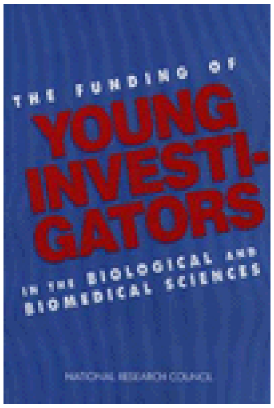

The Funding of Young Investigators in the Biological and Biomedical Sciences

Committee on the Funding of Young Investigators in the Biological and Biomedical Sciences, National Research Council

ISBN: 0-309-58674-7, 128 pages, 6 x 9, (1994)

THE FUNDING OF YOUNG INVESTIGATORS IN THE BIOLOGICAL AND BIOMEDICAL SCIENCES

Committee on the Funding of Young Investigators in the Biological and Biomedical Sciences
Board on Biology
Commission on Life Sciences
National Research Council

NATIONAL ACADEMY PRESS
Washington, D.C. 1994

NATIONAL RESEARCH COUNCIL
COMMISSION ON LIFE SCIENCES
2101 Constitution Avenue Washington, D.C. 20418

CHAIRMAN

May 25, 1994

To the Reader:

Late in the process of preparing this report on the funding of young investigators in the life sciences, the committee obtained data for the NIH grants for fiscal year 1993. As the new data were tabulated in a way that they had not been before, the committee recognized a striking pattern. The number of applications for NIH grants submitted by younger biomedical investigators had plummeted by more than 50% from 1985 to 1993. Until this pattern was recognized, the committee had focused on fluctuations in success rates, and the report continues to reflect that long-standing focus. Readers should know this history in order to understand why the report devotes as much attention to the relatively small, but important, fluctuations in success rates as it does to the dramatic decrease in the number of applications.

The National Research Council considers the findings of this committee so striking and of such concern that it is already developing plans for a followup study to determine the causes of the trend that the committee has discovered. We will try to determine, for example, whether the young biomedical scientists who represent the future of the life sciences are finding other means of research support or are taking jobs in environments where they need not apply for support from the traditional sources. We will also investigate whether young scientists in other life science fields are also applying for research grants in smaller numbers than they have in the past.

Life scientists interested in the future of their field, as well as the many persons who benefit from the discoveries that emerge from biology and biomedical laboratories, owe thanks to the committee for bringing this matter to light.

Sincerely,

Bruce Alberts

Bruce Alberts
Chairman

The National Research Council is the principal operating agency of the National Academy of Sciences and the National Academy of Engineering to serve government and other organizations

NOTICE: The project that is the subject of this report was approved by the Governing Board of the National Research Council, whose members are drawn from the councils of the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine. The members of the committee responsible for the report were chosen for their special competence and with regard for appropriate balance.

The report has been reviewed by a group other than the authors according to procedures approved by a Report Review Committee consisting of members of the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine.

This study by the National Research Council's Commission on Life Sciences was sponsored by Department of Defense PO MDA903-91-M5267, Department of Energy grant DE-FG05-91-ER61167, National Institutes of Health PO 263-MD-107969 and 263-MD-12904, National Science Foundation grant BBS9023767, Markey Foundation grant 90-44, and the National Research Council Basic Science Fund.

Library of Congress Catalog Card No. 94-66103

International Standard Book No. 0-309-05077-4

Additional copies of this report are available from:National Academy Press 2101 Constitution Avenue, NW Box 285 Washington, DC 20055 800-624-6242 202-334-3313 (in the Washington Metropolitan Area)

Printed in the United States of America

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EXECUTIVE SUMMARY

INTRODUCTION

In 1985, 3,040 applications were submitted by scientists 36 years old and younger for individual investigator (R01) grants from the National Institutes of Health, and 1,002 received awards, for a "success rate" of 33%. In 1993, 1,389 applications were submitted by scientists 36 and under for R01 grants, and 302 received awards, for a success rate of 21.7%. The drop in success rates of young investigators followed a general trend of lower success among all applicants. The major difference in age groups was the change in the number of applications. The number of young investigators applying for grants dropped by 54% between 1985 and 1993, whereas the number of older applicants increased by 26%. Even when R23 and R29[1] grant awards are added to the R01 awards, the number of R01 plus R23 awards made in 1985 was 1,308, and in 1993, the number of R01 plus R29 was 527. The implications of these facts for the future of biomedical research are extremely serious. These recent trends in the funding of young biomedical research scientists and the fact that young biological scientists have historically had a smaller base of support to draw on when beginning their careers raise serious questions about the future of life-science research. It is the purpose of this report to present data about the trends and examine their implications. It must remain for another group to try to determine the causes of the trends.

The leading position of the United States in the life sciences and biotechnology is due in large part to generous federal support since World War II. Like the physical sciences in the first decades of this century, the life sciences are in the early phase of a major scientific revolution. This revolution is driven largely by the powerful tools and unifying concepts provided by molecular biology, a field that emerged through basic research on

[1] R23 grants were intended for new investigators until phased out in 1987. R29 grants, also intended for new investigators, were initiated in 1986.

the most fundamental of life processes. Indeed, just as quantum mechanics, a discipline that stems from inquiries into the most fundamental properties of light and matter, is the wellspring of the entire multibillion-dollar electronics and information-processing industry, molecular biology is already beginning to yield applications of enormous medical and economic benefit.

Life-science research is supported through an array of funding sources-including state governments, such nonprofit organizations as voluntary health groups and philanthropies, and private industry-but the federal role remains pre-eminent. The basic research from which modern biotechnology emerged is conducted primarily in universities and funded primarily by the federal government through the National Institutes of Health (NIH) and the National Science Foundation (NSF), and it continues to serve as the wellspring of the insights underlying major new biotechnological innovations.

To maintain its economic and academic leadership in life-science research, the United States must not only maintain a stable funding environment for established life scientists but also provide opportunities for young scientists-our nation's source of established researchers. Indeed, young investigators are not merely apprentices for future positions but a crucial source of energy, enthusiasm, and ideas in the day-to-day research that constitutes the scientific enterprise. Any reduction in the quantity or quality of young people embarking on scientific careers both jeopardizes scientific progress in the years ahead and seriously weakens the current pool of talent from which science flows. Yet, largely as a consequence of changes in the funding environment, many young people perceive biological and biomedical research to be less and less attractive.

PURPOSE AND SCOPE OF THIS STUDY

The mid-1980s marked the beginning of a decline in the fraction of lifescience investigators who were awarded research grants from NIH and NSF. Sufficient funds used to be available to support the top one-third of proposed research programs, but recent years have witnessed intensified competition for increasingly scarce resources. As the fraction of successful grant applications fell to 10–20% in some agencies in the late 1980s, research in the life sciences in the United States came under severe strain. A modest rebound in the last few years has not returned the overall situation to its former state.

This study by the Committee on the Funding of Young Investigators in the Biological and Biomedical Sciences, in the National Research Council's Board on Biology, was prompted by a concern that the diminution of research funds was having a disproportionate effect on investigators beginning their careers as independent research scientists and might be threatening the continued supply of new scientists in basic biological and biomedical research. The committee's concern about the future supply of biological scientists is based on the small increase in recent years in the awarding of doctorates in life sciences and the events reported here that show that the number of young investigators applying for support is decreasing. At the same time, the population of university-based scientists is aging.

The committee is composed of researchers and administrators in academe, industry, and philanthropy. It was charged

- To examine the current funding mechanisms available from major federal and private agencies.
- To examine the current level of funding by these agencies.
- To examine the problems and constraints in the funding system.
- To examine the consequences of inadequacies of funding and in the funding mechanisms.
- To present recommendations for improving the funding system.

The objective is to stimulate increasing numbers of young investigators to pursue academic research careers.

The committee's findings and its recommendations of ways to improve the funding of newly independent investigators are excerpted in this executive summary.

YOUNG INVESTIGATORS AND THE SCIENTIFIC "PIPELINE"

A newly independent scientist who has just secured a junior faculty position has completed a long training process, often lasting 26 years–12 years in elementary and secondary school, 4 years in college, at least 5 years in

Ph.D. training, and usually 2–5 years in postdoctoral research. Of the 4 million U.S. high-school sophomores in 1977, about 10,000 (0.25%) were estimated to receive Ph.D.s in science or engineering by 1992. The process in which students flow through this training process into careers in science or engineering has been referred to as "the pipeline."

The attrition from the pipeline suggests that at all points in the pipeline there are attractive career alternatives to the path that leads to a Ph.D. in science or engineering. Baccalaureates in the life sciences might choose to enter the workforce or go to medical, dental, veterinary, business, or law school, rather than proceed to graduate study. Even for one with a Ph.D. in hand, an academic research position is far from certain. Ph.D. recipients can choose to take industrial or government jobs, rather than continue with academic postdoctoral research. Postdoctoral researchers have a similar array of choices, at a higher level, available to them. The choices that they make depend, in part, on things that can be quantified-salaries, demands for faculty, and the growth of related industries-but also on more qualitative factors, such as the perceived excitement of research in the field or the perceived difficulty in obtaining funding and sustaining a productive research career.

YOUNG INVESTIGATORS: FINDING RESOURCES FOR AN INDEPENDENT RESEARCH CAREER

While setting up a laboratory, young investigators must juggle the demands of research, teaching, departmental responsibilities, and grantapplication writing. Most newly independent life scientists (scientists who have completed their graduate and postgraduate training and have been directing their own laboratory for less than 5 years) are expected to raise funds to support their new research programs and often a substantial proportion of their own salaries. The difficulty is often exacerbated by the need to write multiple grant applications because funding agencies are less likely to provide substantial funds to an untested new investigator than to an established investigator.

The reduced rate of federal funding for young investigators led to a concern that the research funding agencies might be favoring the maintenance of established scientists over initiating the programs of new investigators. Indeed, newly independent investigators usually apply for their first grants in direct competition with established investigators, who are seeking renewals of previous grants or additional funds for continuing projects. In comparison with their senior colleagues, investigators are often criticized for not having sufficient preliminary data to support their applications. That causes pressure to design projects that are based on previous postdoctoral work and to avoid experiments that are novel and perhaps risky, regardless of their potential importance.

Even highly select newly independent scientists, such as recipients of the prestigious Searle Scholar Award, have difficulty in securing funding for research programs. Responses from the 1990 and 1991 Searle award recipients indicate that although 74% received some form of extramural funding to begin their careers, the grants were often small and of short duration. Only a little over half the scholars were funded by major federal agencies, such as NIH and NSF. The average Searle award recipient has been turned down for almost four grants-a remarkable figure, considering their youth and their unusually high quality. Many young investigators that committee members work with daily, whether successful or unsuccessful, describe the current funding situation as "bleak," "dismal," and "depressing." Despite a frequently stated love for research, large numbers of young investigators talk in our laboratories about leaving academic life for the perceived security of industry.

GENERAL CONCLUSIONS

The committee was formed in 1991 because of a perception in the scientific community that newly independent investigators were being selectively disadvantaged over the preceding 5 years as research funds for lifescience research stabilized and the absolute number of research grants actually declined. Newly independent investigators, it was argued, were not competing effectively with more experienced investigators for the increasingly scarce research funds.

The committee found that young investigators suffered in two ways during the late 1980s, when success rates for obtaining awards from the major supporters of biological and biomedical research dropped precipitously. First, the success rate of younger applicants dropped with success rates of applicants of other age groups-a general and shared disadvantage. Second, whereas in earlier years younger applicants consistently had higher success rates than older applicants, their success rate from 1989 to 1991 was lower than that of many age groups-a new and special disadvantage. Thus, in those difficult times, young investigators lost their advantage in the awarding of grants. The number of applications submitted by young investigators was dropping precipitously at this time. The result of the decrease in number of applications and the decrease in success rate was a severe reduction in the number of young investigators being supported by NIH. In 1985, 1,002 R01 grants were awarded to applicants 36 years old and younger. In 1990, only 330 R01 grants were awarded to applicants of that age group; by 1993, the number had dropped to 302. The R23 and R29 grant programs for new investigators did not make up for the decrease in R01 grants. The total of R01 grants plus R23 grants awarded to investigators 36 and under in 1985 was 1,308, and the total of R01 plus R29 grants in 1993 was 527. This committee believes that it is necessary for the continued health of the biological research enterprise that steps be taken to understand and remedy this situation.

PUBLIC AND PRIVATE SUPPORT FOR YOUNG INVESTIGATORS

The committee found striking differences among federal funding agencies in the attention given to ensuring that young investigators were adequately supported. The committee recommends that a public agency that does not have a special grant mechanism for newly independent investigators develop one. The benefit of such programs, aside from their intrinsic value of providing funds earmarked for young scientists, is that they will also provide a framework for long-term development of research personnel in each discipline. The committee encountered a paucity of data on the career paths and funding success of young scientists once they leave graduate school. To ensure a healthy basic-science enterprise, there should be mechanisms for monitoring the scientist pipeline.

In the private philanthropies and voluntary health organizations, there was a remarkable degree of support for young investigators. Many of these organizations favor funding new researchers as a means to direct research toward particular diseases. These organizations have, however, been criticized for a tendency to fund the same few highly qualified scientists, rather than distributing funds more broadly.

DIFFERENCES IN FUNDING FOR BIOLOGICAL AND BIOMEDICAL SCIENCE

The committee noted the difference in overall federal and nonfederal support for biomedical and nonbiomedical, or biological, life-science research. Biologists study phenomena ranging from single plant cells to entire ecosystems with approaches that range from molecular evolution to plant pathology to environmental science. Not only are the funds available for biological sciences much smaller than for biomedical research, but the effort to ensure a future supply of scientists in the field was much less pronounced. The funding prospects appear to be much bleaker for a young biological scientist than for a biomedical scientist, with respect to both the research dollars available and the likelihood of obtaining them. The difficult funding environment in the biomedical sciences, which stimulated this study, has been in place in the biological sciences for many years.

RECOMMENDATIONS

The committee reviewed the mechanisms for funding newly independent investigators in a large number of federal and nonfederal agencies. Chapter 5 of its report contains a list of specific recommendations for the improvement of existing programs and the institution of new ones, from which the following have been drawn.

Following on its findings that young investigators did not fare well during the difficult funding environment of the late 1980s, the committee has designed its recommendations to prevent the recurrence of such events by recognizing that young investigators require special attention at the beginning of their independent research careers. The scientific dominance of the United States in the life sciences is built, at least in part, on the tradition of giving scientists their intellectual independence early, when they are most likely to be innovative and productive. The committee believes that the winnowing process should be least stringent at this point and tighten once the investigators have had some time to demonstrate their ability. The committee recognizes the inherently higher risks in funding less-established investigators but notes that they need not be funded at the levels of established investigators.

Although our recommendations regarding life-science research funding have been framed against the current background of fiscal restraint imposed by our huge national debt, we caution that the financial pressures must not make us short-sighted. The United States still leads the world in most fields of biomedical and biological research. From basic research will flow a host of new approaches to urgent medical, agricultural, and environmental problems. Yet if our lead is to be maintained and if urgent problems are to be solved by American-trained scientists, the federal government and other funding agencies must provide major new resources in support of basic life-science research. Expenditure of the new funds should be viewed as an investment that will not only extend and deepen our understanding of basic life processes, but also speed the development of biotechnology and related industries that will spring from fundamental new knowledge. The United States spent $838.5 billion on health care in 1992 and is expected to spend more than $1 trillion in 1994. The 1992 NIH budget of some $10 billion is only 1% of this total expenditure.

FEDERAL EXTRAMURAL FUNDING OF NEWLY INDEPENDENT INVESTIGATORS IN THE LIFE SCIENCES

National Institutes of Health

The First Independent Research Support and Transition (FIRST) award (R29) program, designed to support newly independent researchers in the initial stage of their research careers, is excellent. However, it is underused by the biomedical community.

To make it a more widely used program, the committee recommends an increase in the total amount of the 5-year award from the current $350,000 to a maximum of $625,000 (i.e., from $70,000 to $125,000 per year). Although the cost of the program will increase, the number of awards should not be diminished, because the pipeline for the supply of biomedical scientists must be maintained to meet the continuing demand. The maximum amount would not be awarded automatically. Rather, like research budgets for R01 grants-the long-standing principal vehicle for NIH support of extramural research-the budgets of R29 awards would be adjustable on the basis of the study sections' recommendations of the funds needed to conduct the research. An increase in the R29 amounts would respond to the most common complaint of newly independent investigators-that the current amount is not sufficient to start up and run a new laboratory in biomedical science, particularly if the investigator must pay a large fraction of his or her salary from the grant.

The R29-application review process should be modified so that study sections are fully aware that the applications have a separate status from R01 applications. The simplest modification would be to review R29 grant applications en bloc at a study-section meeting, giving the chairperson an opportunity to point out the specific conditions of these grants.

The application instructions should clearly state, and the peer-review panels should be instructed, that preliminary data are not necessary in the consideration of a FIRST application but that their absence can be compensated for by the strength and justification of original and untested data.

An R29 recipient should have the option to apply for an R01 grant on the same subject at any time before the expiration of the 5-year period. If the R01 is awarded, the remainder of the R29 money should be returned. That allows a newly independent investigator to use an R29 to gather preliminary results in preparation for a full-fledged R01.

National Science Foundation

NSF has traditionally funded newly independent investigators. The committee encourages NSF to establish an equivalent of the FIRST award that will be funded for terms and in amounts liberal enough, within or beyond the usual practices of the NSF, for adequate support and encouragement of young investigators.

In March 1994, as the committee was preparing this report for publication, NSF's National Science Board approved the initiation of the Faculty Early Career Development Award (CAREER) program. The program will incorporate several existing NSF programs aimed at the young investigator, including the NSF Young Investigators Awards, Research Initiation Awards, and Minority Research Initiation Research Awards. Applicants for the CAREER program will generally be within 4 years of their initial appointment, and applications will be judged on the basis of a career plan that includes research, teaching, and outreach. Awards will be for 3–5 years at a funding level appropriate to the discipline. Depending on program decisions that will be made at the NSF directorate and divisional levels, the program could support a larger number of persons than have been supported under the previous programs.

With time, it will be learned whether the new program answers the need that led this committee to recommend that NSF initiate a program like the FIRST awards.

Locally Administered Funds

The committee acknowledges the importance of locally administered funds, such as the National Oceanic and Atmospheric Administration Undersea Research Program and the Hatch and McIntire-Stennis Act funding program. Those programs, which have been determined to be critical for the universities and for individual research efforts that need extra support, should be maintained and strengthened.

U.S. Department of Agriculture

The National Research Initiative Competitive Grants Program (NRICGP) was adopted by Congress and implemented in 1991. The President's budget for 1994 calls for an increase of the budget to approximately $130 million. This program will have a large impact on the funding of newly independent investigators in the 1990s. The committee recommends continued support and increased funding to the full $500 million for agricultural research recommended in a 1989 National Research Council report but in increments greater than the $50 million per year adopted by the Office of Management and Budget.

NONFEDERAL FUNDING OF NEWLY INDEPENDENT INVESTIGATORS IN THE LIFESCIENCES

Industrial Funding

Newly independent investigators and the graduate and postdoctoral students whom they might train form the pool of scientists on which industry draws for its own research efforts. Although many industrial firms support academic research, the amount of support and the mechanisms of support vary widely. Thus, academic scientists interested in obtaining industrial funding must spend considerable time locating appropriate sponsors. Individual firms approach solicitation, review, and funding of academic research differently. Considerable time and money must be spent by each company with an interest in the funding of basic research. The ad hoc nature of this enterprise tends to militate against the support of newly independent investigators.

The funds spent by industry to solicit and review proposals and to support new investigators could be spent more effectively through the establishment of a foundation to support these scientists. The common goal would be cost-effective use of resources to attract and increase the nation's pool of scientists, but, because of the highly competitive, secretive nature of industrial research, cooperative funding of a foundation of this nature would be possible only if the research were structured to emphasize fundamental new knowledge. Industry could support the foundation through endowments, annual donations, or multiyear subscriptions. Funding might be scaled to the size of the participating companies. The tax treatment of company support and the framework within which any intellectual property would be administered warrant separate expert study.

Philanthropic Funding

The philanthropic foundations are to be commended for their efforts in funding newly independent scientists, for developing grants that directly address the specific needs of this cohort, and for identifying and funding "orphan" fields that are not well supported by other, larger institutions. As with many other organizations, it would be valuable for the general research funding mechanisms used by philanthropies to incorporate data-collection features that allow more accurate monitoring of the flow of students and researchers in the scientist pipeline.

Voluntary Health Organization Funding

The voluntary health organizations (VHOs) should be encouraged to continue their commitment to research on prevention, diagnosis, and treatment of disease, despite the pressure to devote more of their income to service functions. The record of VHO programs reveals that these organizations are heavily committed to supporting young investigators. VHOs are urged to continue, and if possible expand, that commitment.

University Support

New and especially younger faculty are the life blood of the university system, providing the surest protection against academic stagnation and accelerating the expansion of scientific frontiers by applying new techniques and interdisciplinary work. Because it is critical that a university further its new faculty members' careers, we recommend the following.

- To the greatest extent possible, more support should be channeled into startup costs and into salary support to ensure that teaching and administrative responsibilities of newly independent investigators are appropriate. Intramural support programs that favor newly independent investigators, in addition to startup packages, constitute effective mechanisms for rapid adjustment of scientists' research perspectives and goals.

- Scientists should be provided with both encouragement and advice in seeking extramural support.
- Newly independent investigators should have access to graduate students to facilitate their own maturation and encourage a sense of community.
- Each university should establish a university-wide standing committee to examine continuously the special needs of its new faculty and to develop the best possible support packages for them.

SUPPORT FOR NEWLY INDEPENDENT FEMALE INVESTIGATORS AND UNDERREPRESENTED MINORITY GROUPS IN THE LIFE SCIENCES

A detailed analysis of these issues is outside the purview of this committee. Nevertheless, the committee believes that the continued low enrollment record of minority-group members and the failure of women and minority-group members to gain access to positions of authority in the life sciences is a serious issue with direct implications for the long-term vitality of the enterprise.

The committee could identify no difference in likelihood of funding between women and men in the life sciences, once they had assumed faculty positions. The sex disparity identified was the decreased likelihood that women would achieve positions in which they would be eligible to apply for grants. Although almost 40% of all newly trained biologists are women, women made up just 18% of NIH competing research-project grant applicants in 1991. That might be because the percentage of women in the biology workforce has increased only recently, the contingent is relatively younger and junior in rank, and, at some institutions, junior faculty sometimes do not qualify to serve as principal investigators. The success rate of NIH postdoctoral National Research Service Award F32 applications by women decreased slightly from 44.2% in 1990 to 42.2% in 1991.

Numerous local and national initiatives have been designed to attract members of underrepresented minority groups to careers in the life sciences. Institution-wide programs for college undergraduates and high-school students bring students in underrepresented minorities to university and college campuses for summer laboratory research. But the programs often lack followup mechanisms to provide advanced alternatives for study in summers after their first experiences. Also missing is a stable source of funds to administer the summer programs. NSF, NIH, foundations, and VHOs should be encouraged to contribute funds. Individual investigators also should be mobilized by their institutions to participate in these programs. To link the institutions and those who could benefit from the programs, there should be a coordinating national center that can maintain a dynamic inventory of programs and people to facilitate appropriate matching of the two. The center must have knowledge of both the resources, including local and national programs, and the programs for candidates at every stage of preparation from high school (or even earlier) through academic junior appointments to full-time industrial or government positions.

1

INTRODUCTION: NEWLY INDEPENDENT INVESTIGATORS[1] IN THE LIFE SCIENCES[2]

The leading position of the United States in science and biotechnology is due in large part to generous federal support since World War II. Indeed, although there have been severe budget deficits in recent years, the Administration and Congress have made concerted efforts to maintain steady support for science and technology and to allow for their moderate growth.

Although the United States has lost competitive ground in many other fields, it is still consistently ranked as the world leader in biotechnology, which has been cited as a key emerging technology (18,33,70,72). Primarily through the practical application of the tools of biotechnology, life-science research has joined other major scientific disciplines-such as chemistry, engineering, and physics-in having an important role in fields as diverse as medicine, food production, environmental research, engineering, and materials fabrication (27,34,52,69,115).

To maintain its economic and academic leadership in life-science research, the United States must not only maintain a stable funding environment for

[1] A *newly independent investigator* is defined in this report as a scientist who has completed graduate and postgraduate training and has been directing his or her own laboratory for less than 5 years.

[2] *Life sciences* is a broad term that covers many fields. In this report, life sciences are divided into biomedical (Chapter 2) and biological (Chapter 3) disciplines mainly because their support comes from separate agencies with different traditions.

established life scientists, but also provide opportunities for new generations of life scientists. Young scientists are our nation's source of established researchers. However, of the 4 million U.S. high-school sophomores in 1977, only 10,000 (0.25%) were estimated to receive Ph.D.s in science or engineering by 1992 (53). The numbers of new Ph.D.s remained level or declined slightly in the 1980s, although a mild upturn has occurred in the first years of this decade. Fewer U.S. citizens have entered graduate school, and graduate positions are increasingly being filled by young people from abroad (74). The latter are an important source of our nation's scientific talent, but an increasing fraction of these are returning to their home countries after completing their training in the United States. Combined with those losses of talent is the increase in the average age of the academic life scientist over the last decade (62,117,118); many are expected to retire by the turn of the century. In 1991, 18% of nonacademic scientists and engineers in the United States were 55 years old or older-a percentage higher than that in France, Germany, or Japan but lower than that in the United Kingdom (112).

Grants for research in the life sciences are available from federal and state governments, industry, and nonprofit organizations, such as voluntary health and philanthropic organizations. Support from the federal government and nonprofit sources is directed mainly to basic research, most of which is done at universities, and the federal government is the major provider of research dollars for basic science (130); industrial support is mainly for the development of specific products (110). The mid-1980s marked the beginning of a decline in the fraction of life-science investigators who were awarded research grants from the National Institutes of Health (NIH) and the National Science Foundation (NSF). Sufficient funds used to be available to support the top one-third of proposed research programs, but demand has outstripped the supply of funds in recent years. Although the success rates in 1991 and 1992 showed an increase over that in the late 1980s, the rate in 1993 was again down sharply. As the fraction of successful grant applications fell to 10–20% in some agencies in the late 1980s, research in the life sciences in the United States came under severe strain. This study, by the Committee on the Funding of Young Investigators in the Biological and Biomedical Sciences, in the National Research Council's Board on Biology, was prompted by a concern that the diminution of research funds was having a disproportionate effect on young investigators and might be threatening the continued supply of new scientists in basic biological and biomedical research (11,13,15,30,34,41,48,49,54).

A reduction in the funding rate is especially hard on the morale of newly independent investigators. Because young investigators are responsible for a large share of university teaching, their low morale and career enthusiasm infect the students who will form the next generation of scientists. The reduction in resources led to a concern that the research funding agencies might be favoring the maintenance of established scientists over initiation of the programs of new investigators. Indeed, newly independent investigators usually apply for their first grants in direct competition with established investigators, who are seeking renewals of grants or additional grants. In comparison with their senior colleagues, young investigators are often criticized for not having sufficient preliminary data to support their applications. That causes pressure to design projects that are based on previous postdoctoral work and to avoid experiments that are novel and perhaps risky, regardless of their potential importance.

The choice of a research career is a long and highly selective process. Scientists usually undergo more than 12 years of post-secondary-school preparation to achieve the competence necessary to do independent research (60). Most young life scientists are expected to raise funds to support their new research programs and often a substantial proportion of their own salaries. While setting up a laboratory, young investigators must juggle the demands of research, teaching, departmental responsibilities, and grant-application writing. The difficulty is often exacerbated by the need to write multiple grant applications because funding agencies are less likely to provide substantial funds to an untested new investigator; for newly independent investigators at institutions that do not provide full salary support, writing multiple grant applications is common. Universities often provide startup funds to help equip new laboratories and to support the first year or two of research. These funds are usually insufficient to maintain the full thrust of the research if funding for the first extramural grant is not secured. The need to write grant applications during the critical period of launching a research program draws the investigator's time away from research.

Even highly select groups of newly independent scientists, such as the recipients of the prestigious Searle Scholar Award, have difficulty in securing funding for research programs. Responses from the 1990 and 1991 Searle award recipients indicate that although 74% received some form of extramural funding to begin their careers, the grants were often small and of limited duration. Only a little over half the scholars were funded by the major federal agencies, such as NIH and NSF. The average Searle award recipient has been turned down for almost four grants-a remarkable figure, considering their youth and their unusually high quality.

Young investigators, whether successful or unsuccessful, describe the current situation as "bleak," "dismal," and "depressing." Despite a frequently stated love for research, large numbers of young investigators talk about leaving academic life for the perceived security of industry. The following statement by a Searle award recipient, one of the 15% of the nominees who received this prestigious award, exemplifies the impact of funding problems on teaching and public service. This recent recipient of a Searle and NIH award had been turned down for funding on five previous grant applications.

> As I see it, the long term effects of the grant situation are as follows: 1) We are losing potentially excellent educators and researchers to other careers. . . . I love my job and I am sorry that my students see only the stress and the heartache associated with it. 2) I am pressed to publish papers if I want to maximize my chances for securing support. . . . I wish I had time to publish complete pieces of work but I don't. I have to publish what we have. 3) Projects with long-term pay-offs are not possible without stable funding. 4) Because research has turned into fund-raising, the academic job today is no longer what it used to be. It used to be teaching, research and public service. Today we pay lip service to teaching and public service. The academic profession has turned into business. . . . I genuinely enjoy teaching, both in the laboratory and in the classroom (particularly at the undergraduate level). . . . But it isn't a pleasure when one is torn between the demands of students and the demands of a research career (i.e. granting agency). Who loses? The students lose and hence the public loses. Teaching and research are intimately linked. If we are secure in our ability to do research, we will have the time and inclination to teach and to teach with the same commitment, zeal and effort as we do research.

The Committee on the Funding of Young Investigators in the Biological and Biomedical Sciences is composed of researchers and administrators from academe, industry, and philanthropy. It was convened to examine the basic life-science research funding climate as it applies to newly independent investigators. The committee was charged with examining the mechanisms of funding of newly independent investigators in the major federal agencies and private organizations, the current state of such funding, and the major problems and constraints in the funding system. It was also charged with determining the impact of changes in the funding environment on the recruitment and retention of young investigators in basic life-science research. The committee's findings and its recommendations of ways to improve the funding of newly independent investigators are presented in this report.

The committee restricted its attention to the newly independent investigator who is intending to conduct life-science research. It did not address issues that are peculiar to the career paths of investigators in clinical medicine; the Institute of Medicine is conducting a study of career choices for clinician scientists.

Chapter 2 provides an overview of the research budgets and funding mechanisms used to support life-science research initiated by newly independent investigators; it describes support of biomedical research and gives special attention to a comparison of support for the newly independent scientist and the established scientist. Chapter 3 supplements the overview information provided in Chapter 2 and treats specifically the support of biological research. The separation of the two branches of the life sciences permitted equal attention to their different funding mechanisms and research environments. The future supply of new investigators is discussed in Chapter 4, with emphasis on the recruitment of people from underrepresented minority groups and on ways to further the careers of newly independent female scientists. Chapter 5 presents the committee's conclusions and recommendations. An appendix provides detailed data that expand on information presented in Chapter 2.

2

EXTRAMURAL FUNDING OF NEWLY INDEPENDENT INVESTIGATORS IN BIOMEDICAL RESEARCH

OVERVIEW OF FEDERAL SUPPORT OF LIFE-SCIENCE RESEARCH

The U.S. federal government in 1992 provided 43% of the national expenditure for life-science research and development; the remainder was provided primarily by industry with about 2% each from academe and nonprofit philanthropic and voluntary health organizations (130). Since 1980, the federal financial commitment to health research and development has steadily increased while support for other disciplines in the natural sciences (except space research) changed little (130). As a result, in recent years the major recipients of federal research funds have been life scientists (Figure 2-1).

In 1993, the federal government allocated over $6.6 billion for basic life-science research and $4.7 billion for applied life-science research. Those funds were distributed by a large number of federal agencies, as Table 2-1 indicates. Each federal agency has a specific mission, although missions overlap (40). Most of the funds for basic life-science research are allocated for biomedical research through the Department of Health and Human Services (DHHS), primarily through the National Institutes of Health (NIH). The Department of Agriculture (USDA), the Department of Energy (DOE), and the National Science Foundation (NSF) provide the majority of the funding for nonbiomedical life-science research, which is discussed in detail in Chapter 3.

Federal agencies dispense their funds for basic life-science research in a variety of ways. Some, such as the Department of Veterans Affairs, support intramural programs exclusively. NSF relies entirely on external grants to support investigators at universities and research institutions. Most agencies-such as NIH, DOE, the Department of Defense, and USDA-use a combination of internal and external grants.

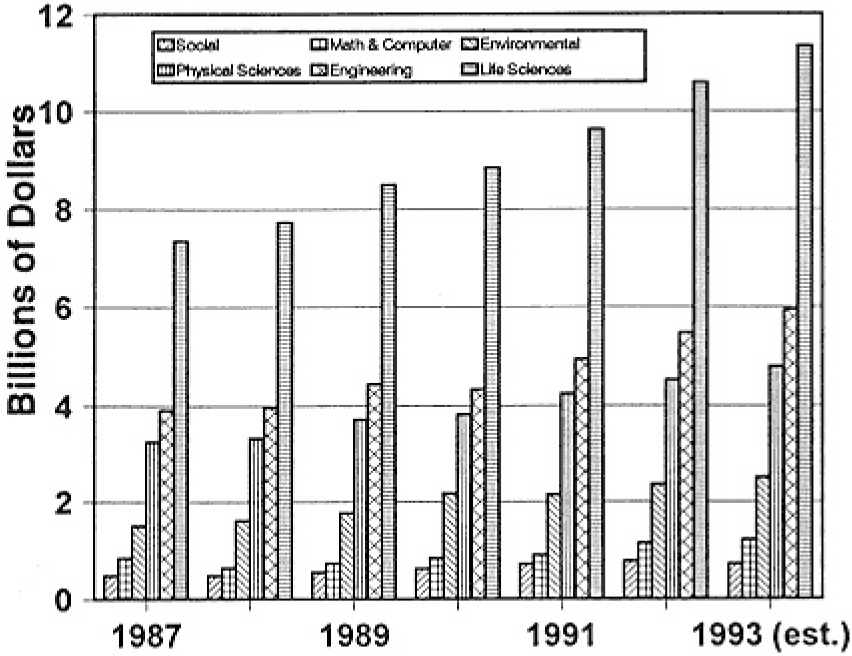

Figure 2-1
Federal obligations for total research, by detailed field of science and engineering, FY 1987–1993.
Source: NSF (133).

Most U.S. young investigators in the life sciences are employed at universities and research institutes and depend on extramural federal funding to initiate and support their independent research. Of all 1989–1990 doctoral recipients, 64% were employed by educational institutions, 16% by industry, 11% by government, and 9% by nonprofit organizations (unpublished data from the National Research Council 1991 Survey of Doctorate Recipients,

Table 2-1 Estimated Federal Obligations for Applied and Basic Research in Life Sciences, by Agency, FY 1992

Agency	Applied Research, Thousands of Dollars	Life Sciences as Percent of Total Applied-Research Budget	Basic Research, Thousands of Dollars	Life Sciences as Percent of Total Basic-Research Budget
Department of Agriculture	473,960	72.0	519,192	84.5
Department of Commerce	85,872	17.3	n/a	n/a
Department of Defense	205,443	6.8	128,316	11.7
Department of Education	18,311	12.8	1,440	22.9
Department of Energy	84,202	4.7	173,187	9.6
Department of Health and Human Services	2,728,668	80.5	4,882,783	88.6
Department of the Interior	95,392	28.5	6,300	2.7
Department of Justice	400	2.4	300	0.6
Department of Transportation	6,138	3.8	n/a	n/a
Department of Treasury	160	0.75	n/a	n/a
Department of Veterans Affairs	179,839	91.1	15,385	98
Agency for International Development	287,590	87.2	3,953	79.6
Environmental Protection Agency	128,362	41.1	40,662	39.5
National Aeronautics and Space Administration	136,876	7.8	56,901	3.0
National Science Foundation	9,682	7.5	280,988	15.5
Smithsonian Institution	n/a	n/a	34,219	34.2
Tennessee Valley Authority	2,458	11.2	1,862	82.8

Source: NSF (132).

personal communication from Dan Pasquini, Office of Scientific and Engineering Personnel). They begin to apply for research grants either shortly before assuming their new position or immediately thereafter. The grant application typically includes an outline of the investigator's research accomplishments, the rationale for the research, and a detailed description of the experimental plan. It is evaluated by the agency staff, a panel of external reviewers who are experts in the field, or a combination of the two (64,68,76,90,103,113,120,144). Proposals are then ranked according to the applicants' professional qualifications, the quality and importance of the proposed research, and the likelihood that the applicants can achieve their research aims. Grants are funded in descending order of rank; occasionally, out-of-order funding occurs to fulfill programmatic goals of the agency or to encourage newly independent scientists or particularly innovative and risky proposals.

A grant budget typically covers both the direct and indirect costs of performing the research. The direct costs may cover some portion of the salary of the principal investigator, the salaries of others who will carry out the research, supplies, travel, equipment purchases, and miscellaneous charges. All these expenditures are largely under the control of the principal investigator. Indirect costs defray institutional costs for carrying out the research, such as the costs of building maintenance, common facilities, and support services.

In addition to grants to individuals, many federal agencies provide grants to groups of scientists who have common research interests. These grants are designed to take advantage of the synergism that can result when several scientists collaborate on a common problem. For example, a core research facility might be funded to prepare monoclonal antibodies for a group to reduce duplication of effort in individual laboratories. Research program project grants (P01), center core grants (P30), and specialized center grants (P50) at DHHS are used by NIH[1] for these purposes (146). Research program project grants are funded from the same part of the agency's budget

[1] On October 1, 1992, in accordance with the provision in PL 10232 entitled "ADAMHA Reorganization Act," the research programs of the Alcohol, Drug Abuse, and Mental Health Administration were transferred to NIH with three research institutions: the National Institute on Alcohol Abuse and Alcoholism, the National Institute on Drug Abuse, and the National Institute of Mental Health.

as individual investigator-initiated grants, whereas center grants are a separate line item in the federal budget.

Several federal agencies provide a flexible source of funds to local directors with allocations based on mathematical formulas that include the size of the research institution (see Chapter 3). Examples of this form of funding are the National Oceanic and Atmospheric Administration Sea Grant funds, the USDA Hatch Act funds, and Fish and Wildlife Cooperative Research Program funds. These funds, although not earmarked for newly independent investigators, are sometimes used by local institutions as startup funds to establish the laboratories of these investigators. NIH terminated such a program, the NIH Biological Research Support Grant (BRSG).

FEDERAL FUNDING OF BASIC BIOMEDICAL RESEARCH[2]

From the 1940s until the late 1980s, the federal government emerged as the major underwriter of biomedical research. Before 1940, philanthropy and industry outpaced the federal government in support of research in the biomedical sciences. In recent years, industry has surpassed government expenditures (Figure 2-2) (95). Nevertheless, spending by every sector has increased dramatically. For example, although the relative contribution by nonprofit organizations remained about the same between 1982 and 1992 as a percentage of the total biomedical research and development (R&D) budget (4%), the actual expenditures almost tripled from $390 million to $1,196 million (95).

The largest source of federal funds for biomedical research is NIH, whose primary mission is to improve the health of the U.S. population. With an annual budget of $8.4 billion in FY 1991, NIH provided approximately 29.2% of the national expenditure in health research and development (95). Of the

[2] Data in this section that are not otherwise attributed were obtained through personal communication in 1991–1994 with L. Nierzwicki and W. McGarvey, D. Worrell, V. Fadeley, R. Moore and J. Tucker, Division of Research Grants, NIH; with G. Galasso, Extramural Affairs, NIH; with J. Hill, National Institute of Allergy and Infectious Diseases (NIAID), NIH; and with B. Holiday, Office of Assistant Secretary for Health.

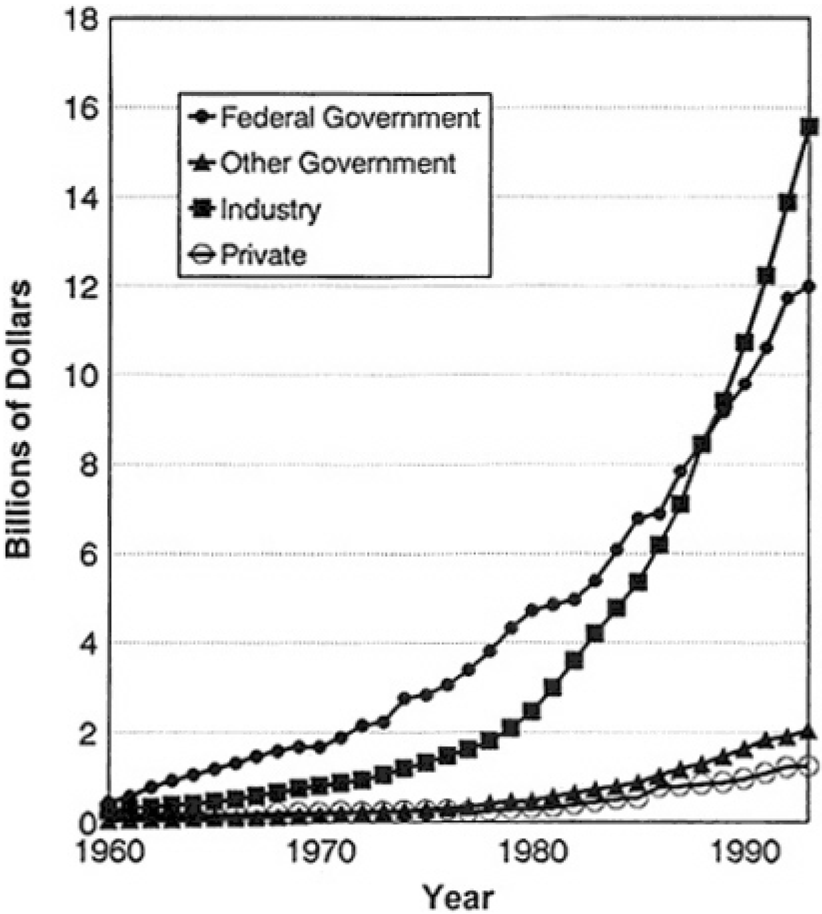

Figure 2-2
National support for health research and development, by source, 1960–1993. Source: Personal communications, NIH Division of Planning and Evaluation, Planning and Policy Research Branch. 1992 figures are estimates and 1993 figures, projections.

NIH budget, about 83% (Figure 2-3) went to extramural awards to independent hospitals, research institutions, and institutions of higher education in 1991 (95). The dominant role of NIH in funding biomedical research means that any perturbations in the manner in which its funds are distributed have profound effects on the nation's research.

GRANTING VEHICLES[3]

Extramural grants are funds provided by NIH for research, training, and contract support outside NIH. Research grants are extramural awards made for research projects, research centers, and other research. NIH groups research grants into activities and identifies them with activity codes; for example, research projects are coded as R01, R22, R23, R29, R35, R37, R44, P01, P42, U01, etc. The *traditional research project grant* (R01) is the long-standing principal vehicle for the support of extramural research by NIH, the Food and Drug Administration, the Centers for Disease Control and Prevention (CDC), and the Agency for Health Care Policy and Research. R01 grants were designed to support well-specified, discrete projects performed by principal investigators holding positions in universities, colleges, or research institutions (146). The grants have a term of 3–5 years, have no budget ceiling, and cover research-related expenses-such as equipment, supplies, and support-service charges-and the salaries of postdoctoral researchers, graduate students, and technicians. In recent years, R01 budgets have covered an increasing fraction of the salaries of the principal investigators. In FY 1991, the average term of NIH support for R01 grants was 3.8 years with an average annual total cost of $184,000 (95). Successful R01 applications require substantial technical and experimental justification and benefit greatly from extensive preliminary results, so newly independent researchers are at a disadvantage in competing for them.

In 1971, NIH initiated its first program in which newly independent investigators were distinguished as a cohort from more seasoned investigators. The goal of the *New Investigator Research Award* (R23) was to provide funds to launch the independent research programs of senior postdoctoral fellows

[3] In many circumstances, *awards and* grants are used as the official designations for different funding vehicles that use the competitive peer-review process. For simplicity, this report will refer to such vehicles as grants.

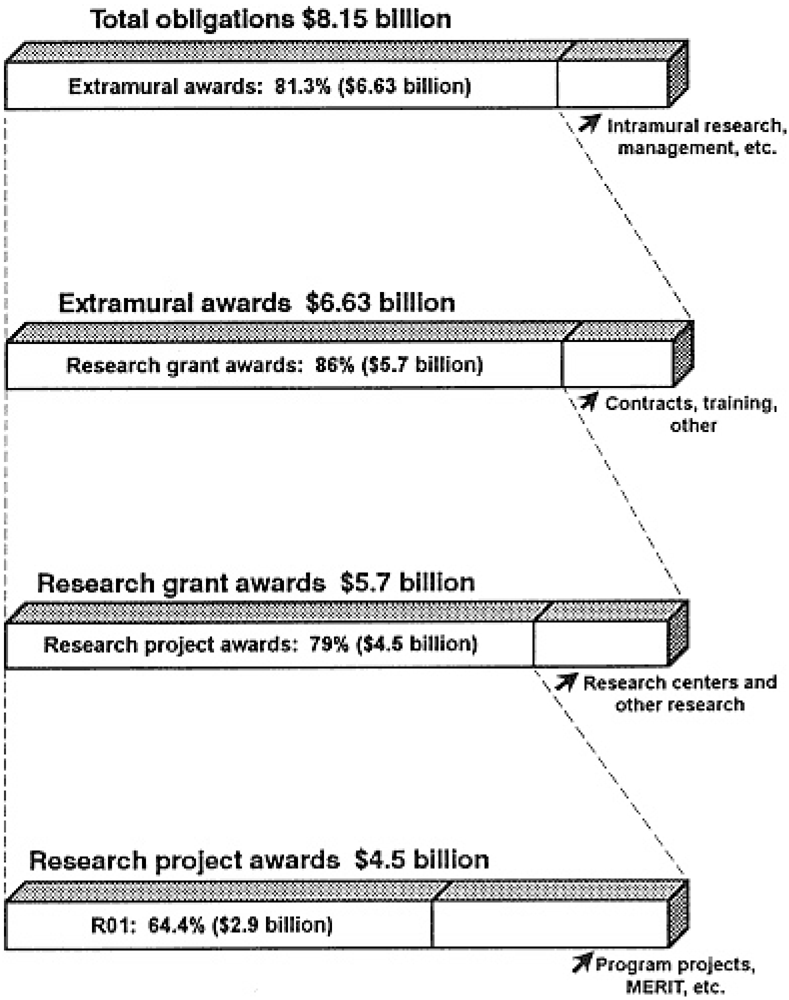

Figure 2-3 NIH obligations, FY 1991.
Source: NIH (95, Tables 8, 18, and 29).

in basic and clinical science (146). The grant was designed as a 3-year award with a maximum total value of $107,500.

The R23 program was phased out beginning in 1986. Its demise resulted from three underlying problems. First, as postdoctoral tenures lengthened beyond the 2–3 years normally supported by fellowship programs, the R23 grant became a mechanism whereby established investigators could support senior postdoctoral fellows in their laboratories. It was impossible for the peer-review panels to distinguish between R23 applicants who were truly independent and those who were not. Second, the small R23 grant budget discouraged applications from precisely the investigators that the grant was designed for-starting assistant professors. With the advent at many institutions of a requirement that assistant professors pay a substantial part (or even all) of their salaries from their research grants, the R23 budget limit proved particularly unattractive. Third, the restriction of the grant to 3 years required investigators to reapply for grants after just 2 years of funding. That encouraged less-risky, short-term experiments that were continuations of postdoctoral studies and discouraged the initiation of innovative research programs.

The R23 grant was replaced in 1986 by the R29 or *First Independent Research Support and Transition (FIRST) Award*. FIRST grants were developed to support the research of newly independent biomedical researchers-those genuinely independent of other principal investigators and in the initial stages of their research careers (87,99,146). R29 grants are unusual in that they are nonrenewable 5-year grants with a maximum direct cost of $350,000, or $70,000 per year. In FY 1990, after budget negotiations, the average R29 grant provided a direct cost of $64,612 per year. The longer funding period (i.e., relative to R23 grants) was intended to provide young scientists with sufficient time to demonstrate the creativity and productivity needed to obtain an R01 grant. From 1986 to 1993, almost 4,000 R29s were awarded by NIH and ADAMHA.

No formal procedure ensures that R29 applications are distinguished in the review or funding process from R01 applications. Both types of applications are reviewed by the same peer-review groups in the same sessions. In addition, funds for R29 grants are not separately budgeted by the NIH institutes; newly independent investigators compete for the same funds as their more seasoned colleagues. The burden of ensuring that new investigators are given a fair opportunity to compete for funds is on the members of the review groups or study sections at NIH that evaluate applications. In the committee members' experience, most study sections judge R29 applications more leniently than R01 applications. The reviewers tend to require less preliminary evidence that a proposed project will succeed and overlook errors in "grantsmanship," such as proposing far more than can be accomplished in the grant period.

The NIH staff and their advisory councils provide a second level of application approval and budget review. Some institutes have encouraged the out-of-order funding of some R29 applications whose scores were below the funding cutoff. In 1990, for example, the advisory council of NIAID decided to fund 40% of the approved R29 applications, irrespective of whether their scores were competitive with those of R01 applications.

The consequence of such practices is that a newly independent investigator has a somewhat greater likelihood of being funded through the R29 mechanism than through the R01 mechanism. For example, in 1993, the success rate, defined as the percentage of reviewed grant applications that are funded, was about 27% for R29 applications and about 21% for R01 applications (NIH/SAES data from Robert Moore and James Tucker).

R29 grants, which provide one avenue for improving the likelihood of funding of new biomedical investigators, are underused. In 1993, only 36% of new investigators under the age of 36 who applied for R01 or R29 grants chose R29 grants (NIH/SAES). The explanation lies in two drawbacks of the program. First, the direct-cost ceiling of $350,000, which is distributed over 5 years, is inadequate for many newly independent biomedical investigators who must support both research and salaries. The second drawback is ironically one of the program's strengths. The commitment of 5 years of stable support is important for a fledgling independent research project. Yet, by the fourth year of a successful program, the $70,000 budget is often insufficient to support the expanding scope of the research project and the efforts of additional graduate students and postdoctoral fellows. The investigator is then forced to write another grant application, an effort that is hindered by the restriction that the aims of the new grant cannot overlap with those stated in the original R29 application.

In addition to the R01 and R29 grants to support specific research projects, NIH sponsors grants that provide salary support to independent investigators. The most prestigious of these is the *Research Career Development Award* (RCDA or K04), a 5-year salary award for "persons who have demonstrated independent research accomplishments but need additional time in a productive, scientific environment to establish an independent research program" (94,146). To be eligible, a candidate must have "at least 5 years of postdoctoral research experience, including 2 years as the principal investigator of an independent peer-reviewed research grant" (94,146). The novel aspect of this award is a "matching" requirement from the host institution to reduce teaching and administrative responsibilities during the duration of the award so that the recipient can focus on research. The award places no limit on an investigator's research plans or additional research support.

FUNDING ENVIRONMENT

In FY 1990, the Public Health Service-primarily through NIH, ADAMHA, and CDC-was funding almost 40,000 research-related grants amounting to a yearly expenditure of $6.4 billion. Because NIH supported the majority of the research, only the NIH statistics and programs are discussed here. The percentage of the NIH extramural research budget that is allocated to research projects and other types of research-related grants rose from 57% in 1980 to 81.3% in 1991 (see Figure 2-3). The individual institutes of NIH independently determine their research priorities, and this is reflected in the emphasis that each places on individual research grants versus larger project and center grants. In 1991, the National Cancer Institute (NCI) allotted the smallest percentage of funds (59%) to R01s; the percentages of the National Institute of Neurological Disorders and Stroke (83%), the National Eye Institute (79%), and the National Institute of General Medical Science (79%) were among the largest (95,101).

The confidence of newly independent investigators that they could reasonably expect initial funding for establishing a laboratory was eroded during the period 1985–1990 by the sharp decline in the percentage of new and competitively funded grants from NIH (Figure 2-4). As the number of their applications rose from 18,470 to 20,154 during that period, the success rate declined. The overall success rate had remained roughly constant over 1985–1988 at around 35%. The rate fell in 1989 to 28% and in 1990 to about 25%. There was an apparent rebound in the success rate in 1991 (Figure 2-4), but it dropped to the low 20% range in 1993. The indicated rebound in success rates in 1991 must be considered in the light of other events that were occurring. NIH counts amended applications (applications that are resubmissions of previously unsuccessful applications) only once if they are submitted in the same fiscal year. That is, even if an application is reviewed more than once in one fiscal year, it is counted only once for purposes of calculating the annual success rate. As the success rate fell from 1988 to 1990, the number of amended R01 applications reviewed by NIH increased by 27% (91,104). By 1990, 31% of all applications and 41% of competing renewal

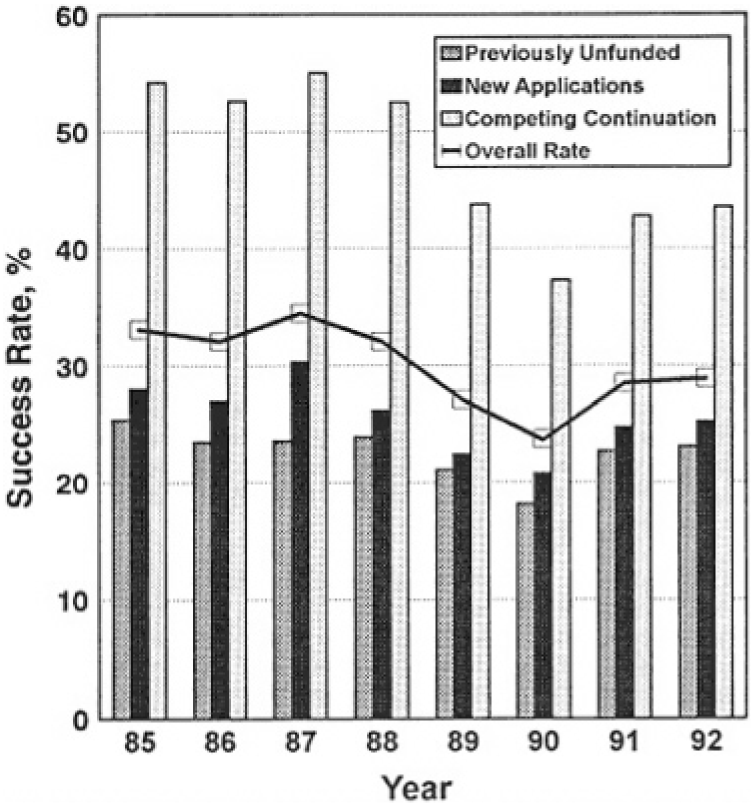

Figure 2-4 Success rates of all (except ADAMHA) NIH competing research-project applications, FY 1985–1992.
Source: NIH (102).

applications reviewed by the study sections were amended applications (104). Because applications that are amended (and they are often extensively revised) are counted only once, the success rate appears higher than it would if amended applications were treated as separate submissions. The success rates calculated by including and excluding amended applications are different by a factor that is directly proportional to the fraction of amended applications submitted to NIH. In fact, at some of the smaller NIH institutes, the success rate fell from 1991 to 1992 to about 10% of *reviewed* applications.

The decrease in the success rate is attributed to several causes. First, a 1986 policy change within NIH increased the length of research grants. Previously, both new and competing renewal applications were usually funded for 3 years, with 5-year grants restricted to seasoned investigators with proven track records. The result was that the average period for which funds were committed to a project was 3.3 years (89). The primary problem with 3-year grants was that investigators were required to submit competing renewal applications after 2.3 years of work. The consensus among the study sections, advisory councils, and investigators was that 2.3 years was not sufficient to generate adequate data to judge the success of a project. That was especially true for new investigators, who were beginning projects and establishing laboratory groups simultaneously.

Several steps were set in motion in response to that concern and to make grant application and review more efficient. First, the 3-year R23 grant was replaced with the 5-year R29 grant. Second, study sections were required by most advisory councils to justify any reduction in the term of a competing renewal request. Third, in 1986, several new programs were initiated to provide 7 or 10 years of support for well-established investigators.

The *Method to Extend Research in Time Award* (MERIT or R37 award) (146) consists of an initial 5-year grant that can be extended for 3–5 years by action of the advisory council alone on the basis of a highly abbreviated renewal application. R37 grants are restricted to investigators whose "research competence and productivity are distinctly superior and who are likely to continue to perform in an outstanding manner" (146). Investigators could not apply for MERIT grants; rather, study sections could make recommendations to institute staff, who selected those likely to continue productive careers. The applications were then presented to the advisory councils for approval. By 1990, a total of 895 MERIT grants had been given, representing 5.3% of the research-project grants budget and 8.3% of the competing and continuation R01 budget. By 1993, 1,789 MERIT grants had been awarded since inception of the program.

Another new long-term grant, the *Outstanding Investigator Grant* (OIG or R35), also provides long-term support (7 years) to proven investigators (146). It differs from MERIT awards in that investigators may apply for them through the regular peer-review channels. R35 grants are designed to consolidate an investigator's support from two or more funded research-project grants within an institute with new funds for innovative research. Compared with the R37 program, the R35 program is small. NCI is the primary distributor of the R35 grant (93,95).

The increase in the average term of an NIH grant resulted in an increase in grant period from 3.3 years in 1980 to 4.2 years in 1990 (95). That meant that a greater percentage of the extramural-research dollars was unavailable for new grants in the fourth and fifth years of the new programs. The percentage of the extramural budget that was tied up in the noncompeting continuation of funded projects rose from 66% in 1985 to 77% in 1990 (Figure 2-5) (88,95,145). The percentage of funds committed to noncompeting continuations fell in 1991 to 73% and in 1992 to 71%, indicating that the system is slowly beginning to adjust as NIH strives for an average grant length of 4 years to improve the prospects for new grants.

Two additional financial pressures exacerbated the decline in the funds available for supporting new projects and the decline in success rate (12). First, the average size of a research grant rose steadily throughout the 1980s and into the 1990s, from $100,400 in 1982 to $163,400 in 1989 and $184,800 in 1991 in current dollars (89,93,95). Even if the higher rate of inflation in research costs than in other costs is accounted for with the Biomedical Research and Development Price Index, there was a 15% increase from 1982 to 1991. The majority of that increase was due to increases in indirect costs, which rose rapidly between 1980 and 1985 and then stabilized considerably (89,95). Second, the inflation-corrected NIH extramural budget has been essentially flat since 1987 (91). Thus, while the average cost of a grant has increased, the total number of dollars available has not kept pace.

As the success rate declined to the 20% range in the late 1980s in response to those changes, there was a growing belief within the scientific community that the peer-review system is not prepared to distinguish properly among grant applications whose ranking is close to the dividing line between those which will and those which will not be funded. When the success rate stood at 35%, funding was essentially ensured for all the best investigators. As the success rate has declined, study sections have been increasingly uncomfortable in making fine distinctions among applications that are deemed highly meritorious. The difficulty in making those distinctions has led to an erosion in confidence in the peer-review system and the growth of the perception that luck plays a major role in the fate of a grant application.

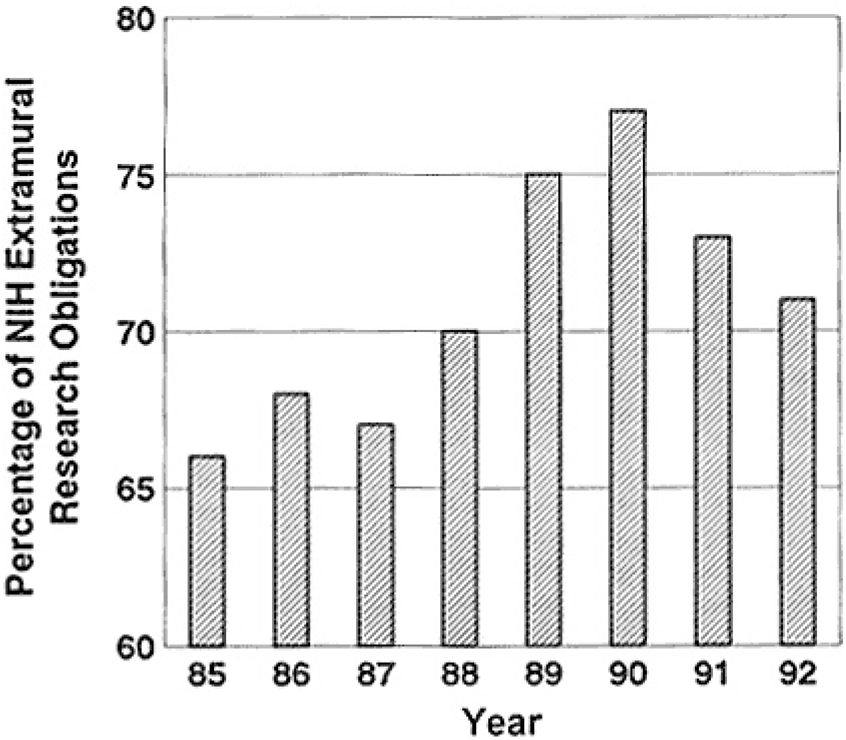

Figure 2-5 Percentage of NIH extramural obligations used in noncompeting continuation of funded projects.
Source: NIH (102).

It is the decline in the success rate at NIH that causes the greatest concern to newly independent biomedical investigators (40,48,49). During their tenure as graduate students and postdoctoral fellows, they see well-established investigators with proven track records failing to renew sources of funding and outstanding younger scientists competing unsuccessfully for grants as independent investigators. They also see both types of investigators spending far greater amounts of time in writing grant applications.

A disproportionate decline in the success rate of previously unfunded applicants at NIH, compared with established investigators submitting new applications and competing continuation applications, is suggested by results of a comparison of the success rate of previously unfunded applications with that of competing renewal applications for previously funded projects. In 1992, 43.5% of competing continuation research-project grant renewals were successful, independently of the ages of the investigators; the success rate was down substantially from 55% in 1987 but was still considerably above the new-application success rate of previously unfunded applications of 23.1% (91). Those figures leave the impression that the NIH peer-review system seems to favor continuation of existing programs, rather than encouraging new ones. Such a policy would present a disadvantage to both newly independent investigators and established investigators who submit new grant applications. In fact, the comparison between the success rates of new and competing renewal applications is affected by the fact that the cohort applying for renewal funds has successfully competed in at least one round of peer review, so it is a preselected group, and success rates would be expected to be higher than for new proposals.

Perhaps a more accurate way to determine whether the funding crisis has presented a disadvantage to newly independent investigators is to compare the decline in this age group's success rate with that of other age groups. Figure 2-6 displays by age groups the 1985–1993 success rates for competing R01 applications. The numbers show that the adverse effects of the decline in the success rate were shared among all age groups. Nevertheless, before 1989, investigators under 41 years old achieved the highest success rates for R01 applications at NIH. Beginning in 1989 and continuing through 1991, there was a change in this pattern such that investigators under 41 years old were less successful than many of their more senior colleagues in competing for R01 grants. Thus, the perception by young investigators is borne out that more-experienced investigators were more successful in the competition for funds during the period when overall success rates reached a low point in 1990 and during the period when success rates rose in 1991. By 1992, younger investigators again had the highest success rates among all age groups, but when overall success rates decreased sharply again in 1993, young investigators' success rates decreased to near the average for all age groups—their marginal advantage was decreased.

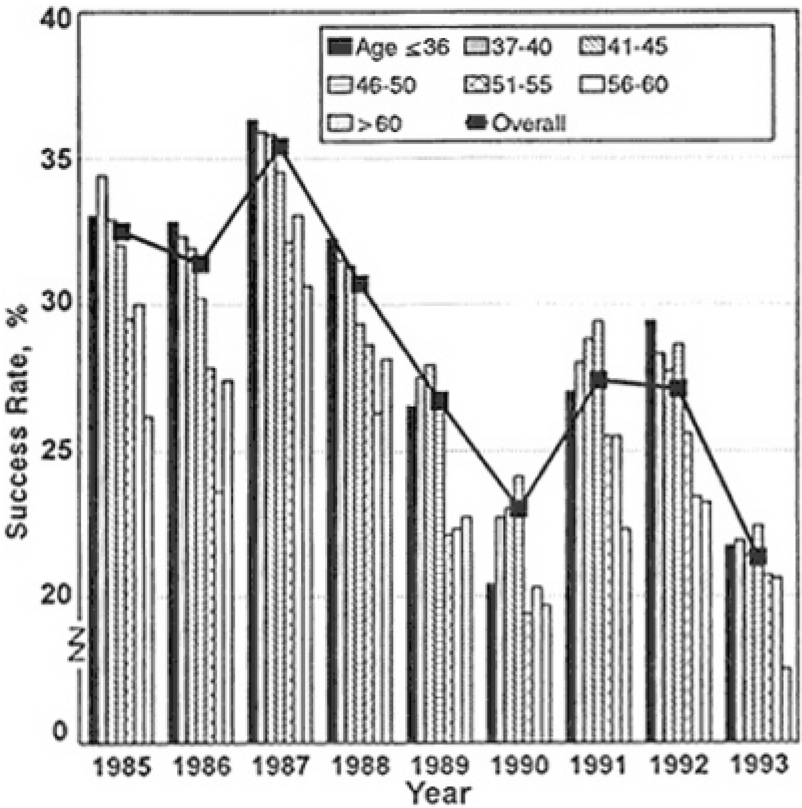

Figure 2-6 Success rates of R01 NIH research-project applications, by age of applicant, FY 1985–1992.
Source: Personal communication, Robert Moore, NIH, DRG, ISB, SAES.

Table 2-2 and Figure 2-7 provide data on events concurrent with changes in success rates during the period 1985–1993 (see appendix for complete data and notes about them). The data show that:

- Applications for R01 grants from investigators age 36 and under dropped from 3,040 in 1985 to 1,389 in 1993, a 54% decrease. At the same time, applications from investigators 37 and older increased from 14,630 to 17,925.

- The number of R01 grants awarded to persons 36 and younger dropped from 1,002 in 1985 to 302 in 1993 (70% decrease) while the number of awards to investigators 37 and older decreased from 4,749 to 3,819 (20% decrease).
- The creation of the R29 grant program in 1986 did not stem the decrease in the number of grants for young investigators. The number of R23 awards (predecessor of the R29 grants) in 1985 to persons 36 and younger was 306; in 1993, they received 225 R29 awards. The number of R01 plus R23/R29 awardees in this age group was 1,308 in 1985 and 527 in 1993, a 60% decrease. The number of awards to investigators 37 and older decreased from 4,600 to 4,032, a 12% decrease.
- In 1985, 21% of all applications for R01 plus R23/R29 grants were from persons under 37, and in 1993, 10% of the applications were from persons in that age group.

The committee believes that the reduction in numbers of young applicants and awards to them demonstrates, more than the small changes in success rates, a problem that has serious implications for the future of the life sciences. This report calls attention to these facts. Because the committee wishes to make these data available without further delay, it has not attempted to determine the causes of these events, but we believe that it is imperative to initiate such a study.

The events described above do not reflect the differential effects of the decline on the morale of the two groups. A seasoned investigator might have multiple sources of funding, which confer some degree of insulation from the loss of one grant or failure to secure a new grant. Likewise, established investigators tend to be far more philosophical about changes in the funding environment, having already experienced similar fluctuations. It is the newly independent investigator, at the beginning of a research career for which he or she has trained for many years, that feels the effects of the decreased success rate most severely. The committee believes that encouraging greater numbers of newly independent investigators to remain in academic science is important because this cohort represents the future of basic-science research.

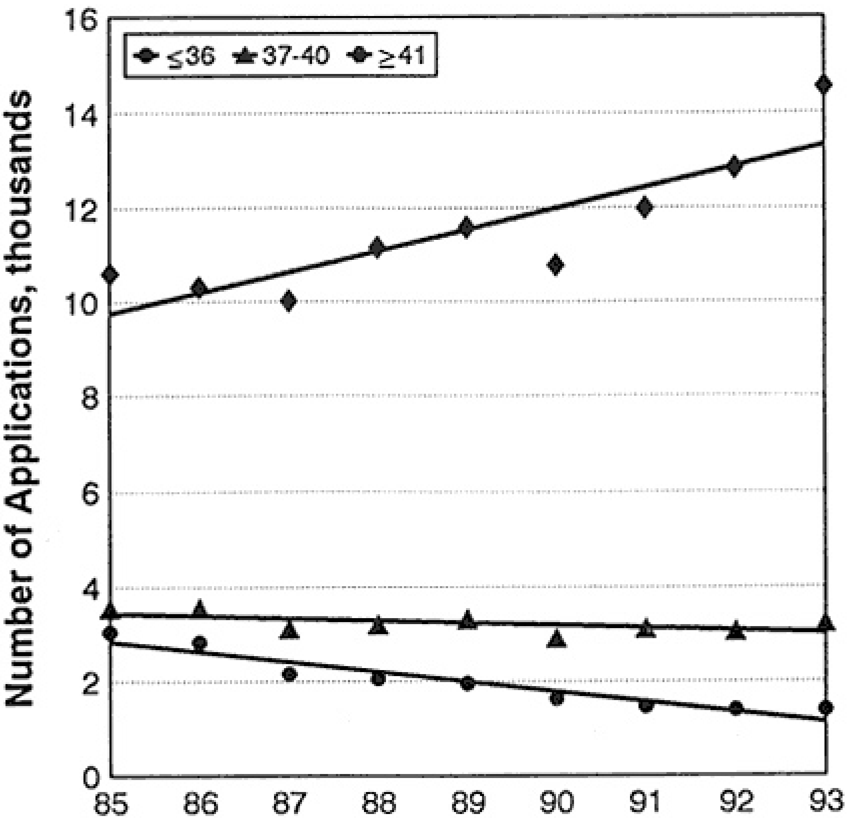

Figure 2-7 Numbers of applications for competing R01 grants, by age.
Source: Personal communication, Robert Moore, NIH, DRG, ISB, SAES.

To be so encouraged, newly independent investigators must have an advantage in applying for funding.

One innovative response of NIH to the decline in the success rate was the creation of the *James A. Shannon Director's Award*. This award provides funds for high-quality R01 and R29 proposals that were approved but not funded (24,92). Proposals are nominated by institutes for review by an 11-member NIH advisory panel, and final funding decisions are made by the

Table 2-2 Number of Applications, Success Rates, and Number of Awards for Competing NIH R01 and R23/29 Grants, by Age

Age	≤36			37 - 40			41 - 45			46 - 50		
Fiscal Year	No. of Apps.	Success Rate	No. Supported	No. of Apps.	Success Rate	No. Supported	No. of Apps.	Success Rate	No. Supported	No. of Apps.	Success Rate	No. Supported
R01 Applications by Age												
1985	3,040	33.0	1,002	3,547	34.4	1,221	4,061	32.9	1,338	2,637	32.0	843
1986	2,823	32.8	927	3,556	32.3	1,150	4,019	31.9	1,281	2,514	30.2	759
1987	2,160	36.3	784	3,132	35.9	1,123	3,804	35.8	1,362	2,592	34.5	893
1988	2,059	32.2	662	3,207	31.5	1,011	4,155	31.3	1,299	3,092	29.3	906
1989	1,945	26.5	516	3,316	27.5	913	4,137	27.9	1,153	3,259	26.7	871
1990	1,621	20.4	330	2,910	22.7	661	3,792	23.0	872	3,050	24.1	736
1991	1,458	27.0	393	3,112	28.0	872	4,275	28.8	1,231	3,355	29.4	986
1992	1,393	29.4	410	3,054	28.3	863	4,448	27.7	1,230	3,542	28.6	1,014
1993	1,369	21.7	302	3,231	21.9	708	4,983	21.4	1,066	4,003	22.4	895
R23 and R29 Applications by Age												
1985	786	38.9	306	214	28.5	61	73	23.3	17	17	17.6	3
1986	711	37.6	267	190	27.9	53	66	28.8	19	18	11.1	2
1987	1,234	27.6	340	519	21.4	111	202	18.8	38	49	10.2	5
1988	1,207	34.2	413	594	29.5	175	245	24.5	60	55	16.4	9
1989	957	34.1	326	563	29.7	167	182	22.0	40	41	14.6	6
1990	803	27.1	218	473	30.0	142	166	19.9	33	40	7.5	3
1991	760	33.9	258	508	28.7	146	187	22.5	42	47	25.5	12
1992	791	35.8	283	620	31.1	193	226	26.5	60	50	20.0	10
1993	787	28.6	225	669	28.3	189	307	21.2	65	68	23.5	16
R01 and R23/R29 Applications by Age												
1985	3,826	34.2	1,308	3,761	34.1	1,282	4,134	32.8	1,355	2,654	31.9	846
1986	3,534	33.8	1,194	3,746	32.1	1,203	4,085	31.8	1,300	2,532	30.1	761
1987	3,394	33.1	1,124	3,651	33.8	1,234	4,006	34.9	1,400	2,641	34.0	898
1988	3,266	32.9	1,075	3,801	31.2	1,186	4,400	30.9	1,359	3,147	29.1	915
1989	2,902	29.0	842	3,879	27.8	1,080	4,319	27.6	1 193	3,300	26.6	877
1990	2,424	22.6	548	3,383	23.7	803	3,958	22.9	905	3,090	23.9	739
1991	2,218	29.4	651	3,620	28.1	1,018	4,462	28.5	1,273	3,402	29.3	998
1992	2,184	31.7	693	3,674	28.7	1,056	4,674	27.6	1,290	3,592	28.5	1,024
1993	2,176	24.2	527	3,900	23.0	897	5,290	21.4	1,131	4,071	22.4	911

Source: Personal communication, Robert Moore, NIH, DRG, ISB, SAES.

Age	51-55			56-60			>60		
Fiscal Year	No. of Apps.	Success Rate	No. Supported	No. of Apps.	Success Rate	No. Supported	No. of Apps.	Success Rate	No. Supported
R01 Applications by Age									
1985	1,660	29.0	482	1,225	30.0	367	1,021	26.2	267
1986	1,641	28.3	465	1,144	23.6	270	989	27.4	271
1987	1,559	30.8	480	1,141	33.0	376	928	30.6	284
1988	1,662	28.0	465	1,213	26.3	319	1,039	28.1	292
1989	1,894	23.2	439	1,175	22.3	262	1,105	22.7	251
1990	1,825	20.9	382	1,051	20.3	213	1,048	19.7	206
1991	2,033	25.4	516	1,153	25.5	294	1,168	22.3	260
1992	2,316	24.3	562	1,271	23.4	297	1,258	23.2	292
1993	2,722	20.3	553	1,361	20.6	281	1,469	17.5	257
R23 and R29 Applications by Age									
1985	4	25.0	1	1	0.0	0	0		0
1986	4	0.0	0	4	25.0	1	3	0.0	0
1987	13	15.4	2	6	0.0	0	1	0.0	0
1988	15	0.0	0	5	0.0	0	5	20.0	1
1989	12	25.0	3	2	0.0	0	2	0.0	0
1990	15	13.3	2	4	0.0	0	1	0.0	0
1991	13	15.4	2	4	75.0	3	2	0.0	0
1992	9	55.6	5	1	0.0	0	1	0.0	0
1993	18	11.1	2	3	0.0	0	0		0
R01 and R23/R29 Applications by Age									
1985	1,664	29.0	483	1,226	29.9	367	1,021	26.2	267
1986	1,645	28.3	465	1,148	23.6	271	992	27.3	271
1987	1,572	30.7	482	1,147	32.8	376	929	30.6	284
1988	1,677	27.7	465	1,218	26.2	319	1,044	28.1	293
1989	1,906	23.2	442	1,177	22.3	262	1,107	22.7	251
1990	1,840	20.9	384	1,055	20.2	213	1,049	19.6	206
1991	2,046	25.3	518	1,157	25.7	297	1,170	22.2	260
1992	2,325	24.4	567	1,272	23.3	297	1,259	23.2	292
1993	2,740	20.3	555	1,364	20.6	281	1,469	17.5	257

NIH director. Shannon grants are for $100,000 allocated over 2 years, with an indirect-cost ceiling of 25% (or a maximum of $20,000). The NIH director used $15 million from the director's discretionary fund and $15 million collected through the director's transfer authority to support 310 researchers at 146 institutions in 1991, the award's first year (50). Although this remains a small program, it provides an important safety net for those who succeed in obtaining these funds.

NONFEDERAL FUNDING AND MECHANISMS OF SUPPORT OF LIFE-SCIENCE RESEARCH

The federal government is the predominant source of funding for life-science research, but support is also derived from state governments, academic institutions, philanthropic and voluntary health organizations, and industry (10,21,125). When considered as a whole, the spectrum of research activities supported is similar to that supported by the federal government, but the research scope of any one funding source is generally much more focused. For example, an industry typically funds applied research or development work in fields directly related to its own interests (126). Likewise, private philanthropies, voluntary health organizations, and industry-supported foundations generally focus on a single research topic or disease.

Through institutional support of research and development—about $6 billion in 1993 for all fields (112)—academic institutions provide funds for their own researchers. Because these institutions design and negotiate startup packages, they play a critical role in the funding of newly independent investigators. These startup packages provide for salary and research support, laboratory remodeling, and equipment purchase. Funds for the packages are derived from indirect-cost recovery, grants from federal and state agencies and nonprofit organizations, and endowment income and taxes.

Nonfederal sources usually provide grants that are smaller in amount and of shorter duration (1–2 years) than federal sources. The grants often contain salary and overhead restrictions and matching-fund requirements. However, these programs are important sources of funds during the first few independent years; they can supplement and extend the startup funds provided by universities to new investigators.

INDUSTRY

The U.S. pharmaceutical industry invested about $8 billion in R&D in 1989 and $9.2 billion in 1991. The latter figure represents 16% of total sales-a high level of investment. Within the industry, R&D expenditures rose at an estimated 16% per year from 1979 to 1989. Several factors contributed to the rapid increase in investment levels; one is industry leaders' perception of the level of investment required to remain competitive.

Within the scope of the subject of this report, there are two issues of vital importance for the U.S. pharmaceutical industry. First, the industry needs a continuous source of trained biologists; an estimated one-third will need to have at least doctoral and also postdoctoral training. Second, the industry needs a strong fundamental science base derived from discoveries made in universities and independent research institutes on which to build its own applied research.

Drug discovery is an applied-research problem that builds on fundamental knowledge and technology. Much contemporary pharmaceutical research rests on newly acquired knowledge of cell growth and differentiation, cell recognition and communication, the molecular organization of cells, the structure of macromolecules (proteins, DNA, and RNA), receptor structure and function, cell signaling pathways, and gene regulation. Moreover, the research in the pharmaceutical industry is being transformed by the new technologies developed elsewhere, such as those used in gene cloning and expression, gene and protein sequencing and synthesis, production of monoclonal antibodies, cell-culture technology, x-ray crystallography and computer graphics, nuclear magnetic resonance studies, and the development of transgenic animals as models of human disease.

The information-base and technology development has relied heavily on university-based research, which benefits not only U.S. pharmaceutical companies, but also physicians and patients around the world. A long time is required for the economic and medical benefits of fundamental research to be realized: successful commercial innovations can lag fundamental discoveries by 30–50 years. For example, the determination of the double-helical structure of DNA was presented by Watson and Crick in 1953, preceding by about 30 years the successful commercial production of the first recombinant therapeutic proteins. In the United States, human insulin, human growth hormone, and human alpha-interferon were introduced as drugs produced by recombinant methods in 1982, 1985, and 1986, respectively.

The lag from the appearance of enabling technology to successful commercial production can be 10–15 years. The enabling technology that permitted the commercial innovations just noted was the demonstration in 1973 that chimeric plasmids containing foreign DNA fragments could be created and functionally inserted into the bacterium *Escherichia coli*. A strong, productive academic research enterprise is critical for making the enabling discoveries and providing the additional knowledge needed for introduction into the marketplace. A weakened basic-research endeavor or a decrease in the availability of trained scientists would have a damaging effect on the competitiveness of the U.S. pharmaceutical industry.

Pharmaceutical and biotechnology companies have developed a variety of ways of providing extramural support for research. These include training and research grants to universities; university-industry liaison programs and joint mentorship of graduate students; graduate and postdoctoral fellowships; postdoctoral positions in industry and federal laboratories; university-industry cooperative research alliances; charitable support via company-funded foundations or fellowships in federal laboratories; funds for equipment, travel, and sabbaticals; and matching funds for NSF's Presidential Young Investigator awards.

Members of the Pharmaceutical Manufacturers Association and the Industrial Biotechnology Association were surveyed for their approach in funding basic research. The 47 respondents indicated that their inhouse and off-site postdoctoral research support increased from an average of $528,000 and $185,000 per company, respectively, in 1985 to $2,634,000 and $219,000 per company in 1990. Targeted grants are the most commonly used vehicle, although institutional grants, gifts, indirect funding via faculty support, and cooperative research and development agreements (CRADAs) are also used.

A small number of newly independent investigators are supported through industrial research grants. This type of funding has increased more slowly than postdoctoral support, from an average of $518,000 per company in 1985 to $747,000 in 1990. In addition to targeted research grants, vehicles include gifts, institutional grants, consulting agreements, and contracts. Survey respondents indicated that their preferred solutions to the perceived impending shortage of scientists were to enhance high-school programs and to increase federal and industrial support of trainees and newly independent investigators.

The relatively small proportion of funds expended to support newly independent investigators reflects a bias in industry in favor of established investigators and their postdoctoral researchers, who are likely to obtain data more expeditiously. Supporting a new investigator is more risky and requires a longer-term commitment.

PHILANTHROPY

Philanthropic and voluntary health agencies provide support for biomedical research, often emphasizing awards for the young investigator. Because of the variety of such organizations and the varied terms, amounts, and conditions of their awards, it is difficult to determine the degree to which such support made up for the decrease in support of young investigators by NIH and NSF during the late 1980s. It is safe to assume that their role, although important, was smaller than that of the federal agencies, which have vastly greater resources. For example, the largest of the philanthropic institutions, the Howard Hughes Medical Institute, supports over 200 investigators, more than one-third of whom are assistant investigators (and probably less than 41 years old). But NIH awarded 1,421 R01 and R29 grants to investigators under 41 in 1993 alone.

Young Investigator Programs

The philanthropic foundations are a diverse group of organizations that fund initiatives in public welfare, education, religion, liberal arts, and environmental concerns, as well as basic science. The *Foundation Directory* lists 7,581 private and community foundations that each have at least $1 million in assets or provide at least $100,000 in annual funding (20). These organizations have been highly responsive to the needs of young investigators, as reflected in their programs that target young investigators. Although their awards are few, they are prestigious (6,16,31,36,51). Some examples are highlighted below.

- The Pew Charitable Trusts Scholars Program in the Biomedical Sciences identifies about 20 young investigators per year who have shown outstanding promise in basic or clinical sciences. Each scholar receives $200,000 over a 4-year period. The only restriction on the use of the funds is that expenditures must be related to research or work activities and that only 10% of the funds can be used to cover salary (51).

- The Searle Scholars Program invites 100 academic institutions each year to nominate newly appointed faculty candidates who are likely to make an important contribution to biomedical science. Each institution can nominate no more than two candidates per year, from whom about 18 are selected for the award. The award consists of $180,000 over 3 years. The achievements of Searle Scholars attest to the success of the program. Of the 121 Scholars appointed from April 1981 to April 1987, 30 have become full professors and 62 associate professors (55).
- The Lucille P. Markey Charitable Trust's Scholars In Biomedical Science Program (36) is unusual in that its awards span the critical transition from postdoctoral fellow to independent investigator. During the last 10 years, the average tenure of a postdoctoral fellow has gradually increased with no parallel increase in the duration of most postdoctoral fellowship awards. In response to the federal funding gap, the trust created a program that begins in the third postdoctoral year and supports young investigators through the last years of postdoctoral training and the first 5 years of a faculty appointment. The award provides full salary support through this period in addition to a decreasing annual amount of research funds during the faculty years. The sliding scale of research funds is based on the expectation that the scholars will attract extramural support. These awards were particularly attractive to newly independent investigators because they provided research support in the first year of independence, at a time when many young scientists have no extramural support and must therefore depend on the startup funds of their institutions. Unfortunately, the program was small: only eight Ph.D. and eight M.D. or M.D.-Ph.D. Scholars were selected each year. The last group of Scholars was chosen in 1991, and the trust will be discontinued in 1999, when its funds will have been spent. Thus, the impact of this innovative and successful program will be brief.

Awards from philanthropic foundations to newly independent investigators are few, so they can ease the struggle of only a small number of young scientists. Many of the philanthropic foundations compete for the same group of elite young scientists, thereby further reducing their overall impact (6). In the near future, philanthropic support of biomedical research can be expected, at best, to be maintained at a steady rate. In fact, there might be a slight decline as foundations withdraw their support or largely redirect it to what are considered to be the more pressing needs of ensuring health-care accessibility and quality in clinical practice. Providing support to the biomedical sciences already represents a major portion of some foundations' grant capacity, and an increase in their support is highly unlikely.

For others, finding a meaningful and visible niche in the biomedical sciences has been difficult in the face of the large federal commitment in the field. Many foundations find it important to have some assurance that their investments make a difference. There is a concomitant tendency to withdraw from fields where their contributions are likely to be lost among those of the larger funders. Indeed, some major philanthropies in the health-care field have specific prohibitions against supporting biomedical science.

The financial grounding of this field is expected to continue as it has over the last 50 years: federal and corporate resources will remain dominant. Foundations will play a smaller role in supporting training and research, but it is hoped that they will continue to serve as catalysts for change and as proponents of neglected subjects and new frontiers.

Howard Hughes Medical Institute

The Howard Hughes Medical Institute (HHMI), a philanthropic organization, is the second largest provider of basic biomedical research funds, after the federal government. Its 1953 charter states that "the primary purpose and objective of the Institute shall be the promotion of human knowledge within the field of basic sciences (principally the field of medical research and medical education) and the effective application thereof for the benefit of mankind" (25).

The endowment of HHMI came from the sale of Hughes Aircraft Company to General Motors in 1985. In an agreement with the federal government in 1987, HHMI was designated a medical research organization that, unlike a foundation or voluntary health organization, can employ scientists and also make educational grants (25,28). HHMI does not provide grants to investigators; rather, it employs researchers who work in university, hospital, or academic medical-center laboratories. In this cooperative structure, a university benefits from the presence of HHMI scientists who function as university faculty, and HHMI does not need to create new research facilities.

In 1992, HHMI employed 222 investigators at 53 institutions (29). Over one-third were assistant investigators. An assistant investigator is nominated by the host university and appointed to HHMI after its review. HHMI provides full salary support and a generous research allowance, which is sufficient to launch a newly independent investigator's research career. Although encouraged to obtain additional sources of extramural support, an assistant investigator is usually funded well enough by HHMI to make the need for additional funds less urgent. The FY 1992 budget for HHMI investigators is $237 million.

In addition to funding its own investigators directly, HHMI provides funds for construction and renovation of laboratory space at its host institutions, some of which may be used by newly independent investigators. It also funds fellowships to persons enrolled in Ph.D., M.D., and postdoctoral programs.

HHMI has been particularly active in targeting funding for improvements in science education at minority-group colleges and liberal-arts colleges that have little research base. Since 1987, HHMI has provided about $219 million in a grants program for education and training in biomedical and medical science (29).

VOLUNTARY HEALTH ORGANIZATIONS

Voluntary health organizations (VHOs) raise funds from the public and dispense a portion of them for research either directly or through academic societies that foster intellectual exchange and educational or curricular initiatives (10). Each organization is dedicated to encouraging research on specific health problems. The VHOs have generally targeted newly independent investigators to receive funds because they represent tomorrow's established scientists and future progress of disease-related research (Table 2-3). In addition, they support established scientists and the training of graduate students and postdoctoral scientists.

The total of annual funds available for research from all VHOs in the United States is difficult to estimate. The most recent available figure for 23 of the largest VHOs is $188 million. That 1986 figure, found in the report of HHMI, included grants for "science education and research" (26). Spending in 1991 can be approximated from the projected investment of the American Cancer Society (ACS). ACS spent about $100 million in biomedical-and behavioral-science research in 1992, an increase of about 77% over 1986. In fiscal 1993, over $9 million was invested in the Postdoctoral/Physician Training Fellowship program at ACS. If that increase is applied to the other

22 organizations, the 1992 spending by the 23 organizations can be estimated at $300–350 million.

The research grants offered by the VHOs vary widely in size, duration, and eligibility requirements. The usual pattern is short-term, nonrenewable provision (1–2 years) of small amounts. A relatively large number of grants to young scientists provide partial salary (up to $40,000 per year), although some limit the use of the funds to supplies and small equipment. Most of the VHO grants carry little or no indirect-cost reimbursement to the host institution. The grant applications are generally reviewed by an independent peer-review panel and funded in order of quality.

Table 2-3 summarizes examples of the monetary support available specifically to newly independent investigators from some VHOs. It is not a comprehensive list of organizations and is intended only to illustrate the characteristic favorable attitude by VHOs to newly independent investigators. The evidence from the reports of large and small VHOs points overwhelmingly to an emphasis on support of young investigators. Almost 54% of the funds spent by the organizations listed in Table 2-3 is designated for young investigators as a means of attracting physicians and scientists into research on the diseases for which the VHOs solicit funds from the public. The research focus and funding mechanism are peculiar to each VHO, so newly independent investigators are obliged to search carefully among the VHOs for the precise grants for which they qualify.

ACADEMIC AND RESEARCH INSTITUTIONS

Universities and research institutions have a remarkable variety of mechanisms to support the efforts of their researchers. The majority of institutions allocate startup funds to support beginning investigators. Although the expectation is that a newly hired faculty member will secure outside research funding, the university is often the primary source of funding in the first year. In an informal survey, the committee found that startup funds vary with institution and discipline: $250,000 approximates an upper limit, and these once-only awards average about $50,000. In addition to funds for research supplies and equipment, startup packages can include a reduced teaching responsibility for the first year, faculty summer salary, graduate-assistant salaries, and travel and equipment funds.

Table 2-3 Estimated 1990 Research Funds Provided by 17 Representative Voluntary Health Organizations

Organization	Research Funds, Millions of Dollars	Amount to Newly Independent Investigators, Millions of Dollars
American Cancer Society	87	37
American Diabetes Association and Associates	9	7
American Federation for Aging Research	1.3	1.3
American Heart Association and Affiliates	70	30
American Lung Association and Affiliates	5	5
Arthritis Foundation	10	6
Cystic Fibrosis Foundation	13	10
Epilepsy Foundation of America	1	1
Juvenile Diabetes Foundation International	14	11
Leukemia Society of America	6	5
March of Dimes	15	7
Muscular Dystrophy Association	21	10
Crohn's and Colitis Foundation of America	3	2
National Kidney Foundation	3	2
National Multiple Sclerosis Society	22	13
National Society to Prevent Blindness	12	9
United Cerebral Palsy Research and Education Foundation	1.5	1.5

Source: Personal communication with representatives of the organizations listed.

In addition, universities and research institutions provide support to both senior and junior faculty in the form of small competitive grants and one-time project initiation or pilot grants to encourage exploratory research and interdisciplinary collaboration. Interim or bridge grants are used to provide funds for brief periods when there are lapses in external funding. Applied-research grants (for both planning and operational phases), assistance in identifying industrial partners, and technology-transfer assistance are provided to encourage university-industry cooperation and identification of sources for matching funds. Grants for travel, conferences, salary (including release time from teaching to do research), summer-salary support, sabbatical leave, equipment, and technical support are provided. Most of these grants provide modest funds for short periods. In many cases, the funds are distributed through a formal application process in which applications are peer-reviewed and funded in order of quality and need. The institutional funds also provide the universities with some ability to develop their own unique blends of research disciplines.

Novel faculty appointments have been adopted by several U.S. universities and research institutions—for example, the Carnegie Institution of Washington and the Whitehead Institute at the Massachusetts Institute of Technology—to counteract the dilemma facing a young investigator who has to establish an active research program while juggling the ancillary duties of university life, including teaching and administrative responsibilities. These appointments provide unusually gifted young investigators the time to launch an original line of research and to set up an experimental system that will provide a basis for future direction and grant support. Little or no institutional responsibilities accompany the position. The investigator, often called a "fellow," is appointed for a nonrenewable term of 5 years, either directly out of graduate (or medical) school or after postdoctoral (or residency) training. The newly independent investigator is not part of any faculty member's "team." Funding sources vary, but usually a young investigator in one of these programs will eventually need to apply for an extramural grant.

Extramural grants are usually procured by newly independent investigators in the second year. To assist their junior faculty, many universities have developed information networks to enhance extramural grant procurement, including seminars, information packages, workshops, grant-writing assistance, and offices to monitor requests for proposals. Some universities organize workshops that are attended by representatives of federal funding agencies; these act as conduits for information exchange and personal contact between researchers who have sparse funds or few opportunities to visit federal agencies.

It is increasingly difficult for universities to support their intramural research because the mechanisms available to pump money into the system are under great stress. Federal and state support is leveling off, if not declining; full recovery of indirect costs is being questioned; and there are increasing calls to provide matching funds for projects. The NIH Biological Research Support Grant (BRSG) program, a long-standing source of federal funding to universities, has been terminated. The BRSG provided a flexible source of noncompetitive dollars that was based on the size and number of Public Health Service research grants to, and cooperative agreements with, principal investigators at a given institution (23,56). In FY 1991, 628 institutions were eligible for BRSG awards; the largest was $131,000, and the average was $38,000. Although those do not appear to be large sums, the committee's informal survey of universities and a survey by the Association of American Medical Colleges (56) indicated that the BRSG program provided valuable support for newly independent investigators. In FY 1990, more than 220 investigators who had received BRSG funds in FY 1988 and 1989 were awarded 5-year FIRST awards totaling $19.6 million. Recipients of BRSG awards in those 2 years garnered 18% of the new regular research grants (R01s) awarded by NIH (105).

3

EXTRAMURAL FUNDING OF NEWLY INDEPENDENT INVESTIGATORS IN BIOLOGICAL SCIENCE

OVERVIEW OF FUNDING OF THE BIOLOGICAL SCIENCES

The biological (nonbiomedical) sciences constitute a large number of scientific disciplines that range from the study of single plant cells to the study of ecosystems and embrace such diverse subjects as molecular evolution, plant pathology, and environmental science. In many respects, the state of funding of biological research in the United States is markedly different from that of funding of the biomedical sciences. Unlike the biomedical sciences, which have experienced a steady increase in funding over the last 30 years, the biological sciences have seen only a modest increase, as reflected in the research commitments of the National Science Foundation (NSF) and the Department of Agriculture (USDA), the two principal sources of funds for biological sciences. No dominant federal agency considers the well-being of biological-science research as a central part of its mission, as the National Institutes of Health (NIH) considers the well-being of biomedical science. Most of the federal and nonfederal agencies that support the biological sciences have only a limited commitment to encouraging young investigators. The only grant programs specifically targeting newly independent investigators in the biological sciences are relatively small ones administered by NSF and the Department of Defense (DOD) Office of Naval Research (ONR).

Biological research (e.g., in agriculture and the environment) has traditionally been less generously funded than biomedical research. Fewer persons have sought advanced degrees in these fields, the research facilities have deteriorated, and the academic infrastructure will have to be rebuilt to respond to new scientific challenges. Compared with biomedical research, one can expect a longer time between advances in basic research and their practical application.

The relative insufficiency of funding of biological research is evident from a comparison of the numbers of Ph.D. recipients in the United States in 1990 who planned academic careers in the biomedical and biological sciences with the funding available in each group of disciplines. The estimated 6,600 Ph.D.s in biological sciences, health sciences, and agricultural sciences were divided almost equally between scientists who pursued academic biomedical and biological research careers (14,42), but funding for the support of nonbiomedical fields is small, compared with that for biomedical research.

The granting mechanisms that support the biological sciences have much in common with the research-project grant (R01) of NIH. However, biological-science grants tend to be for shorter periods and smaller amounts, and sometimes they entail indirect-cost ceilings and cost-sharing requirements for the host universities or a matching-fund provision. In several federal agencies, peer review is less formalized than the standing study-section committees established at NIH. Newly independent investigators generally compete directly with established investigators for funding.

FEDERAL FUNDING OF BASIC BIOLOGICAL RESEARCH

The federal obligation for applied and basic research by agency in the life sciences is summarized in Figure 3-1.

U.S. DEPARTMENT OF AGRICULTURE

USDA spent about $1 billion in basic and applied research in the life sciences in FY 1992, including about $519 million in basic and $473 million in applied life-science research (128), largely through the auspices of the Agricultural Research Service (ARS), the Forest Service (FS), and the Cooperative State Research Service (CSRS).

The largest source of funds for basic and applied research in USDA is ARS. It does not fund extramural grants; rather, it employs over 1,200 scientists at about 130 agricultural research stations. In 1980, ARS initiated a 2-year Postdoctoral Research Associate Program intended to attract young

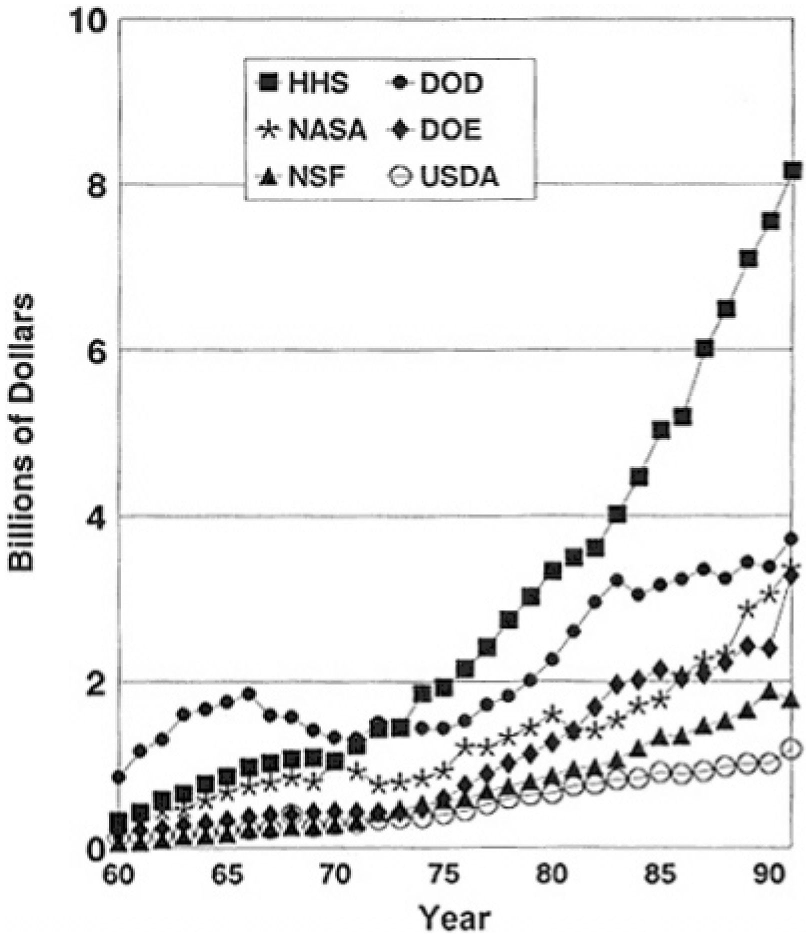

Figure 3-1 Federal obligations for applied and basic research by major research agencies in the life sciences, 1960–1991.
Source: NSF (133).

scientists to work at its stations to bring a fresh perspective to agricultural problems and applications of biotechnology. In 1987–1992, 179 postdoctoral research associates became permanent employees of ARS. In 1990, the program employed 436 researchers at a cost of $19 million. In 1993, the number of researchers employed increased to 550 at a cost of $24 million.

FS manages the renewable resources of forest and range land, performs research in cooperation with state and private forestry, and conducts research at research stations. Research grants are funded primarily through eight research stations and 185 work units. In FY 1990, about $11.7 million in research funds was allocated via cooperative agreements, research grants, and research contracts to academic institutions. About $4.2 million of this money was allocated to basic research and $7.5 million to applied research. FS funded 21 research grants for $1.4 million (personal communication, R. Guldin, Forest Service Research, USDA). FS does not have a specific program for newly independent investigators.

Cooperative State Research Service

CSRS supports basic and applied investigator-initiated research through the National Research Initiative Competitive Grants Program (NRICGP), formerly the Competitive Research Grants Office. This is a highly competitive program, with success rates that are below those common at NIH. In the NRICGP, success rates of 10–18% have been common in such disciplines as weed science, entomology, and plant pathology. Somewhat higher success rates have been the norm for plant molecular biology, plant genetics, and research on domestic animals. The average NRICGP grant is for about $55,000 per year for 2 years. The small size and short duration of these grants severely limit the research scope and complexity of projects.

There are no data as to the number or size of NRICGP grants that have been made to newly independent investigators in academic institutions, federal laboratories, or industry. No special programs have been created for newly independent investigators. At a time when approximately 25% of agricultural scientists are over 50 years old, compared with 20% of all other scientists, and a shortage of agricultural researchers looms, support for plant and domestic-animal research has decreased, and this will continue to decrease the ability of universities to recruit qualified students in these fields.

Data compiled by NSF indicate that scant funding of basic plant sciences has been pervasive for many years and that, in fact, over the decade

1976–1986, the total amount of money available for this subject averaged only about $135 million per year, including all amounts awarded by NIH, NSF, the Department of Energy (DOE), and USDA (130). From 1986 to 1989, there was a small increase in funding, owing in part to the creation of three plantscience centers jointly funded by NSF, DOE, and USDA, but the total never exceeded $150 million per year (113).

National Research Initiative[1]

The underfunding of plant sciences was one of the major arguments presented in 1989 by the National Research Council's Board on Agriculture report *Investing in Research: A Proposal to Strengthen the Agricultural, Food, and Environmental System*, which described the National Research Initiative (43). That report concluded that for this country to remain competitive in the agricultural sciences, a minimum of $500 million should be made available annually for basic and applied research in plant and animal systems. The Office of Management and Budget (OMB) adopted the report's recommendations and included a substantial increase (up to $100 million) in the amount available for NRICGP in the president's budget for FY 1991. In spite of a tight budget, Congress increased the amount allocated to NRICGP, nearly doubling the budget from $42 million to $73 million in 1991 and then increasing it to $97.5 million in 1992. Those increases are well below what OMB recommended, however, and funds are still seriously inadequate to cover the greatly expanded responsibilities of NRICGP. It is OMB's plan to recommend increases of $50 million per year until a total of $500 million is reached. The program is expected to be funded at $130 million in 1994.

If Congress continues to support the NRICGP, it should be able to strengthen existing programs, expand into previously neglected fields, and provide more substantial, longer-term grants. Equally important, newly independent investigators could look forward to increased success rates and increased support. For example, the Food, Agriculture, Conservation, and Trade Act of 1990 (67) specifies that fully 25% of all new funding for research in agriculture should be devoted to providing fellowships and grants to "investigators who are beginning their research careers," further described as "individuals who have less than 5 years of post-graduate experience." Increased funding should allow the creation of a specific grant program for

[1] Data in this section were obtained through personal communication with Arthur Kelman, NRICGP and USDA.

newly independent investigators. In addition, all grants should include postdoctoral appointments as an important means of attracting scientists in a wide range of fields into agricultural research.

The recommendations for the National Research Initiative included direct support for fundamental research by individuals and multidisciplinary teams (70%), support for mission-oriented, applied research (20%), and support designed to improve the research capability in academic institutions and departments that aspire to, but have not attained, nationally recognized research and development capacity (10%). No funds were recommended for expansion or renovation of facilities. A 14% cap on indirect costs (overhead) instituted by USDA at the direction of Congress will make it impossible for institutions to provide the infrastructure necessary to rebuild strong research facilities (3). If the full $500 million is appropriated by Congress without a change in this cap and without construction funds, many of the new research positions might be unattractive to newly independent scientists who would not have the necessary research facilities.

A 1992 report of the National Research Council, *Plant Biology Research and Training for the 21st Century*, recommended that support for plant-biology research be increased and that a National Institute of Plant Biology be established in USDA. The report expressed particular concern for the training and funding of the next generation of plant scientists and drew attention to the need to provide the funding necessary to attract and retain the best investigators.

Formula-Funding System

An additional important source of USDA funding of newly independent investigators in plant and animal sciences is the so-called formula funds. Those funds are made available to individual states via the 1887 Hatch Act, which created the state agricultural experiment stations, and the McIntire-Stennis Cooperative Forestry Act. They are substantial ($212 million in FY 1991) and are distributed to individual experiment-station directors on the basis of a complex formula that takes account of population, agricultural acreage, and other factors. At one time, formula funds were the main source of support for applied agricultural research, but increased costs and demands at individual stations have resulted in a system that supports relatively small projects at modest levels. Use of the funds for staff salaries is also increasing. Experiment-station directors have complete control of the funds, and their systems for distributing them vary widely. Some stations set up a competitive system in which funds are provided to the faculty on the basis of project evaluations by committees made up of local scientists. At other stations, distribution of the funds is decided by the land-grant college's dean or the experiment station's director.

At most, if not all, stations, formula funds are an important element in startup packages for new staff scientists. A sample of reports from some 20 station directors who replied to an informal survey indicates that an average of about 20% of formula funds is used to support newly independent investigators. Startup packages range from $20,000 to $150,000 per investigator; grants to newly independent investigators for research projects range from $12,000 to $20,000 per year. Those are important sums; and in plant sciences it is evident that formula funds are one of the most important sources of support for newly independent investigators. However, although formula funds have shown steady, yearly increases in total dollars, they have not kept pace with inflation or with the increased needs for agricultural research in many states.

In addition to providing startup packages, formula funds have been used as seed money for exploratory projects in applied biology. The results of such projects have provided the basis for proposals from both newly independent and established investigators to granting agencies. Also, important subjects like plant breeding, which are highly applied and difficult to fund in the present competitive granting systems, traditionally have been supported by formula funds.

The USDA budget has also been the traditional source of "special research grants" that fund numerous research projects throughout the country. These grants appear year after year in congressional budgets, in spite of frequent criticisms from research scientists and others who view them as "pork barrel" politics (37). Most of these grants are direct appropriations by Congress to state institutions, but some are administered as competitive grants. Examples of competitive grants are in the Animal Health Program and the Aquaculture Program, both administered by CSRS. Similarly, ARS provides funds for commodity-oriented research at different experiment stations, and some of these funds are administered on a competitive basis. The competitive programs are small and have generally had a modest impact on the support of research by newly independent investigators.

NATIONAL SCIENCE FOUNDATION[2]

NSF has a broad mission to support basic science and engineering research and education, as reflected in its seven directorates, which are listed in Table 3-1.

Table 3-1 NSF Budget, FY 1992

Directorate	Millions of Dollars
Biological Sciences	271.3
Computer and Information Sciences and Engineering	215.2
Education and Human Resources	487.5
Engineering	261.1
Geosciences	379.8
Mathematical and Physical Sciences	619.9
Social, Behavioral, and Economic Sciences	89.5
Total	2,324.3

Source: AAAS (2).

[2] In this section, data not otherwise attributed were obtained through personal communication with NSF personnel L. Parker and V. Ross, Office of Planning and Assessment, P. Werner, Directorate for Biological Sciences, and M. Cavanaugh, Division of Chemistry.

The mandate of NSF in the biological sciences overlaps that of NIH in basic molecular, developmental, and cell biology. In other fields of the life sciences, NSF occupies a unique funding niche; it is the only federal agency that supports research in many fields (134). NSF estimated that it supplies 95% of the federal funding for research in anthropology at universities and research institutions, 75% in environmental biology, 95% in systematics, 50% in plant biology, 55% in basic social sciences, and 66% in economics (127). In general, it does not fund health-related research (40,121). The recognition of the important role of NSF in supporting basic science and engineering research was underscored by the Bush Administration's initiative to double the NSF budget by 1993.

Much of the funding of biological research is supported through the Biological Sciences (BIO) directorate, although NSF encourages cross-disciplinary research. BIO is made up of four divisions; these are listed in Table 3-2 with their expenditures in FY 1992 (2).

Table 3-2 NSF Biological Sciences Directorate Budget, FY 1992

Division	Millions of Dollars
Biological Instrumentation and Resources	41.1
Environmental Biology	71.7
Integrative Biology and Neural Sciences	76.4
Molecular and Cellular Biosciences	82.1
Total	271.3

Source: AAAS (2).

Granting Vehicles at Nsf

In 1993, 49% of NSF research funds was expended to support small research projects of less than $250,000; the remainder supported groups, centers, and large facilities (114,121,124). Group research grants (medium-size grants) support coordinated research by four or more principal investigators, and center grants support complex, large-scale research efforts for a long duration. Those two kinds of projects usually require special facilities and interdisciplinary collaboration (136). Of the 11 NSF-funded centers, the two in the life sciences-the Center for Development of an Integrated Protein and Nucleic Acid Biotechnology and the Center for Microbial Ecology-account for 1.7% of the BIO research budget. In addition, a plant-science center has been created that focuses on plant molecular biology. Facility funds support large research resources, such as ocean-going ships, and multiuser national research facilities, such as the National Center for Atmospheric Research.

Between 1989 and 1993, the funds invested in medium-size and large grants increased far more rapidly than those for small grants. Medium-size grants increased from $236.5 million to $429.9 million (a 82% increase), large grants from $550.7 million to $908.9 million (a 65% increase), facility support from $355.2 million to $397.2 million (a 12% increase), and small grants from $1,003 million to $1,283 million (a 28% increase). The consequence of this trend was a 7% drop in the percentage of the total budget committed to small grants (124). However, the total number of competitive proposals-a measure of the demand for funds-increased by 9% over that same period.

The Individual Investigator Research Grant is the most common vehicle for support of research at NSF. In current dollars, the median annual active research project (including direct and indirect costs) grew from $49,000 in 1983 to $63,000 in 1993. When converted to constant 1993 dollars, that translates into a decline from $69,000 to $63,000. Unlike NIH R01 research grants, the duration of NSF grants remained roughly constant at 2 years in the decade from 1983 to 1993.

The peer-review system at NSF is coordinated by program officers in the directorates. In most instances, standing peer-review panels evaluate proposals with extensive input from ad hoc outside reviewers. Ad hoc committees are used in special circumstances. The proposals are judged on the basis of researcher competence, intrinsic merit of the research, utility or relevance of the research, and potential effect of the research on the infrastructure of science and engineering (120). Although newly independent investigators compete directly with established investigators for research funding, young investigators tend to fare well at NSF. In fact, many young scientists view NSF as the first agency to apply to and, having gained success and experience through NSF, apply to other agencies (113,127). NSF has a reputation of being responsive to new ideas and of having some administrative flexibility; both characteristics are appealing to newly independent investigators.

With minor exceptions, the number of competitively reviewed individual-investigator proposals at NSF progressively increased from about 17,000 (FY 1983) to 30,000 (FY 1993) while the number of awards made annually increased from 6,500 (FY 1983) to 9,000 (FY 1993). Thus, the overall success rate decreased from 38% in FY 1983 to 30% in FY 1993 (with a minimum of 28% in FY 1988). However, the NSF-wide success rate does not reflect the extremely low funding rates in specific programs, particularly in BIO. The success rate in BIO has been consistently lower than the overall NSF rate-rates of 25% or less occurred in important biological programs in FY 1993. In FY 1993, 32% of the awards went to support scientists who had not been funded in the preceding 5 years.

The average success rate for all of NSF over 1983–1993 for investigators who completed their Ph.D. within 7 years of applying for the grant was 28%. The success rate increased progressively with age up to 40% for those who received Ph.D.s more than 22 years earlier. As the committee noted with respect to similar data from NIH, the older cohort was a group of seasoned and tested investigators, so its higher success rate is not altogether surprising.

Young Investigator Awards

In 1984, NSF created its first award designed specially for young investigators, the Presidential Young Investigator (PYI) award. Its goals were to increase the attractiveness of academic careers in engineering and computer science, to promote research funding by the private sector, and to foster cooperation between academe and industry. The program has expanded to include other fields supported by NSF research grants. In 1990, 211 awards were given, 26 of them in BIO (119). The success rate of applicants in BIO was only 7%.

The small number of these awards has resulted in their being viewed as honorific; indeed, applicants are not free to apply, but must be nominated by their supporting institutions (123). PYI applications are separately reviewed by the research directorates on the basis of an abbreviated research proposal and letters of recommendation. The funds are not set aside, but rather are derived from the research budgets of the NSF directorates.

A PYI award is a 5-year grant, which is unusually long for an NSF grant, with a guarantee of $25,000 per year; funds can be secured from nongovernment organizations and matched by NSF to increase the award size up to $100,000 per year. Although finding matching funds can be difficult and can be perceived as competing with a supporting institution's fund-raising efforts, one of the PYI program goals is to foster university-industry interaction. Involvement by the supporting institution is secured by requiring that it guarantee the recipient's academic-year salary and provide a portion of the indirect costs (only 10% of NSF funds can be used to defray indirect costs) (119).

The PYI program was reviewed for its effectiveness by NSF in cooperation with Westat, Inc. (122,151). In a study of the first two "classes" of awardees (FY 1984 and FY 1985), it was concluded that although the award promotes the careers of recipients, some of the features-specifically the matching requirement and the nomination process-were disadvantages.

On September 17, 1991, President Bush announced a new NSF program, the Presidential Faculty Fellows Program. It called for only 30 awardees, with each to receive a 5-year grant totaling $500,000. No more than two nominations per academic institution are accepted, and matching funds are not required (38). The new program was created at the expense of the PYI program, and the PYI program was renamed the NSF Young Investigators Program.

In the FY 1992 budget request, BIO also included a $3.8 million setaside for a program to support newly independent investigators. The program awards 40–50 grants of $50,000–60,000 per year (direct costs) over a 5-year period (127). The goals of this setaside, with those of the PYI awards and the Presidential Faculty Fellows Program, represent an appropriate concern on the part of NSF for young investigators.

In March 1994, as the committee was preparing this report for publication, NSF's National Science Board approved the initiation of the Faculty Early Career Development Award (CAREER) program. The program will incorporate several existing NSF programs aimed at young investigators, including the NSF Young Investigators Awards, Research Initiation Awards, and Minority Research Initiation Research Awards. Applicants for the CAREER program will generally be within 4 years of their initial appointment, and applications will be judged on the basis of a career plan, including research, teaching, and outreach components. Awards will be for 3–5 years at a funding level appropriate to the discipline. Depending on program decisions that will be made at NSF divisional levels, the program could support a larger number of persons than have been supported under the previous programs.

The NSF Experimental Program to Stimulate Competitive Research (EPSCoR) is designed to cultivate research and development efforts in regions of the country that have been traditionally less competitive in obtaining funding (121). Several institutions in the participating states have cited the EPSCoR program as an important source of funds for newly independent investigators and established researchers. State EPSCoR committees are formed to develop proposals submitted to NSF. Once an effort is funded, a local institution is designated as the financial agent and disburses funds to the participating investigators. The program is currently operating in 16 states. The program has a cost-sharing requirement; NSF has invested about $52 million and the participating states over $156 million in this program (135).

OTHER AGENCIES

The Departments of Energy, Defense, Commerce, and the Interior and the National Aeronautics and Space Administration support life-science research, although in no case is it the primary research mission. Although the overall budgets for programs in life-science research are not large, they are often the only source of federal support for these endeavors. Thus, they are crucial to the careers of many life-science investigators.

Department of Energy[3]

The Department of Energy (DOE) is the fourth largest source of federal funds (after the Department of Health and Human Services, DOD, and the National Aeronautics and Space Administration) for basic and applied research (see Figure 3-1). Its original commitment to life-science research, which now accounts for less than 10% of its total research budget in basic research, arose from the pressing need to understand the impact of radiation on biological systems after World War II. Radiation biology remains one of DOE's primary research missions, but it has expanded its research agenda to include mammalian genetics, genome organization and function, structural biology, and environmental sciences. Much of the effort is focused on intramural programs at the large DOE National Laboratories at Brookhaven, Oak Ridge, Los Alamos, and Berkeley, although DOE also maintains an external grants program.

[3] In this section, data not otherwise attributed were obtained through personal communication with R. Rabson, Division of Energy Biosciences, Office of Basic Energy Sciences, and B. Burrier, DOE.

The external grants program is administered through the Office of Energy Research (OER) (75–78). Usually, submitted proposals are peer-reviewed by ad hoc volunteer committees. In FY 1991, the Division of Energy Biosciences of OER supported 887 research grants for a total of $24.7 million. The average grant was funded for 3 years with a total annual cost (direct and indirect) of about $80,000. The Ecological Research Division provided $8.1 million for terrestrial ecological research, of which $2.2 million supported theoretical ecology (79). About 75% of the $2.2 million went to support ecological research in universities.

DOE has no special programs for newly independent biological scientists, so young investigators must compete directly with senior investigators. Only one in five proposals submitted to OER was funded in FY 1991.

Department of Defense[4]

DOD, through its own research offices and those of the individual services, supports research in diverse disciplines, including life sciences, psychology, physical sciences, environmental sciences (nonbiological), mathematics and computer sciences, and engineering. About $128.4 million of the basic-research budget is expended in the life sciences. The research offices of each service operate independently of each other, but there are attempts to coordinate overlapping research interests (32,71). About half of basic research supported by DOD takes place at universities; the remainder is supported at government, industrial, nonprofit, and contract laboratories. Research is generally funded by grants to individual investigators. The only program that targets newly independent investigators is administered by the Office of Naval Research (ONR).

Army Research Office. With an annual research budget of $2 million, the Army Research Office supports five to 10 new research grants in the biological sciences each year (63,64). These 3-year grants are funded on a competitive basis, with newly independent investigators competing directly with established scientists. Biomedical research is supported primarily through the Army Medical Research and Development Command, which awards contracts and grants to organizations, rather than individuals. Only one in five applications is funded, with annual budgets of about $100,000.

[4] In this section, data that are not otherwise attributed were obtained through personal communication with J.W. Cutting, Office of the Director of Defense Research and Engineering, and W.D. Hein, Department of the Army.

Office of Naval Research. ONR provides the majority of the funding for basic research in the Navy. The administration of programs is organized in four directorates: Mathematical and Physical Sciences, Ocean Sciences, Engineering Sciences, and Life Sciences. Of the various mechanisms used to support research, individual research contracts to industry and grants to nonprofit institutions predominate.

ONR has the only grant program within DOD that specifically targets newly independent investigators (143,144). The Young Investigator Program is designed "to identify and support young scientists and engineers who show exceptional promise for doing creative research. The objectives of this program are to attract outstanding young university faculty members to the Navy's research program, to support their research, and to encourage their teaching and research careers" (142). "Young" is defined as having received a Ph.D. within 5 years of the fellowship granting date and is not tied to age (138–142). The grants are for $75,000 per year (direct and indirect costs) for 3 years. A 2-for-1 matching program allows the grant size to increase by $75,000 if funds are obtained from other Navy sources to supplement the ONR grant. The applicants' institutions must recommend them for the award and must guarantee a long-term commitment to the applicants by providing partial support for their research needs or salary. Young Investigator grant recipients can apply for continuing research support through the Research Program Department (138–142).

Although it is an excellent model, the ONR Young Investigator Program is small, especially in the life sciences. In FY 1990, 297 proposals were received, of which 13 were funded, two in the life sciences (141). In FY 1991, 15 of 316 proposals were funded; again, only two were in the life sciences (142).

Air Force Office of Scientific Research. The Air Force Office of Scientific Research (AFOSR) supports both graduate-student and faculty research programs. Although it lacks a separate young-investigator program, it sponsors a single new-investigator award (for 1 year and $61,750) administered by the Society of Toxicology (57). A summer research program for faculty and graduate students is also available through AFOSR (147). The stated goals of the program are "to develop the basis for continuing research of interest to the Air Force at the faculty member's institution," "to stimulate continuing relations among faculty members and their professional peers in the Air Force," and "to enhance the research interests and capabilities of science engineering educators in technical areas of interest to the Air Force." A substantial portion of the roughly 150 participants are assistant and associate professors. After taking part in the program, the participants can submit a Research Initiation Program proposal, which if funded provides $20,000 plus cost-sharing for 1 year. Proposals may also be submitted to AFOSR in response to a Broad Agency Announcement (9,65).

Department of Commerce: National Oceanic and Atmospheric Administration

In FY 1991, the Department of Commerce spent about $449.7 million on basic and applied research. Of this total, $14.8 million supported life-science research and was disbursed by the National Oceanic and Atmospheric Administration (NOAA). Like many other federal agencies, NOAA does not keep statistics on the age distribution of its funded investigators, and it does not have a formal program specifically for newly independent investigators. NOAA is divided into several line offices, including the National Environmental Satellite, Data, and Information Services; the National Weather Service; the Office of Oceanic and Atmospheric Research; the National Marine Fisheries Service; and the National Ocean Service. Those offices are responsible for the administration of research efforts, a few of which are described here.

The National Undersea Research Program (NURP) is part of the Office of Oceanic and Atmospheric Research. It focuses on "research related to processes in the world's oceans and great lakes in order to understand global ecosystems" (109). NURP awarded $9.5 million in grants in 1990 and supported 616 scientists involved in the submersible facilities and network of the National Undersea Research Centers. For the last 9 years, researchers who rely on NURP support have seen funding removed by the Office of Management and Budget and reinstated by Congress (58). Researchers are required to plan long-term research projects in an environment of severe fiscal uncertainty.

The National Sea Grant College Program is also part of the Office of Oceanic and Atmospheric Research (106). It provides funds to local directors ($40.8 million in FY 1990) that tend to be directed toward continuing, applied projects. There appear to be no special provisions for advancing the careers of newly independent investigators in this program. The local directors of the program indicated that many of the fund recipients are newly independent, although they generally compete with established investigators for funding.

The National Estuarine Research Reserve System is part of the National Ocean Service (107,108). Research proposals are evaluated strictly on the basis of technical merit, and no provisions are made for promoting newly independent investigators. In FY 1990, $700,000 was available for research;

this was reduced to $400,000 in FY 1991 to increase land acquisitions for field programs.

National Aeronautics and Space Administration[5]

In FY 1991, the National Aeronautics and Space Administration (NASA) spent about $1.7 billion on basic research; of that amount, $47 million was devoted to the basic life sciences. NASA funds extramural life-science research through the Life Sciences Division of the Office of Space Science and Applications. The Life Sciences Division supports scientific research and enabling technologies in the fields of operational medicine, biomedicine, space biology, biospherics, exobiology, and controlled ecological life-support systems. Research funds can be obtained through the NASA Specialized Centers of Research and Training (NSCORT) program or the investigator-initiated competitive grants program (84,85).

NSCORT proposals are competitively reviewed center grants administered by a local institutional director (85). NSCORT program goals include encouraging interdisciplinary research; providing long-term, stable funding to the research community; and involving students, research scientists, and engineers from academe and the public and private sectors. A NSCORT proposal contains a set of interactive, independent research projects that are evaluated on the basis of scientific merit, relevance to the NASA mission, and cost. Institutions are funded on an annual basis—not to exceed total indirect and direct costs of $1 million per year—for 5 years. In 1990, three centers were funded after the evaluation of 47 proposals; in 1991, three centers were funded after the evaluation of 13 proposals.

NASA also funds individual research projects through a competitive peer-review process. Proposals are generally funded on an annual basis for up to 3 years. In FY 1991, the average grant was funded at $87,000. In FY 1991, the Life Sciences Division supported 370 new and continuing grants.

Department of the Interior

Within the Department of the Interior (DOI), the U.S. Geological Survey (USGS), the Bureau of Land Management, the Bureau of Mines, the Bureau of Reclamation, the Minerals Management Service (MMS), the National Park

[5] In this section, data not otherwise attributed were obtained through personal communication with F.M. Sulzman, NASA.

Service, and the Fish and Wildlife Service (FWS) support basic or applied life-science research. In 1991, DOI spent about $229 million in support of basic research and $324 million for applied research (128).

U.S. Geological Survey. In 1990, USGS awarded $1.3 million in applied life-science research (128). Its Water Resources Research Grant Program supports research on biological processes in natural water resource systems (81,82). It is interested in applications emphasizing "influences of microbial processes on water quality and biogeochemical cycling as applied to hydrologic systems; interactions between both physical and chemical hydrologic processes and the ecological characteristics of water systems; pollutant effects on species and populations of aquatic organisms in natural systems of differing hydrologic character; applications of biotechnology to water resources in natural systems; and control of pathogenic or parasitic organisms in natural water systems and the fate of disease-causing chemicals in such systems" (83).

Successful applicants must have acceptable matching nonfederal funds (on a 1:1 basis) committed at the time their applications are submitted to USGS. USGS funds are not designated for newly independent investigators, and the matching requirement probably restricts access to more experienced investigators.

Minerals Management Service. MMS is responsible for the conduct of environmental studies of the outer continental shelf. In 1992, Environmental Studies Program funding is about $21.7 million. Most studies are performed by contractors to DOI; no program identifying or selectively favoring newly independent investigators appears to exist.

Fish and Wildlife Service. FWS was responsible for the disbursement of $6.2 million in basic research in 1991 (128). FWS supports the operation of 41 regionally administered Cooperative Research Units, which are cooperatively funded by various federal and state agencies through FWS (35). Each unit is headed by three scientists who are FWS employees. Although newly independent scientists can be hired by FWS, no special programs exist to promote research initiated by newly independent investigators.

NONFEDERAL FUNDING OF BASIC BIOLOGICAL RESEARCH

INDUSTRY

A review of private-sector research funding was provided in the National Research Council report *Investing in Research: A Proposal to Strengthen the Agricultural, Food, and Environmental System* (43). In summary, biological research in the private sector occurs chiefly in agriculture-based companies, at a level estimated at $2.1 billion per year. There is wide variation among corporations in the magnitude of funding for their research efforts. About 4–5% of total sales is reinvested in agricultural research and development, in contrast with the 7–10% of total sales reinvested in biomedical research and development by all pharmaceutical firms worldwide. (Reinvestment by U.S. pharmaceutical firms is even higher-some 16% of total sales.)

About two-thirds of private-sector research and development is carried out by agricultural-input industries and one-third by firms engaged in the postharvest processing and marketing of food products (43). Funding is provided for research on plants and animals, including crop breeding and management, plant protection and nutrition, and livestock. There is also research support for mechanization and postharvest process improvement. Although some of the applications of the research will be in the development of human and animal pharmaceuticals, most are for food or manufacturing process improvements (43).

PHILANTHROPY

The majority of funds for life-science research spent by philanthropies is provided by independent foundations; company-sponsored and community foundations provide substantially less support. Private-foundation support for the biological sciences is less than that for the biomedical sciences. However, recent trends indicate that might change. Private foundations are finding it increasingly difficult to define a niche for themselves in the biomedical sciences and are turning to subjects in the biological sciences that have been traditionally underfunded by the federal government. There is a new emphasis on developing and supporting programs in conservation and the environment. For example, the Pew Scholars Program in Conservation and the Environment (for early-career to midcareer scholars), established in 1988, provides $150,000 over 3 years for up to 10 conservation scholars a year (51). Another sign of the shift is seen in the funds awarded by private foundations in 1989: $114 million for medical research (a decline of $15.7 million from 1988) and $69.4 million for biological research (an increase of $18.4 million from 1988). Both the total funds expended and the number of grants funded in medical research declined, whereas the total funds in biological sciences increased, although the absolute number of grants declined by 86. In 1989, 1,737 grants for $128.7 million were awarded to support environmental research (including both physical and biological research) and 321 grants for $31.1 million to support animal and wildlife research (20).

ACADEMIC INSTITUTIONS

The support available to investigators in biological sciences from academic institutions is similar to that described for biomedical sciences in Chapter 2. Biological scientists are assisted by formula-fund mechanisms, such as the 1887 Hatch Act and the National Sea Grant College Program, and by NURP funds, which are under the control of local institutional directors. It is common for these funds to be used to provide salary and some modest research support. Although newly independent investigators are rarely singled out for special attention, these funds are critical to the operation of many biological research departments.

4

THE FUTURE SUPPLY OF NEWLY INDEPENDENT LIFE SCIENTISTS

OVERVIEW

A newly independent scientist who has just secured a junior faculty position has completed a long training process, often lasting 26 years–12 years of elementary and secondary school, 4 years of college, typically 5–6 years of Ph.D. training, and usually 2–5 years of postdoctoral research. The numbers of students flowing through this training process into careers in science have been referred to as "the pipeline." As students advance from high school through college to graduate school, decreasing numbers express interest in science careers. Of the 4 million students in the entire high-school sophomore class of 1977, it is estimated that only 10,000 (0.25%) earned Ph.D. degrees in natural sciences or engineering in 1992. For minority groups, the narrowing of the pipeline is more pronounced —only 0.04% of the minority-group members of the 1977 sophomore class received Ph.D.s in 1992 (53). In recent years, concern has been expressed over the ability of the American school system to produce a science-literate public and an adequate number of well-trained academic and industrial scientists. Numerous publications have addressed the current state of education and presented plans to revitalize science education (1,19,46,59,61,73). The result is that corporations, nonprofit organizations, and many state and federal government agencies have attached a high priority to science education.

On the basis of projections generated by modeling the future supply of basic research scientists and the demand for their skills, a 1989 National Research Council report (45) predicted a serious shortage of U.S. academic biologists by the year 2000. Increased retirements, declining interest in scientific careers, and increased nonacademic employment opportunities are some of the chief factors that contributed to this prediction. The reliability of the projection has been questioned, and a more recent analysis of the situation might find that the demand will at most increase slowly. However, the committee views as self-evident the continuing need for the supply of scientists in the field to be refreshed and for the nation's education system and funding mechanisms to produce trained scientists to fill industrial and academic positions.

CURRENT SUPPLY OF SCIENTISTS

The attractiveness of the biological sciences as an undergraduate major has declined over the last 15 years. In the mid-1970s, 4% of all majors in U.S. universities were in biological sciences; by 1986, that fraction had declined to 2.8%. In the early 1980s, the decline reflected, in part, the growing popularity of the preprofessional curricula—those aiming at law, business, medicine, and management (22,125). By the mid-1980s, the number of students in these curricula ceased to increase, but the natural sciences, biological sciences, and engineering fields were still experiencing declines. As shown in Figure 4-1, bachelor's degrees in the biological sciences declined in the late 1970s and in the 1980s after reaching a peak in 1976. The number of Ph.D. degrees awarded in the biological sciences has been generally around 3,500–4,000 per year from 1971 to 1992. The most recent data (for 1992) indicate that the number of degrees rose —fueled, perhaps, by growth in interest in microbiology, biochemistry, and cell and molecular biology (42,129)—while other fields remained steady or declined.

The slow growth in the scientific pipeline suggests that at all points in the pipeline there are attractive career alternatives to the path that leads to a Ph.D. in science and engineering (45). Baccalaureates in the life sciences might choose to enter the workforce or go to medical, dental, veterinary, business, or law school, rather than proceed to graduate study. Ph.D.s can choose to take on industrial or government jobs, rather than continue with academic postdoctoral research (22,45,116). Postdoctoral researchers have a similar array of choices, at a higher level (47). The choices that they make depend, in part, on things that can be quantified—salaries, demand for faculty, and the growth of related industries—but also on more qualitative factors, such as the perceived excitement of research in the field or the perceived difficulty in obtaining funding and sustaining a productive research career.

Most successful academic scientists train many more undergraduates, graduate students, and postdoctoral associates than are required to maintain a steady population of academic scientists. The assumption that these scientists-in-training become academic scientists has led to the suggestion that the number of scientists is ever-increasing-the "Sorcerer's Apprentice phenomenon" (4,148). However, as Figure 4-1 indicates, no Sorcerer's Apprentice has been at work in the life sciences. The number of persons who have received bachelor's and masters degree's in the life sciences has declined

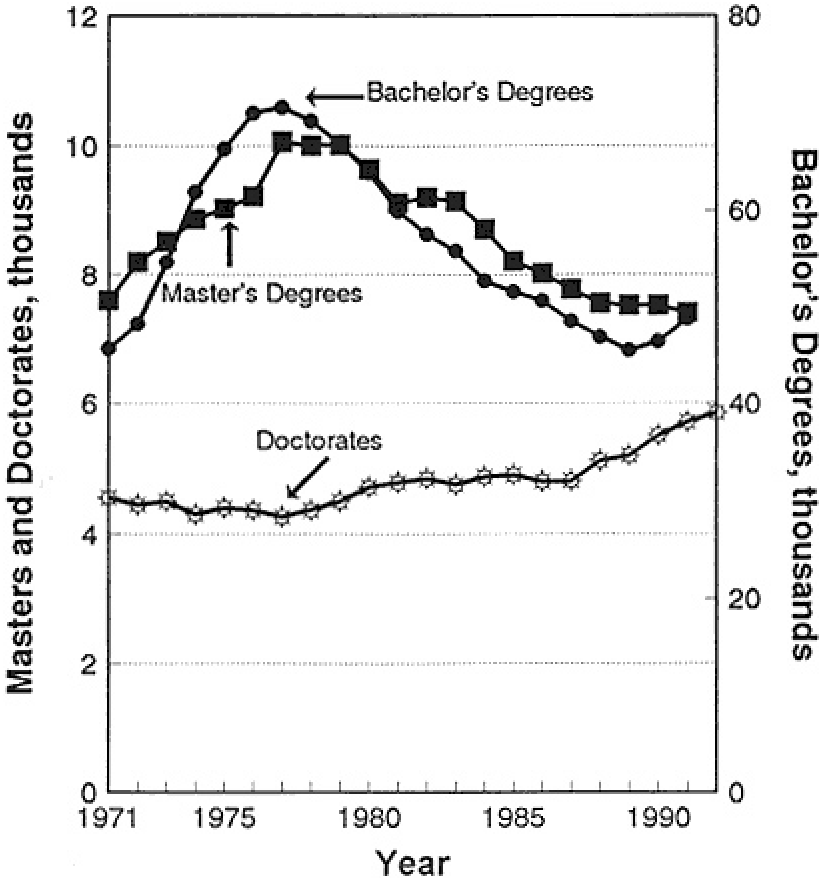

Figure 4-1 Number of degrees in biological and agricultural sciences conferred by U.S. universities.
Source: NSF (112,131).

dramatically since peaks were reached in the late 1970s, and the small increase in the number of doctorates does not foreshadow a rapid increase in the number of young scientists in the near future.

Although the number of Ph.D. degrees awarded annually in the life sciences has not changed dramatically, the absolute number of life scientists has steadily increased over the last 15 years (110). The mean age of the academic life-scientist population has been steadily increasing (17,62,80,110,118). The average age of applicants for R01 and R29 funding from the National Institutes of Health (NIH) rose from 42.0 years in 1980 to 43.8 years in 1990 (104). More striking, however, is the fact that the percentage of total applicants 36 or younger fell from 1980 to 1993 from 20.3% to 10.3%. Even when one considers only new competing R01 applications, which should bias the distribution in favor of newly independent investigators, the percentage of applicants under 36 fell from 17.2% in 1985 to 7.2% in 1993.

The reasons underlying the aging of the applicants for NIH grants are complex and might include the longer training periods for both graduateschool and postdoctoral fellowships. At least some part of the trend is attributable to the decline in attractiveness of the academic research track. Ironically, as discussed in detail in Chapter 2 (see Table 2-2), somewhat higher success rates at NIH were enjoyed by the youngest applicants in previous years (104).

The aging of the academic population means that the rate of retirements might increase before the turn of the century. A recent survey indicated that 57% of colleges and universities expect an increased pace of retirement; although community colleges will be most severely affected, 40% of doctorate-granting universities expect a similar trend (17). It is crucial that sufficient young academics be in place to compensate for these retirements.

The perception that there are fair and reasonable research opportunities for newly independent investigators is critical in maintaining continuity among graduate students and postdoctoral, newly independent, and senior scientists. Recently, a few research funders, recognizing that, have introduced programs targeted to young investigators. For example, the Howard Hughes Medical Institute (HHMI) has targeted the hiring of young scientists; as a result, the median age of those appointed as independent investigators from January 1988 to mid-1991 is 37 years, whereas the average age of all HHMI investigators was 41 years in February 1991 (personal communication, P. Choppin, HHMI, July 1991).

The National Aeronautics and Space Administration (NASA), faced with concerns about an aging professional population and a potential surge of retirees in 1994, has been stressing the hiring of recent graduates. The average age of the NASA scientist and engineer workforce declined from 44 years in 1981 to 42 years in 1991 (80).

The concern about the ability of our system to produce adequate numbers of newly independent academic scientists stems from a combination of the decreasing overall success rates discussed in Chapters 2 and 3, the sharp decrease in the number of young investigators who are applying for grant support, and an apparent decrease in the number of students interested in science careers.

WOMEN IN THE PIPELINE[1]

At all levels, women constitute a growing fraction of degree recipients in the life sciences. Over the decade from 1980 to 1990, their share of lifescience doctorates grew from 24% to 34% and their share of baccalaureates from 39% to 45% (111). Yet this growth in female participation in the life sciences is not yet reflected in participation in tenure-track or principal investigator positions.

Until they enter academic positions, statistics on women show that they perform much like their male counterparts in the life sciences. Once registered in doctoral programs, women take almost exactly as long as men to complete the doctorate (6.8 years for women, 6.6 years for men), although their total time from baccalaureate to doctorate is longer (9.7 versus 8.8 years) (42,54). After receipt of the Ph.D., almost equal percentages of women and men plan to go on to postdoctoral study (55.3% of women, 55.8% of men), which is the usual precursor to a faculty appointment (42).

[1] In this section, data not otherwise attributed were obtained through personal communication with Brooke Whiting, Association of American Medical Colleges, and L. Parker, Program Evaluation, National Science Foundation.

A survey of U.S. medical-school faculties in 1993 revealed that 17,642 (23.5%) of the faculty were female (5). However, women are overrepresented in the lower academic ranks, which have the least professional recognition and job security in medical schools. For example, just 9.1% of full professors and 19.1% of associate professors are female.

The underrepresentation of women in the senior ranks can be partially explained by the fact that the increase in the number of women receiving a doctorate in the life sciences is relatively recent. Time, it is argued, will balance the scale. However, studies (7,8) of full-time male and female medical-school faculty in 1991 who were first appointed in 1976 suggest that women have not moved through the academic ranks at the same rate as men-a phenomenon often referred to as "hitting a glass ceiling." As Table 4-1 shows, within the 1976 cohort, just 10% of women but 22% of men had attained the rank of full professor by 1991; women were overrepresented in the assistant-professor and instructor ranks. The failure of women to attain full-professor status could not be attributed to a higher dropout rate, a commonly reported explanation for the "glass ceiling," inasmuch as they exhibited only a slightly higher dropout rate. Rather, these data suggest that even after women achieve faculty status, they are not assuming leadership positions in proportion to their numbers.

In many institutions, scientists in part-time and non-tenure-track positions are ineligible to serve as principal investigators. That might partially explain why, in 1989, only 16.4% of competing applications and 19.2% of new applications at NIH were submitted by women (104). Those numbers were increased from 9.6% and 13.2%, respectively, in 1979 but were still well below what would be expected on the basis of the number of women in academic positions. The overall success rate of women who competed for NIH R01 grants in 1990, 22.3%, was almost identical with that of male applicants (96); but it accounted for only 577 grants, compared with the 2,557 awarded to male applicants.

The picture is similar for grant applicants at the National Science Foundation (NSF), where women constitute 27% of the funded grant applicants in biological sciences-roughly in keeping with their percentage in the applicant pool. The NSF Research Opportunities for Women (ROW) program conducted a telephone survey to assess its first 3 years (137). ROW, funded through a separate line item, funds grants through a competitive peer-review process to women seeking their first federal grant. Women in biology, behavior, and geosciences are the main beneficiaries of this program. The survey revealed that the lack of more senior role models and the limitations of the research network were perceived as serious impediments to female entry into research careers. The nonavailability of funding, institutional committee assignments, excessive teaching responsibilities, administrative duties, inadequate clerical support, and family responsibilities were the most frequently cited difficulties. Of those, family responsibilities were cited as a greater impediment for women than for men, although some respondents felt that teaching responsibilities, institutional committee assignments, and funding nonavailability were also sex-related (137).

Table 4-1 Percentages of Full-Time Medical-School Faculty Who Were First Appointed in 1976, by Rank

Rank	% Female	% Male
Professor	10	22
Associate professor	25	30
Assistant professor	25	18
Instructor	11	5
Dropped out	27	24
Unknown	2	1

Source: Bickel and Whiting (8).

The available information on women in the life-science pipeline suggests that the major point at which women are disproportionately lost from research positions is between the end of graduate school and appointment as assistant professors. The postdoctoral and early faculty years coincide with the time when a woman investigator in the life sciences often considers having a child. Given the cultural milieu in the United States, which places a greater share of the responsibility for child-rearing on women, they are more likely than men to decide that the pursuit of a full-time research career and parenthood are incompatible. Yet studies have found that the success rates of women who have children and continue in research careers are the same as those of women who do not have children (150). If women are to participate fully within the research community, the community must recognize the competing demands on women's time. Otherwise, it will lose talented people or relegate them to marginal positions.

Greater flexibility in the timing of tenure decisions for both men and women who take on child-rearing responsibilities can help to prevent the loss of talented people. Some research institutions have abandoned tenure in favor of rolling appointments that are reviewed regularly. Logistically, the establishment of on-site child care with schedules that reflect the needs of scientists could help to improve the career paths of women in science. Most important, though, is the development of an attitude among senior researchers that the talents of scientists who are responsible parents are needed by the research enterprise. Given that attitude, reasonable accommodation of the needs of this part of the research workforce cannot help but follow.

The committee is unaware of comprehensive studies that tracked the career paths of women trained in the life sciences after they received their advanced degrees. This type of study could be an important step toward the creation and implementation of programs for the greater participation of women at all levels in academic science.

UNDERREPRESENTED MINORITY GROUPS[2]

During the last 10 years, several programs have emerged that are aimed at encouraging participation of members of underrepresented minority groups in the biological research enterprise. The continued inability of our educational system to produce sizable numbers of African-American,

[2] In this report, underrepresented minority groups are defined as African-Americans, Hispanics (Puerto Ricans and Mexican-Americans), native Americans, and Pacific Islanders. Although Asian-Americans are considered an underrepresented minority group in the population as a whole, in the scientific population they are not.

Hispanic, and native American scientists has been a source of growing concern to the nation's research community for over a decade. Data show that the share of high-school sophomores in underrepresented minority groups who were interested in natural science and engineering (12%) was only about half the share in nonminority groups (21%) (53,59). By college graduation, the ratio of these shares was even smaller (2% vs. 5.8%), and it remained small when these students obtained Ph.D.s (0.1% vs. 0.25%) (53,59). "Leakage" from the science and engineering pipeline is serious for all U.S. citizens, but it is most serious for minority-group members.

Concern about the leakage is heightened by the recognition that minorities make up an increasing share of the U.S. population as a whole and particularly the population that attends school and, later, institutions of higher education. Minorities make up 22% of the U.S. population and are projected to make up 30–40% by the year 2020 (53,66). Many more minority-group researchers in the life sciences are needed both as teachers and for the insights that minority-group scholars are most likely to provide into minority-community behavior and health problems.

The federal programs that contribute most to graduate training of minority-group members in the life sciences were initiated in the 1980s and have only now begun to provide funds for a sizable number of trainees (97,98,149). Two such programs are the NSF fellowship program for minority groups and the Minority Access to Research Careers (MARC) program at NIH (86), which is directed toward undergraduates. Recently, both NSF and NIH have instituted policies of providing supplementation to grantees who hire minority-group research assistants (39,86). The numbers of minority-group NSF recipients in the biological sciences and of MARC fellowships are shown in Figure 4-2.

The results of those efforts are not apparent in the pipeline. In 1988–1989, bachelor's degrees in the life sciences were conferred on 11% fewer minority-group members than 10 years earlier, even though the total number of minority-group baccalaureates had risen by almost 10%. The largest decline of interest in the life sciences at the baccalaureate level has occurred among minority-group men. The number of minority-group women in the life sciences has actually grown, but total baccalaureate degrees have grown more rapidly (74).

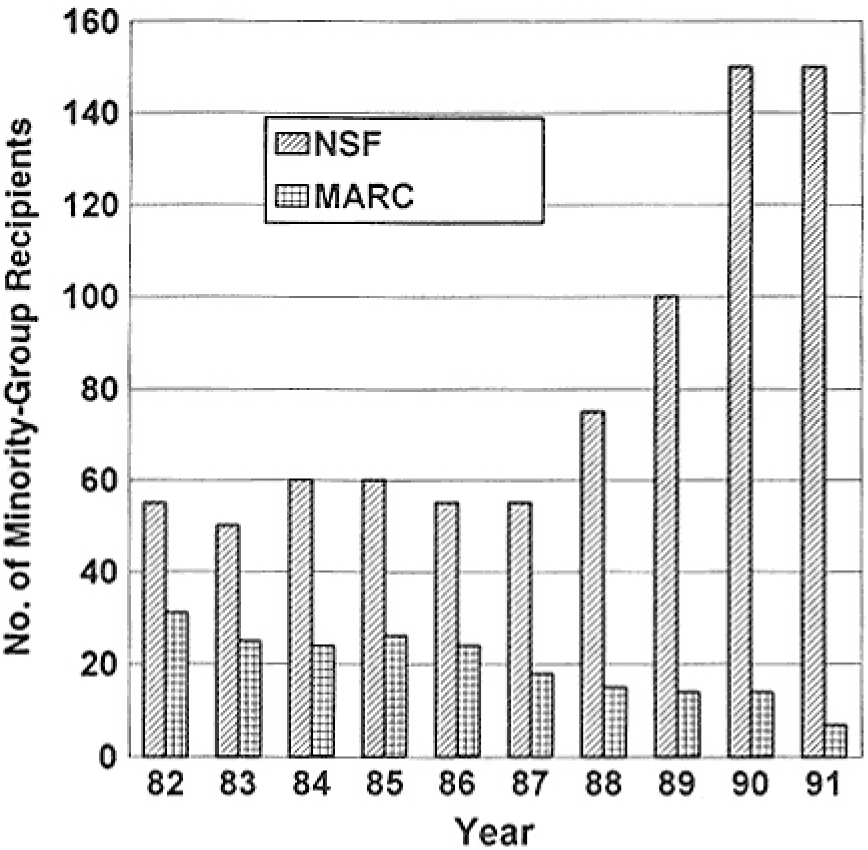

Figure 4-2 Numbers of individual minority-group recipients of NSF and MARC fellowships.
Source: NIH, DRG (100).

Minority groups account for 10% of all the doctoral degrees conferred in 1990, compared with 7% in 1980. The numbers show a great deal of variability both across years and between minority groups; it is difficult to discern trends. What is striking is how small the numbers are and have remained over the entire decade. Of about 4,000 doctorates in the life sciences conferred in each of the years 1980 and 1990, African-Americans received 58 in 1980 and 56 in 1990; Asian-Americans, 198 and 223; native Americans, six and seven; and Hispanics, 36 and 111 (111). A National Research Council report on biomedical and behavioral research scientists indicates that minority groups, except Asian-Americans, are underrepresented in the science workforce by a factor of 6 or 7 (45). In addition, recent data indicate that both men and women in those groups are underrepresented both in NIH predoctoral programs and among those expressing postdoctoral plans. The pace of recruitment from these groups into scientific careers is not proportional to their growth as segments of the population.

There is continuing debate as to whether there is "enough" funding for fellowships to encourage more minority-group members to undertake study in science and engineering. Recent attention has focused on what form funding takes, as well as how much is provided. There is general agreement that money alone is not the answer. Rather, students need to work closely with faculty to be included in the "culture" of their discipline. The results of efforts to draw minority-group students into the research culture are unlikely to be evident until 1995 at the earliest.

Increasing the representation of minority groups in science careers must begin with efforts that reach students long before their entry into professional or graduate schools. The main problems cited in recruitment and retention of underrepresented groups in science curricula and careers are poor primary and secondary educational systems, scarcity of role models (149), and financial limitations that are different from those for members of the majority. Gains through model programs supported by foundations and government-sponsored initiatives are cause for guarded optimism, as is the increased awareness of the need for such programs and their better coordination.

5

CONCLUSIONS AND RECOMMENDATIONS

GENERAL CONCLUSIONS

The Committee on the Funding of Young Investigators in the Biological and Biomedical Sciences was formed in 1991 to study the status of research support for newly independent investigators, scientists who have completed graduate and postgraduate training and have been directing their own laboratories for less than 5 years. The stimulus for such a study was the perception in the scientific community that newly independent investigators were being selectively disadvantaged over the preceding 5 years as research funds for life-science research stabilized and the absolute number of research grants actually declined. Newly independent investigators, it was argued, were not competing effectively with more experienced investigators for the increasingly scarce research funds. There was concern that the review groups that determine funding priorities, faced with a difficult choice of maintaining an already active research program or beginning a new one, were favoring the former.

The committee found that young investigators suffered in two ways during the late 1980s when success rates in obtaining awards from the major supporters of biological and biomedical research dropped precipitously. First, the success rate for younger applicants dropped with the rate for applicants of other age groups—a general and shared disadvantage. Second, whereas in earlier years younger applicants consistently had higher success rates than older applicants, their success rate from 1989 to 1991 was lower than that of many age groups—a new and special disadvantage. Thus, in those difficult times, young investigators lost their special advantage in the awarding of grants. The number of applications submitted by young investigators was also dropping precipitously. The result of the decrease in number of applications and a low success rate was a severe reduction in the number of these investigators being supported. This committee believes that for the continued health of the biological research enterprise it is necessary that steps be taken to understand and remedy this situation.

In the private philanthropies and voluntary health organizations, there was a remarkable degree of support for young investigators. Many of these organizations actually favor funding new researchers as a means to direct research toward particular diseases of interest. A criticism that has been directed toward these organizations is that they tend to fund the same few highly qualified people, rather than distributing the limited funds more broadly.

The committee noted the difference in overall federal and nonfederal support between biomedical and nonbiomedical, or biological, life-science research. Not only are the funds available for biological sciences vastly smaller, but the effort to ensure a future supply of scientists in the field was also much less pronounced. The funding prospects appear to be much bleaker for a young biological scientist than for a biomedical scientist, with respect to both the research dollars available and the likelihood of obtaining them. The funding difficulties in the biomedical sciences that stimulated this study have been in place in the biological sciences for many years.

Like the physical sciences in the first decades of this century, the life sciences are in the early phase of a major scientific revolution. This revolution is driven largely by the powerful tools and unifying concepts provided by molecular biology, a field that emerged from basic research in the most fundamental of life processes. Just as quantum mechanics, a discipline that stemmed from inquiries into the most fundamental properties of light and matter, was the wellspring of the entire multibillion-dollar electronics and information-processing industry, molecular biology is beginning to yield applications of enormous medical and economic benefit.

Thus, although our recommendations regarding biomedical and biological research funding have been framed against the background of the current fiscal restraint imposed by our huge national debt, it is our firm conviction that these financial pressures must not make us short-sighted. The United States still leads the world in most fields of biomedical and biological research. From American basic research will flow a host of new approaches to urgent medical, agricultural, and environmental problems. Yet if this lead is to be maintained and if these urgent applications are to be developed by American-trained scientists, the federal government and other funding agencies must provide major new resources to support basic biological research. The new funds should be viewed as an investment that will not only extend and deepen our understanding of basic life processes, but also speed the development of biotechnology and related industries that will spring from new fundamental knowledge.

A MODEL FOR GRANTS TO NEWLY INDEPENDENT INVESTIGATORS

In the course of its study, the committee reviewed many programs designed to support the initial stages of the careers of newly independent investigators and generated a set of features that it deemed important in any program designed for their benefit. It is likely that no granting program can adhere completely to this list. Rather, we provide it as a guide for agencies and organizations that wish to establish new programs or modify existing programs. The features are as follows:

- Grant applications from newly independent investigators should be reviewed separately from those from more seasoned investigators. This provides a means to judge newly independent investigators as a cohort, rather than against more experienced scientists. Young investigators tend to cluster in exciting and active fields of research. That leaves them at a competitive disadvantage relative to their colleagues in less popular fields.
- Review panels should be encouraged to consider the promise of an applicant and the research plan. The research plan should be judged on its merits and on its likelihood of providing new information, without a requirement for extensive evidence that it will succeed. A requirement for preliminary data discourages young investigators from trying new ideas. In its place, panels could require letters of recommendation from past preceptors.
- A grant period should be at least 3 years, and optimally 5 years. The young investigator has to establish a new laboratory and train inexperienced personnel during the period of the first grant. Grants of short duration discourage young investigators from establishing a new avenue of investigation.
- The budget allocation should be sufficient to fund the project in its entirety. Budgets should include adequate funds for both equipment and supplies and recognize that the laboratories of young investigators are likely to grow more quickly over a 5-year

span than those of senior investigators. Provision of adequate budgets would reduce the time spent in preparing multiple applications for research support.

- Grants should reward institutions that limit administrative responsibilities of the newly independent investigator and carefully structure teaching responsibilities. A model for such a program is the Research Career Development Award, which provides salary support for investigators in return for partial release from teaching and administration. In addition to its honorific attribute, this award affords the recipient more time to pursue research. Because it uses the same research application that is submitted for research support, it also reduces the number of applications that an investigator needs to write. The amount and type of teaching assigned to newly independent investigators should be structured to stimulate their research. Teaching courses at the advanced level exposes young faculty to potential research students for their laboratories (both senior undergraduates and graduate students) and provides a forum for the discussion of research ideas.

The model grant system described above clearly is designed to *advantage* young investigators at the beginning of their independent research careers. The dominance of the United States in the life sciences is built, at least in part, on the tradition of giving scientists their intellectual independence early, when they are most likely to be innovative and productive. It is the committee's view that the winnowing process should be least stringent at this point and tighten once they have had some time to demonstrate their ability. The committee recognizes the inherently higher risks in funding less-established investigators but notes that they need not be funded at the levels of established investigators.

The cost of research varies with the discipline, as well as with the age and experience of the scientist. The committee therefore makes no general recommendation regarding the absolute amount of an initial research award.

MONITORING THE NUMBERS OF SCIENTISTS

The committee found a paucity of data on the career paths and funding success of young scientists once they leave graduate school. To ensure a healthy basic-science enterprise, the scientist pipeline should be monitored.

The committee found that very few organizations can accurately track their funding of newly independent investigators and recommends that methods for the confidential monitoring of age and scientific-experience characteristics and the sex of applicants and awardees be adopted. The committee recognizes that federal statutes require that such data be provided voluntarily by applicants. Nevertheless, in the absence of such data the ability to ensure an adequate supply of young scientists and to maintain a stable population of established scientists is impaired. Availability of such data would also provide a way to monitor the effectiveness of new educational initiatives and to measure the proposal pressure generated by newly independent investigators. The National Research Council's biennial survey and database of doctorate recipients might serve as a means for the tracking we suggest.

RECOMMENDATIONS ON FEDERAL EXTRAMURAL FUNDING OF NEWLY INDEPENDENT INVESTIGATORS IN THE LIFE SCIENCES

NATIONAL INSTITUTES OF HEALTH

The First Independent Research Support and Transition (FIRST) Award

The First Independent Research Support and Transition (FIRST) Award (R29) program is excellent. However, it is underused by the biomedical community. To make it a more widely used program, the committee recommends an increase in the total amount of the 5-year award from the current $350,000 to a maximum of $625,000 (i.e., from $70,000 to $125,000 per year). The maximum would not be automatically awarded. Rather, like R01 research budgets, the budget of the R29 would be negotiable and based on the study section's recommendations of the funds needed to conduct the research. An increase in the R29 budget would respond to the most common complaint of newly independent investigators: that the current amount is not sufficient to start up and run a new laboratory in biomedical science, particularly if the investigator must pay a large fraction of his or her salary from the grant.

An increase in the R29 funding ceiling will inevitably have an impact on the grants portfolio at the National Institutes of Health (NIH). For instance, if the raised ceiling is instituted, one would expect the size of the budgets for R29 grants to increase and their number to rise as more qualified investigators apply for R29s, instead of R01s. The successful applicants will receive more funding, reducing the need for multiple applications with their many associated costs. A second important benefit will accrue to young investigators who were forced by budgetary constraints to apply for R01s. If the current higher success rate for R29s than for R01s is maintained, more young investigators will obtain funding. That might require larger numbers of R29 grants for the R29 success rate to remain approximately where it is today. Finally, there is a benefit to the scientific community in having all young investigators considered as a cohort, rather than having them compete in two arenas for funding, as they must do now.

Raising the budget ceiling for R29 grants will also help to alleviate a problem that arises at the time of the first renewal application: the need to award large increases in funds to successful investigators whose laboratories have expanded during the period of the FIRST award. Nevertheless, the institutes should continue to be flexible in awarding budgetary increases to renewal applications to ensure that the most productive investigators are adequately funded.

The review process should be modified so that study sections are fully aware that R29 applications have a separate status from R01 applications. The simplest modification would be to review R29 grant applications en bloc at the beginning of the study-section meeting, giving the chairperson an opportunity to point out the specific conditions of these grants. The chairperson would be assisted by the development and circulation of a brochure containing the guidelines for judging new grants. Such a document would reduce variability among study sections in evaluating applications for new grants.

The committee also recommends the consideration of NIH-wide panels organized by broadly defined research disciplines to review R29 applications separately, as is the practice for postdoctoral-fellowship applications. The advantage of this system is that it permits a more accurate overview of research interests among newly independent investigators. In addition, it equalizes the competition among research applications in "hot" and "cool" fields.

Application instructions should clearly state, and the peer-review panels should be instructed, that preliminary data are not necessary in the consideration of a FIRST application but can be replaced by the strength and justification of an original and untested idea. That would make it possible for an applicant to propose research on the basis of only an original and untested new idea, rather than a continuation of postdoctoral research. Applicants could then submit research proposals once they had been assured of faculty positions while they were still holding senior postdoctoral positions. Receiving the grant at about the time the applicant begins a faculty appointment would facilitate the setting up of the laboratory and the conduct of research.

The R29 recipient should have the option to apply for an R01 grant on the same subject at any time before the end of the 5-year period. If the R01 is awarded, the remainder of the R29 money must be returned. That allows a newly independent investigator to use an R29 to gather preliminary results in preparation for a full-fledged R01.

Locally Administered Funds

The committee acknowledges the importance of locally administered funds, such as National Oceanic and Atmospheric Administration National Undersea Research Program funds and Hatch and McIntire-Stennis Act funds. Funding programs that have been determined to be of critical importance to universities and to individual research efforts that need extra support should be maintained and strengthened. NIH's Biological Research Support Grant program has been terminated after long years of criticism of the program for vague funding guidelines and accounting procedures that made it difficult to measure effectiveness. The committee suggests that NIH consider reinstitution of the program while encouraging local directors of it to use funds primarily for newly independent investigators. To ensure that the research funded is the most meritorious, funding decisions should be made through locally established peer-review panels. Additionally, a more rigorous accounting of the distribution of funds should be established at the local institution.

DEPARTMENT OF AGRICULTURE

The National Research Initiative Competitive Grants Program (NRICGP) will have a large impact on the funding of newly independent investigators in the 1990s. The program was initiated in 1991 at a funding level of $73 million and increased in 1992 to $97.5 million. The program is to be funded at $130 million in 1994. These funds are administered by the NRICGP on a competitive basis to support fundamental research relative to sustainable agriculture.

Data on the total funding and success rate of young investigators, particularly of untenured faculty at academic institutions, should be maintained for the NRICGP to permit accurate assessment of the effectiveness of the initiative. Similar mechanisms should be established to monitor the effectiveness of Hatch and McIntire-Stennis Act funds.

NATIONAL SCIENCE FOUNDATION

The National Science foundation (NSF) has traditionally funded newly independent investigators. The young investigator awards profiled in Chapter 3 are examples of this commitment. The committee encourages NSF to continue to emphasize programs for the newly independent investigator and to monitor the development of the recently initiated Faculty Early Career Development Award program to ensure that it meets its mission goals.

NSF should also maintain its current policy of restricting the number of publications listed in a curriculum vitae to a maximum of 10. That helps to reduce the disparity introduced by prior funding success or simply by experience and thus can benefit newly independent investigators. The committee believes that switching the emphasis from quantity to quality of publications is a laudable action for all levels of research funding.

RECOMMENDATIONS ON NONFEDERAL FUNDING OF NEWLY INDEPENDENT INVESTIGATORS IN THE LIFE SCIENCES

INDUSTRIAL FUNDING

Newly independent investigators and the graduate and postdoctoral students that they train form the pool of scientists from which those who will contribute directly to industrial advances are drawn. Although many industrial firms support academic research, the dollar level of support and the mechanisms through which they do it vary dramatically. Thus, academic scientists interested in obtaining industrial funding must spend considerable time locating appropriate sponsors. Individual firms approach solicitation, review, and funding of academic research differently. Considerable time and money must be expended by each company with an interest in the funding of basic research. The ad hoc nature of this enterprise tends to militate against the support of newly independent investigators.

The funds expended by industry in soliciting and reviewing proposals and in supporting new investigators could be spent more effectively through the establishment of a foundation to support these scientists. The common goal would be cost-effective use of resources to attract and increase the nation's pool of scientists, but—because of the highly competitive, secretive nature of industrial research—cooperative funding of a foundation of this nature would be possible only if the research were structured to emphasize fundamental new knowledge.

Industrial support of the foundation could be through endowments, annual donations, or multiyear subscriptions. Funding might be scaled to the size of the participating companies. Administration of the foundation would need to be independent of participating companies; e.g., grant applications would have to be reviewed through an independent peer-review mechanism. Grants would be funded in the name of the foundation and would have features similar to those described earlier in this chapter.

The tax treatment of company support and the framework within which any intellectual property would be administered warrant separate expert study.

PHILANTHROPIC FUNDING

The philanthropic foundations are to be commended for their efforts in funding newly independent scientists, for developing grants that directly address the specific needs of this cohort, and for identifying and funding "orphan" fields that are not well supported by other, larger institutions. As with many other organizations, it would be valuable for the general research funding mechanisms used by philanthropies to incorporate data-collection features that allow more accurate monitoring of the flow of students and researchers in the scientist pipeline.

It is recommended that philanthropies increase their support of all fields of life-science research, particularly newly emerging fields. Their ability to move support rapidly from one field to another is ideally suited to the support of newly emerging disciplines and for underfunded established disciplines, such as conservation biology, systematics, environmental biology, marine biology, and limnology.

Philanthropic grants are highly prestigious and create a competitive atmosphere among the funders for applicants and among the applicants for the grants. A highly talented applicant can receive comparable grants from several philanthropies. To support as many scientists as possible, the committee recommends that the philanthropies that serve common constituencies cooperate to ensure that the grants are widely distributed by limiting either the value or the number of grants that a person can receive.

VOLUNTARY HEALTH ORGANIZATION FUNDING

The voluntary health organizations (VHOs) should be encouraged to continue their commitment to research into prevention, diagnosis, and treatment of disease, despite the pressure to devote more of their income to service functions. The record of VHO programs reveals that these organizations are heavily committed to supporting young investigators. VHOs are urged to continue, and if possible expand, that commitment.

Although the smaller sums of the VHOs' 1-to 2-year grants serve young investigators well as supplements to larger grants, somewhat larger grants extended to 3 years could prove more effective for organizations with larger programs, such as the American Heart Association and the American Cancer Society. The additional time would serve the important purpose of allowing newly independent investigators to gather sufficient preliminary data to justify applying to the major federal agencies for research grants.

UNIVERSITY SUPPORT

New, younger faculty are the life blood of the university system, providing the surest protection against academic stagnation and providing for expansion of scientific frontiers by the application of new techniques and interdisciplinary work. State-and private-university funds are essential for newly independent investigators. The committee was unable to identify consistent patterns of state support favoring newly independent investigators that were independent of the universities.

Full recovery of direct and indirect costs associated with extramural grants is necessary to maximize university research efforts; underrecovery requires an institution to subsidize current research programs, thus drawing scarce funds away from other university funding vehicles designed to support newly independent faculty. It is clear that recovered costs are used to develop startup packages and indirectly facilitate the work of newly independent investigators through support of services. Support of services is a low-visibility effort but comes at the critical junction between postdoctoral status and faculty career.

Because it is critical that a university further its new faculty members' careers, we recommend the following:

- New faculty members should be provided substantial unencumbered time, but not isolation. Careful structuring of teaching responsibilities can provide unencumbered time, and adequate collegial advice can avoid isolation. To the greatest extent possible, more support should be channeled into startup costs and into salary support to limit the teaching and administrative responsibilities of newly independent investigators and to provide appropriate teaching duties. Intramural support programs that favor newly independent investigators, in addition to startup packages, constitute effective mechanisms for rapid adjustment of a scientist's research perspectives and goals.
- Procedures should exist for providing scientists with encouragement and advice in seeking extramural support. Many universities have developed informal mentorship programs focused on improving the grant applications of newly independent investigators. Such programs require additional time on the part of established faculty, but the payoff is in the increase in extramural funding of junior faculty.
- Newly independent investigators should have access to graduate students to facilitate their own maturation and encourage a sense of community.
- Each university should establish a university-wide standing committee to examine continuously the special needs of its new faculty and to develop the best possible support packages for them.

RECOMMENDATIONS ON SUPPORT FOR FEMALE NEWLY INDEPENDENT INVESTIGATORS IN THE LIFE SCIENCES

The committee could identify no difference in the likelihood of funding between women and men in the life sciences, once they had assumed faculty positions. The disparity identified was the decreased likelihood that a woman would achieve a position in which she would be eligible to apply for a grant.

Although almost 40% of all newly trained biologists are women, they made up just 19% of NIH-grant applicants in 1990. In addition, only 31% of the postdoctoral-fellowship dollars at NIH were directed to women scientists.

A detailed analysis of this issue is outside the purview of this report. However, the committee believes that the continued failure of women to gain access to positions of authority in the life sciences is a serious issue with direct implications for the long-term vitality of the enterprise.

As women proceed through many years of training in the life sciences and begin to enter the workforce, the constraints on their success and career progress become more apparent. The transition from postdoctoral fellow to faculty member coincides with many women's child-bearing years. Universities that recognize this problem and provide inexpensive extended-hour day care are to be commended and should be encouraged. Industry seems to have already grasped the implications of the increased number of women in the workforce, and many companies are now providing financial support to employees in need of day-care assistance as part of their own recruitment and retention initiatives.

Attention should be given to the promotion of women to department chairs, deanships, and other executive positions to achieve a sex balance and reflect the increase in the number of women entering the scientific workforce. The lack of senior role models, limited access for women to the research network, and excessive institutional committee assignments, teaching responsibilities, and mundane administrative duties are impediments to the advancement of women that require institutional attention.

RECOMMENDATIONS ON SUPPORT FOR UNDERREPRESENTED MINORITY GROUPS IN THE LIFE SCIENCES

From the summary in Chapter 4, it is apparent that numerous local and national initiatives already in place are designed to attract members of underrepresented minority groups to careers in the life sciences.

Institution-wide programs for college undergraduates and high-school students bring students in underrepresented minorities to university and college campuses for summer laboratory research. The programs often lack followup mechanisms to provide advanced alternatives for summers after their first experiences. Also missing is a stable source of funds to administer the summer programs. NSF, NIH, foundations, and VHOs should be encouraged to contribute funds. And individual investigators should be mobilized by their institutions to participate in these programs.

Although the existing initiatives provide adequate model programs to increase dramatically the recruitment of members of underrepresented groups to science and mathematics careers, program implementers are frustrated by the difficulties in finding the most suitable candidates in sufficient numbers. To link the institutions and those who could benefit from the programs, there should be a national coordinating center that can maintain a dynamic inventory of programs and people to facilitate appropriate matching of the two. The center must have knowledge of both the resources, including local and national programs, and the programs for candidates at every stage of preparation from high school (or even earlier) through junior academic appointments to full-time industrial or government positions. The Washington, D.C., area would be an ideal location for the center, because of the presence of federal agencies and the national offices of key interest groups.

The center must be in a position to assemble, through staff and volunteer participation, well-informed and independent advocates who are in a position to counsel federal, state, and local establishments and the private sector. There is reason to believe that the flow of students in underrepresented minority groups from secondary school into advanced programs has started in earnest and that programs are in place to accommodate them when they reach the stages of advanced training. Therefore, a national center could be an effective means of matching programs and people. The center should be equipped to advertise itself, through public-relations campaigns, to the underrepresented minority groups that are targeted for recruitment.

No new specific programs for young investigators in underrepresented minority groups are recommended here. However, the existing programs should be strengthened.

APPENDIX: ADDITIONAL DATA

Chapter 2 presents data on R01 and R23/29 applications and awards. This appendix provides additional detail.

The following tables show the complete series of data for R01, R23, R29, and R37 awards. These award types are described in Chapter 2. All support individual investigators, but they differ in important respects. R23/R29 awards are intended for investigators at an early stage of their careers. As the figures here indicate, almost all applicants are in the younger age cohorts. R37 awards recognize persons at a more advanced stage of their careers who are invited to apply for the awards. The applicants are mainly in the middle to older age groups. The success rate for R37s is almost 100%. This committee considers R01 grants to be the best medium for comparison among different age groups because R01s may be applied for by persons of any age or degree of experience. Thus, Figure 2-6 uses R01 data only. Readers who wish to examine the influence of adding R23/29 or R37 grants or both to the R01 data are provided with the basic information here.

For each age group, a column has been added to show the percentage of all applications submitted by the persons in that age group. The added figures show, for example, that persons 36 and under constituted 17.2% of all R01 grant applicants in 1985 and 7.2% in 1993.

Totals of applications submitted and awards made and overall success rates for all age groups are included in this appendix.

The data presented here are for all competing applications in the series shown and for all of the National Institutes of Health (NIH), including the research programs of the Alcohol, Drug Abuse, and Mental Health Administration and related institutes that were transferred to NIH in 1992. Data on persons of unknown age are excluded.

We are indebted to Robert Moore and James Tucker of the National Institutes of Health, Division of Research Grants, Information Systems Branch, Statistical Analysis and Evaluation Section, for their patient responses to frequent requests for data and special analyses and for confirmation of the data we have presented on NIH grants.

Age	≤ 36				37 - 40				41 - 45				46 - 50			
Fiscal Year	No. of Apps.	Percent of All Apps	Success Rate	No. Supported	No. of Apps	Percent of All Apps	Success Rate	No. Supported	No. of Apps.	Percent of All Apps	Success Rate	No. Supported	No. of Apps.	Percent of All Apps	Success Rate	No. Supported
R01 Applications by Age																
1985	3,040	17.2	33.0	1,002	3,547	20.1	34.4	1,221	4,061	23.0	32.9	1,338	2,637	14.9	32.0	843
1986	2,823	16.4	32.8	927	3,556	20.7	32.3	1,150	4,019	23.3	31.9	1,281	2,514	14.6	30.2	759
1987	2,160	13.6	36.3	784	3,132	19.8	35.9	1,123	3,804	24.0	35.8	1,362	2,592	16.4	34.5	893
1988	2,059	12.2	32.2	662	3,207	19.1	31.5	1,011	4,155	24.7	31.3	1,299	3,092	18.4	29.3	906
1989	1,945	11.3	26.5	516	3,316	19.2	27.5	913	4,137	24.0	27.9	1,153	3,259	18.9	26.7	871
1990	1,621	9.1	20.4	330	2,910	16.3	22.7	661	3,792	21.2	23.0	872	3,060	17.0	24.1	736
1991	1,458	8.5	27.0	393	3,112	18.1	28.0	872	4,275	24.9	28.8	1,231	3,355	19.5	29.4	986
1992	1,393	7.9	29.4	410	3,054	17.4	28.3	863	4,448	25.3	27.7	1,230	3,542	20.1	28.6	1,014
1993	1,389	7.2	21.7	302	3,231	16.7	21.9	708	4,983	25.8	21.4	1,066	4,003	20.7	22.4	895
R23 Applications by Age																
1985	786	69.4	38.9	306	214	18.9	28.5	61	73	6.4	23.3	17	17	1.6	17.6	3
1986	682	68.4	35.0	239	186	18.7	26.3	49	65	6.5	27.7	18	18	1.8	11.1	2
1987	144	54.3	31.9	46	67	25.3	20.9	14	29	10.9	24.1	7	9	3.4	22.2	2
R29 Applications by Age																
1985																
1986	29	82.9	96.6	28	4	11.4	100.0	4	1	2.9	100.0	1				
1987	1,090	59.5	27.0	294	452	24.7	21.5	97	173	9.4	17.9	31	40	2.2	7.5	3
1988	1,207	55.3	34.2	413	594	27.2	29.5	175	245	11.2	24.5	60	55	2.5	16.4	9
1989	957	52.6	34.1	326	563	30.9	29.7	167	182	10.0	22.0	40	41	2.3	14.6	6
1990	803	47.2	27.1	218	473	27.8	30.0	142	166	9.7	19.9	33	40	2.3	7.5	3
1991	760	46.6	33.9	258	508	31.1	28.7	146	187	11.5	22.5	42	47	2.9	25.5	12
1992	791	45.5	35.8	283	620	35.7	31.1	193	226	13.0	26.5	60	50	2.9	20.0	10
1993	787	42.2	28.6	225	669	35.9	28.3	189	307	16.5	21.2	65	68	3.6	23.5	16
R37 Applications by Age																
1985																
1986	3	1.8	100.0	3	7	4.1	100.0	7	27	16.0	100.0	27	48	28.4	97.9	47
1987					16	8.2	100.0	16	34	17.3	100.0	34	41	20.9	100.0	41
1988	2	0.9	100.0	2	11	4.9	100.0	11	44	19.7	97.7	43	48	21.5	95.8	46
1989	2	1.0	100.0	2	11	5.5	90.9	10	45	22.6	100.0	45	48	24.1	97.9	47
1990					5	3.3	100.0	5	14	9.2	100.0	14	39	25.5	94.9	37
1991					2	0.7	100.0	2	38	13.9	92.1	35	60	22.0	96.7	58
1992	2	0.6	100.0	2	3	0.9	100.0	3	41	11.8	97.6	40	69	19.9	91.3	63
1993	1	0.3	0.0	0	6	1.8	100.0	6	34	10.4	97.1	33	76	23.2	92.1	70

Age	51 - 55				56 - 60				>60				Totals		
Fiscal Year	No. of Apps.	Percent of All Apps	Success Rate	No. Supported	No. of Apps.	Percent of All Apps	Success Rate	No. Supported	No. of Apps.	Percent of All Apps	Success Rate	No. Supported	Total Apps Rec'd	Total Awards	Overall Rate
R01 Applications by Age															
1985	1,660	9.4	29.0	482	1,225	6.9	30.0	367	1,021	5.8	26.2	267	17,670	5751	32.5
1986	1,641	9.5	28.3	465	1,144	6.6	23.6	270	989	5.7	27.4	271	17,212	5408	31.4
1987	1,559	9.9	30.8	480	1,141	7.2	33.0	376	928	5.9	30.6	284	15,825	5608	35.4
1988	1,662	9.9	28.0	465	1,213	7.2	26.3	319	1,039	6.2	28.1	292	16,814	5170	30.7
1989	1,894	11.0	23.2	439	1,175	6.8	22.3	262	1,105	6.4	22.7	251	17,257	4607	26.7
1990	1,825	10.2	20.9	382	1,051	5.9	20.3	213	1,048	5.9	19.7	206	17,898	4112	23.0
1991	2,033	11.8	25.4	516	1,153	6.7	25.5	294	1,168	6.8	22.3	260	17,203	4709	27.4
1992	2,316	13.2	24.3	562	1,271	7.2	23.4	297	1,258	7.2	23.2	292	17,579	4769	27.1
1993	2,722	14.1	20.3	553	1,361	7.0	20.6	281	1,469	7.6	17.5	257	19,314	4121	21.3
R23 Applications by Age															
1985	4	0.4	25.0	1	1	0.1	0.0	0					1,133	409	36.1
1986	4	0.4	0.0	0	4	0.4	25.0	1	3	0.3	0.0	0	997	332	33.3
1987	3	1.1	33.3	1	2	0.8	0.0	0					265	79	29.8
R29 Applications by Age															
1985															
1986													35	34	97.1
1987	10	0.5	10.0	1	4	0.2	0.0	0	1	0.1	0.0	0	1,831	468	25.6
1988	15	0.7	0.0	0	5	0.2	0.0	0	5	0.2	20.0	1	2,181	695	31.9
1989	12	0.7	25.0	3	2	0.1	0.0	0	2	0.1	0.0	0	1,820	576	31.6
1990	15	0.9	13.3	2	4	0.2	0.0	0	1	0.1	0.0	0	1,703	486	28.5
1991	13	0.8	15.4	2	4	0.2	75.0	3	2	0.1	0.0	0	1,631	505	31.0
1992	9	0.6	55.6	5	1	0.1	0.0	0	1	0.1	0.0	0	1,739	574	33.0
1993	18	1.0	11.1	2	3	0.2	0.0	0					1,865	505	27.1
R37 Applications by Age															
1985															
1986	33	19.5	100.0	33	26	15.4	100.0	26	21	12.4	100.0	21	169	168	99.4
1987	38	19.4	100.0	38	31	15.8	100.0	31	19	9.7	100.0	19	196	196	100.0
1988	42	18.8	100.0	42	31	13.9	100.0	31	37	16.6	100.0	37	223	220	98.7
1989	38	19.1	97.4	37	22	11.1	100.0	22	28	14.1	100.0	28	199	196	98.5
1990	25	16.3	96.0	24	23	15.0	91.3	21	23	15.0	95.7	22	153	138	90.2
1991	70	25.6	90.0	63	40	14.7	95.0	38	57	20.9	96.5	55	273	257	94.1
1992	96	27.7	91.7	88	55	15.9	85.5	47	74	21.4	86.5	64	346	312	90.2
1993	76	23.2	92.1	70	51	15.6	92.2	47	79	24.2	91.1	72	327	302	92.4

Age	≤ 36				37 - 40				41 - 45				46 - 50			
Fiscal Year	No. of Apps.	Percent of All Apps	Success Rate	No. Supported	No. of Apps.	Percent of All Apps	Success Rate	No. Supported	No. of Apps.	Percent of All Apps	Success Rate	No. Supported	No. of Apps.	Percent of All Apps	Success Rate	No. Supported
R01 and R23/ R29 Applications by Age																
1985	3,826	20.3	34.2	1,308	3,761	20.0	34.1	1,282	4,134	22.0	32.8	1,355	2,654	14.1	31.9	846
1986	3,534	19.4	33.8	1,194	3,746	20.5	32.1	1,203	4,085	22.4	31.8	1,300	2,532	13.9	30.1	761
1987	3,394	18.9	33.1	1,124	3,651	20.4	33.8	1,234	4,006	22.4	34.9	1,400	2,641	14.7	34.0	898
1988	3,266	17.2	32.9	1,075	3,801	20.0	31.2	1,186	4,400	23.2	30.9	1,359	3,147	16.6	29.1	915
1989	2,902	15.2	29.0	842	3,879	20.3	27.8	1,080	4,319	22.6	27.6	1,193	3,300	17.3	26.6	877
1990	2,424	12.4	22.6	548	3,383	17.3	23.7	803	3,958	20.2	22.9	905	3,090	15.8	23.9	739
1991	2,218	11.8	29.4	651	3,620	19.2	28.1	1,018	4,462	23.7	28.5	1,273	3,402	18.1	29.3	998
1992	2,184	11.3	31.7	693	3,674	19.0	28.7	1,056	4,674	24.2	27.6	1,290	3,592	18.6	28.5	1,024
1993	2,176	10.3	24.2	527	3,900	18.4	23.0	897	5,290	25.0	21.4	1,131	4,071	19.2	22.4	911
R01, R37, and R23/ R29 Applications by Age																
1985	3,826	20.3	34.2	1,308	3,761	20.0	34.09	1,282	4,134	22.0	32.78	1,355	2,654	14.1	31.88	846
1986	3,537	19.2	33.8	1,197	3,753	20.4	32.24	1,210	4,112	22.3	32.27	1,327	2,580	14.0	31.32	808
1987	3,394	18.7	33.1	1,124	3,667	20.2	34.09	1,250	4,040	22.3	35.5	1,434	2,682	14.8	35.0	939
1988	3,268	17.0	33.0	1,077	3,812	19.8	31.4	1,197	4,444	23.1	31.55	1,402	3,195	16.6	30.08	961
1989	2,904	15.1	29.1	844	3,890	20.2	28.0	1,090	4,364	22.6	28.37	1,238	3,348	17.4	27.6	924
1990	2,424	12.3	22.6	548	3,388	17.2	23.85	808	3,972	20.1	23.14	919	3,129	15.8	24.8	776
1991	2,218	11.6	29.4	651	3,622	19.0	28.16	1,020	4,500	23.6	29.07	1,308	3,462	18.1	30.5	1,056
1992	2,186	11.1	31.8	695	3,677	18.7	28.8	1,059	4,715	24.0	28.21	1,330	3,661	18.6	29.69	1,087
1993	2,177	10.1	24.2	527	3,906	18.2	23.12	903	5,324	24.8	21.86	1,164	4,147	19.3	23.66	981

Age	51 - 55				56 - 60				>60				Totals		
Fiscal Year	No. of Apps.	Percent of All Apps	Success Rate	No. Supported	No. of Apps.	Percent of All Apps	Success Rate	No. Supported	No. of Apps.	Percent of All Apps	Success Rate	No. Supported	Total Apps Rec'd	Total Awards	Overall Rate
R01 and R23/ R29 Applications by Age															
1985	1,664	8.8	29.0	483	1,226	6.5	29.9	367	1,021	5.4	26.2	267	18,803	5908	31.4
1986	1,645	9.0	28.3	465	1,148	6.3	23.6	271	992	5.4	27.3	271	18,244	5465	30.0
1987	1,572	8.8	30.7	482	1,147	6.4	32.8	376	929	5.2	30.6	284	17,921	5798	32.4
1988	1,677	8.8	27.7	465	1,218	6.4	26.2	319	1,044	5.5	28.1	293	18,995	5612	29.5
1989	1,906	10.0	23.2	442	1,177	6.2	22.3	262	1,107	5.8	22.7	251	19,077	4947	25.9
1990	1,840	9.4	20.9	384	1,055	5.4	20.2	213	1,049	5.4	19.6	206	19,601	3798	19.4
1991	2,046	10.9	25.3	518	1,157	6.1	25.7	297	1,170	6.2	22.2	260	18,834	5015	26.6
1992	2,325	12.0	24.4	567	1,272	6.6	23.3	297	1,259	6.5	23.2	292	19,318	5219	27.0
1993	2,740	12.9	20.3	555	1,364	6.4	20.6	281	1,469	6.9	17.5	257	21,179	4559	21.5
R01, R37, and R23/ R29 Applications by Age															
1985	1,664	8.8	29	483	1,226	6.5	29.9	367	1,021	5.4	26.15	267	18,803	5908	31.4
1986	1,678	9.1	29.7	498	1,174	6.4	25.3	297	1,013	5.5	28.83	292	18,413	5629	30.6
1987	1,610	8.9	32.3	520	1,178	6.5	34.6	407	948	5.2	32.0	303	18,117	5977	33.0
1988	1,719	8.9	29.5	507	1,249	6.5	28.0	350	1,081	5.6	30.53	330	19,218	5824	30.3
1989	1,944	10.1	24.6	479	1,199	6.2	23.7	284	1,135	5.9	24.58	279	19,276	5138	26.7
1990	1,865	9.4	21.9	408	1,078	5.5	21.7	234	1,072	5.4	21.27	228	19,754	3921	19.8
1991	2,116	11.1	27.5	581	1,197	6.3	28.0	335	1,227	6.4	25.67	315	19,107	5266	27.6
1992	2,421	12.3	27.1	655	1,327	6.7	26.9	344	1,333	6.8	26.71	356	19,664	5526	28.1
1993	2,816	13.1	22.2	625	1,415	6.6	23.2	328	1,548	7.2	21.25	329	21,506	4857	22.6

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