPRODUCE AND DISSEMINATE THIS MATERIAL IN MICROFICHE, AND IN ELECTRONIC MEDIA FOR ERIC COLLECTION SUBSCRIBERS ONLY, HAS BEEN GRANTED BY ______ Sample ______ TO THE EDUCATIONAL RESOURCES INFORMATION CENTER (ERIC) 2A	PERMISSION TO REPRODUCE AND DISSEMINATE THIS MATERIAL IN MICROFICHE ONLY HAS BEEN GRANTED BY ______ Sample ______ TO THE EDUCATIONAL RESOURCES INFORMATION CENTER (ERIC) 2B
Level 1 ☑	Level 2A ☐	Level 2B ☐
Check here for Level 1 release, permitting reproduction and dissemination in microfiche or other ERIC archival media (e.g., electronic) and paper copy.	Check here for Level 2A release, permitting reproduction and dissemination in microfiche and in electronic media for ERIC archival collection subscribers only	Check here for Level 2B release, permitting reproduction and dissemination in microfiche only

Documents will be processed as indicated provided reproduction quality permits.
If permission to reproduce is granted, but no box is checked, documents will be processed at Level 1.

I hereby grant to the Educational Resources Information Center (ERIC) nonexclusive permission to reproduce and disseminate this document as indicated above. Reproduction from the ERIC microfiche or electronic media by persons other than ERIC employees and its system contractors requires permission from the copyright holder. Exception is made for non-profit reproduction by libraries and other service agencies to satisfy information needs of educators in response to discrete inquiries.

Sign here,→ please

Signature:	Printed Name/Position/Title: Joseph G. Perpich, M.D., J.D. Vice President for Grants and Special Programs	
Organization/Address: HOWARD HUGHES MEDICAL INSTITUTE 4000 JONES BRIDGE ROAD CHEVY CHASE, MD 20815	Telephone: 301-215-8890	FAX: 301-215-8888
	E-Mail Address: grantvpr@hhmi.org	Date: 10/28/98

(over)