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Essay

Trends in the Early Careers of Life Scientists
Preface and Executive Summary

Committee on Dimensions, Causes, and Implications of Recent Trends in the Careers of Life Scientists

Board on Biology, Commission on Life Sciences, Office of Scientific and Engineering Personnel, National Research Council, Washington, DC 20418

PREFACE

The National Research Council has regularly reported on issue of the scientific and engineering work force, including questions related to the education, training, and deployment of scientific personnel. It actively maintains files on doctoral awardees and periodically surveys their employment in science. The Council's interest in the arena is based on the importance of scientific research to the nation's welfare, and that is also the reason for interest in support of the education and training of life scientists.

That support has chiefly come from three federal agencies: the National Institutes of Health (NIH), the National Science Foundation (NSF), and the US Department of Agriculture; numerous private foundations and public and private universities have also contributed. The US Congress has manifested interest in questions of supply of and demand for trained scientists in biomedical and behavioral science by establishing the National Research Service Award program at NIH, which provides funding explicitly for training scientists, and by requesting a periodic report from the National Academy of Sciences on national needs for biomedical and behavioral research personnel. Other agencies support life science education and research through separate programs. Thus, this report, by the Committee on Dimensions, Causes, and Implications of Recent Trends in the Careers of Life Scientists, in the Board of Biology of the Research Council's Commission on Life Sciences, deals with issues that are pertinent to the agendas of a very wide array of agencies and institutions.

The committee was charged to examine trends in research careers of life scientists in training, at the conclusion of training, and in the years immediately after training and to examine the implication of these trends for the persons involved and for the health of the life science enterprise. The committee's goal was to frame recommendations that would be beneficial both to the young aspirants to scientific careers and to the enterprise they had committed to. The committee recognized that it was dealing with interdependencies among educators, trainees, investigators, funders, and entrepreneurs that truly constituted a sociotechnical system of great complexity. The importance of established stakes in the status quo quickly became apparent, and the committee recognized that there was no single locus of power to make changes in the system that has produced undesirable outcomes for some young scientists. If change is to occur, it will be through the uncoordinated action of many persons at many institutions who try to consider what is best for their students and their profession and then take appropriate action.

Those insights tempered any ambition that the committee might initially have had to "reform" the system overnight by taking bold measures. The risk of doing more damage than good is great, given the complexity of the educational system, the size of the enterprise, and its importance for the nation's long-term interest. Accordingly, the committee's principal recommendations are measured rather than dramatic.

The committee appointed to prepare this report was intentionally composed of individuals with a broad range of backgrounds and experience. To be sure, 10 of them were life scientists, but their occupations and scientific expertise were diverse. Five of the 10 were tenured full professors at major universities, one a postdoctoral fellow, and one a graduate student at the time of their appointment. Two were employed in industry. Among the nonbiologists, bringing experience in studies of the scientific labor force and scientific careers and a distance from direct interest in life science research were two economists, two psychologists, and a sociologist. The age range of the members was from the middle 20s to the middle 70s. Two department heads, a vice-president for academic programs and planning, a dean of a graduate school, and a director of a research institute brought academic, administrative viewpoints to the deliberations. (See APPENDIX for the affiliations of the committee members.) In short, the interests of very nearly all of the "stakeholders" in the life-science enterprise were

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represented on the committee. Such diverse outlooks richly widened the arena of discussion and were mutually educative. They also tended to slow any rush to judgment until a true consensus could be achieved.

To ensure that even the broad spectrum of views found among the committee members was enriched by outside views, we invited representatives of government and professional associations to testify before us. And we convened a public meeting at which 18 speakers presented their views, and more than 50 other persons attended the meeting or made their views known through written comments. A liaison group of government and scientific organization data experts were asked to provide reactions to our early collections of data; we established contact with institutions performing relevant studies and used the information they provided. The members of the liaison group are listed after the committee roster.

An alternative perspective on the committee's recommendation 3, regarding training grants, is included in the full report (available at http://www.nap.edu). All members of the committee except the author of the alternative perspective endorsed recommendation 3 after extensive discussion at several committee meetings.

We have many other people to thank for assistance in accomplishing our task. Persons who in many instances gave up parts of their weekends to share their knowledge with the committee are Ruth Kirschstein, Walter Schaffer, John Norvell, and James Onken of NIH; Mary Clutter and Joanne Hazlett of NSF; Douglas Kelly, Jennifer Sutton, and Stanley Ammons of the Association of American Medical Colleges (AAMC); Mary Jordan of the American Chemical Society; and Roman Czujko of the American Institute of Physics. Walter Schaffer of NIH and James Edwards of the NSF were extremely helpful in their roles as program officers on behalf of their agencies. Data were made available by and useful discussion was held with John Norvell of NIH, Lawrence Burton of NSF, Lisa Sherman and Brooke Whiting of AAMC, Georgine Pion of Vanderbilt University, and Thomas J. Kennedy, Jr. Edward O'Neill and Renee Willard of the University of California, San Francisco (UCSF) Center for the Health Professions provided us with their report on Pew scholars in the biomedical sciences, and the Bio-Medical Association of Stanford University and the Postdoctoral Scholars Association of UCSF shared the results of their surveys of graduate students and postdoctoral fellows.

The committee's task would have been immeasurably harder without the constant logistic, managerial, and professional support of Al Lazen, Porter Coggeshall, James Voytuk, Karen Grief, Charlotte Kuh, and Molla Teclemariam. At every stage of our work, these dedicated National Research Council staff prepared material for our enlightenment, responded to requests for more help, and took a constructive part in our meetings; they deserve no blame and much credit for our report.

Shirley Tilghman
Chair
Committee on Dimensions, Causes,
and Implications of Recent Trends
in the Careers of LIfe Scientists

Executive Summary

INTRODUCTION

The 50 years since the end of World War II have seen unprecedented growth in the life sciences. In 1997 US government investments in health research exceeded $14 billion, private foundations contributed more than $1.2 billion, and industry's investment in health research and development exceeded $17 billion. Government and private support of agriculture and environmental research approached $5 billion. Clearly, the life-science enterprise is large and vigorous.

The large investment in the life sciences has produced many important results. Discoveries in agricultural science have improved our understanding of soils and their chemistry and have led to the development of new strains of crop plants that are resistant to diseases and yield more food per cultivated acre. Environmental sciences and forestry have evolved new methods for managing sustainable resources that will help our expanding population to pass on more of its natural wealth to future generations. Medical science has provided fundamental understanding of the molecular basis of numerous diseases which has led to the elimination of some and the containment of many. Advances in molecular biology not only have spawned the economically important biotechnology industry but have contributed fundamental knowledge about the structure of genes and the behavior of biological macromolecules. These advances have yielded new insights into the relationships among organisms and into the continuum of structure and function that connects living and nonliving things. The long-range implications of all the rapidly evolving knowledge are hard to predict, but many additional benefits are now on the horizon.

The continued success of the life-science research enterprise depends on the uninterrupted entry into the field of well-trained, skilled, and motivated young people. For this critical flow to be guaranteed, young aspirants must see that there are exciting challenges in life-science research and they need to believe that they have a reasonable likelihood of becoming practicing independent scientists after their long years of training to prepare for their careers. Yet recent trends in employment opportunities suggest that the attractiveness to young people of careers in life-science research is declining.

In the last few years, reports from the National Research Council have detailed a changing world for young scientists. A 1994 study sought to determine whether young investigators in the biologic and biomedical sciences might be at a disadvantage compared with older, established scientists in the competition for research support. The study found no evidence of discrimination by age in National Institutes of Health (NIH) awards; but it did reveal that NIH research-grant applications from investigators below the age of 37 had plummeted between 1983 and 1993. The reasons for the decline were not immediately obvious, but concern over the seeming contraction of young research talent led to the appointment of the present committee. A 1995 study examined graduate education in all fields of science and engineering and the changing employment opportunities for PhD graduates. That committee found that more than half of new graduates with PhDs in all disciplines now find employment in nonacademic settings, and it recommended that graduate programs diversify to reflect the changing employment opportunities afforded PhD scientists.

This report extends the analyses of the previous reports by examining the changes that have occurred over the last 30 years in graduate and postgraduate training of life scientists and the nature of their employment on completion of training. It suggests reasons for the decrease in the number of young scientists applying for NIH grants and the growing "crisis in expectation" that grips young life scientists who face difficulty in achieving their career objectives.

CHARGE

This committee was charged to: (1) construct a comprehensive data profile of the career paths for recent PhD recipients in the life sciences; (2) use the profile for assessing the implications of recent career trends for individuals and for the research enterprise; and (3) make recommendations, as appropriate, about options for science policy.

The charge called on the committee to consider all the life sciences and the health of the enterprise in addition to the well-being of the individuals involved.

The committee approached its first task by analyzing data contained in the large databases maintained by the National Research Council Office of Scientific and Engineering Personnel, which provides the most comprehensive and accurate record available of the educational course and employment status of scientists educated to the PhD level in the United States. These records are collected when degrees are awarded and updated biennially through surveys of a sample of doctorate holders. The committee's analysis included the 1970–1995 surveys, and thus enabled documentation of trends in important career stages.

FINDINGS

The training and career prospects of a graduate student or postdoctoral fellow in the life sciences in 1998 are very different from what they were in the 1960s or 1970s. Today's life scientist will start graduate school when slightly older and take more than 2 years longer to obtain the PhD degree. Today's life-science PhD recipient will be an average of 32 years old. Furthermore, the new PhD today is twice as likely as in earlier years to take a postdoctoral fellowship and thus join an ever-growing pool of postdoctoral fellows—now estimated to number about 20,000—who engage in research while obtaining further training and waiting to obtain permanent positions. It is not unusual for a trainee to spend 5 years—some more than 5 years—as a postdoctoral fellow. As a consequence of that long preparation, the average life scientist is likely to be 35–40 years old before obtaining his or her first permanent job. The median age of a tenured or tenure track faculty member is now about 8 years more than that of the faculty member of the 1970s.

Those facts suggest one source of the seeming contraction of "young investigator" applicants for NIH research grants. "Young" investigators have grown older, and fewer are in faculty positions before the age of 37. More of them are postdoctoral fellows, who, by most institutional regulations, may not submit applications for individual research grants.

There have been major changes in career opportunities for PhDs over the last 3 decades. Historically, the three major employment sectors for life scientists have been academe, industry, and government; academe has been the largest. The opportunity to secure an academic appointment has steadily narrowed since the 1960s. Of life scientists who received the PhD in 1963 and 1964, 61% had achieved tenured appointments at universities or 4-year colleges 10 years later. For the cohort who graduated in 1971–1972, that percentage had dropped to 54%; and for the 1985–1986 cohort, to 38%. The probability of industrial employment rose from 12% to 24% for the cohorts described above, and the probability of working in a federal or other government laboratory dropped from 14% to 11%. Overall, the fraction of PhDs with "permanent"[1]

[1] The committee defines the goal of graduate education and postdoctoral training in the life sciences as the preparation of young scientists for careers as independent researchers in academe, industry, government, or a private research environment. We call positions in those careers "permanent," although it is understood that no employment is guaranteed, to distinguish them from the "impermanent" positions, such as postdoctoral and research associate positions held by persons whose career objective is to obtain permanent positions.

positions in the traditional employment sectors for PhD scientists—academe, industry, and government— 9–10 years after receipt of the PhD declined from 87% to 73% from 1975 to 1995. For the cohort 5–6 years after receipt of the PhD, the fraction has declined from 89% to 61% from 1975 to 1995.

During most of the time that those changes in permanent research-career outcomes were taking place, the number of life-science PhDs awarded annually by American universities was growing steadily, but slowly, from about 2,700 in 1965 to about 5,000 in the middle 1980s. Then, in 1987, the number began to rise rather steeply—to 7,696 in 1996. PhDs awarded to foreign nationals made up the majority of the increase after 1987. There has been a steady increase in the number of women receiving PhDs since 1965. Differences exist between biomedical and nonbiomedical fields; almost all the growth in numbers among life-science PhDs has been in the biomedical fields.

The 42% increase in PhD production between 1987 and 1996 was not accompanied by a parallel increase in employment opportunities, and recent graduates have increasingly found themselves in a "holding pattern" reflected in the increase in the fraction of young life scientists who after extensive postdoctoral apprenticeships still have not obtained permanent full-time positions in the life sciences. In 1995, as many as 38% of the life-science PhDs—5–6 years after receipt of their doctorates—still held postdoctoral positions or other nonfaculty jobs in universities, were employed part-time, worked outside the sciences, or were among the steady 1–2% unemployed. The comparable fraction in 1973 was only 11%. What may be most alarming about the 1995 figure is that it reflects the situations of those earning PhDs in 1989 and 1990, at the beginning of the sharp rise in the rate of PhD production.

The frustration of young scientists caught in the holding pattern is understandable. These people, most of whom are 35–40 years old, typically receive low salaries and have little job security or status within the university. Moreover, they are competing with a rapidly growing pool of highly talented young scientists—including many highly qualified foreign postdoctoral fellows—for a limited number of jobs in which they can independently use their research training. This situation—and its implications for both individual scientists and the research enterprise—is a matter of concern to the committee.

The committee viewed it as unlikely that conditions will change enough in the near future to provide employment for the large number of life-science PhDs now waiting in the holding pattern. Federal funding for life-science research is expected to grow but the growth is unlikely to compensate for the imbalance in production of PhDs as federal funding was growing substantially through the 1980s and 1990s while the employment situation for the increasing number of young life graduates worsened. We believe that the growth in funding does not ensure that trends in obtaining permanent jobs will improve. The cost of doing research at private universities has been borne traditionally by federal and private granting agencies, and it is highly unlikely that tuition, already high, can be increased to the extent that it could provide needed research support. Schools of medicine, where large numbers of PhDs are educated and work, are faced with the need to adjust to the era of "managed care" with a marked reduction in income from clinical-practice plans that previously contributed substantially to the support of research and training. Finally, industry—and perhaps specifically the biotechnology sector—which employed large numbers of new life-science PhDs in the 1980s, has slowed its hiring in the 1990s.

In response to the increasing difficulty of finding employment in traditional sectors, trainees and their mentors have looked to alternative careers, such as law, science writing, science policy, and secondary-school teaching. Our analysis suggests that opportunities in these fields might not be as numerous or as attractive as advocates of alternative careers imply.

IMPLICATIONS

Whether the career trends described above are a source of concern depends on the viewpoint of the stakeholder observing them. To the graduate student and postdoctoral trainee who have invested many years of preparation with the expectation of having a research career, the situation is discouraging indeed. To the established investigator and the overseers of life-science research, the availability of large numbers of bright young scientists willing to work very hard for relatively little financial compensation is an asset that contributes to a remarkably successful enterprise. Since World War II, the structure of life-science research has been built around these young scientists, who are the primary producers of research. The public, whose taxes support the enterprise, has benefited from the abundance of young trainees.

The imbalance between the number of life-science PhDs being produced and the availability of positions that permit them to become independent investigators concerns the committee. The long times spent in training, the delay in achieving independence, and especially the difficulty in finding positions where young scientists can independently use their training have led to a "crisis in expectation." The feelings of disappointment, frustration, and even despair are palpable in the laboratories of academic centers. Many graduate students entered life-science training with the expectation that they would become like their mentors: they would be able to establish laboratories in which they would pursue research based on their own scientific ideas. The reality that now faces many of them seems very different. The future health of the life sciences depends on our continuing to attract the most talented students. That will require that students be realistically informed at the beginning of their training of their chances of achieving their career goals and that faculty recognize that current employment opportunities are different. The challenges for the life-science community are to acknowledge that it is the structure of the profession that has led to declining prospects for its young and to develop accommodations to maximize the quantity and quality of the scientific productivity of the future.

CONCLUSIONS AND RECOMMENDATIONS

The committee's analysis of the patterns of employment of recent recipients of life-science PhDs suggests that the current level of PhD production now exceeds the current availability of jobs in academe, government, and industry where they can independently use their training. While only a small minority of recent PhDs have left the field entirely, a large fraction of the "excess" supply is currently found in two kinds of appointments, "postdoctoral" and "other academic," where they may be called "fellows," "research assistants," "adjunct instructors," or some other title that conveys a clear message of impermanence in academe—outside the tenure track of regular faculty.

The professional structure of the life sciences research enterprise, in which the important work of conducting experiments rests almost entirely on the shoulders of graduate students and postdoctoral fellows, was based on the premise that there would be continuous expansion of available independent research positions to provide employment commensurate with their training for the ever-growing number of trainees. By the 1980s, however, there were signs of trouble ahead as the postdoctoral pool began to swell in size. The dramatic jump in number of graduates from PhD programs that began in 1987, driven by the influx of foreign-born PhD candidates together with the increase in foreign-trained PhDs who have sought postdoctoral training in the US, has greatly exacerbated what was already the growing imbalance between the rate of training versus the rate of growth in research-career opportunities.

Although the current abundance of PhDs is an advantage to established investigators, those responsible for graduate education in the life sciences should realize that further growth in the rate of PhD training could adversely affect the future of the research enterprise. Intense competition for jobs has created a "crisis of expectation" among young scientists; further increase in the competition could discourage the best from entering the field.

Recommendation 1: Restraint of the Rate of Growth of the Number of Graduate Students in the Life Sciences

The committee recommends that the life-science community constrain the rate of growth in the number of graduate students, that is, that there be no further expansion in the size of existing graduate-education programs in the life sciences and no development of new programs, except under rare and special circumstances, such as a program to serve an emerging field or to encourage the education of members of underrepresented minority groups.

The current rate of increase in awards of life science PhDs—5.1% from 1995 to 1996—if allowed to continue, would result in a doubling of the number of such PhDs in just 14 years. Our analysis suggests that would be deleterious to individuals and the research enterprise. The committee recognizes that the number of PhDs awarded each year might already be too high. Although a return to pre-1988 levels of training might be beneficial, we believe that a concentrated effort to reduce the size of graduate-student populations rapidly would be disruptive to the highly successful research enterprise. While our data show a current abundance, some unanticipated discovery in the life sciences or unexpected change in funding trends might lead to an increase in demand for life scientists. The committee believes that the current system is well prepared to meet such a need.

We caution that it will be necessary to distinguish among fields when making decisions about optimal numbers of graduate students. As shown in chapter 2, almost all the increase in life-science PhD production has been in biomedical fields. Actions taken in one field of the life sciences might be unnecessary in others. It is worth noting, however, that the data shown in Figure 3.10 (in the full report) suggest that biomedical and nonbiomedical life-science fields are experiencing similar changes in employment trends, for example, smaller fractions of PhDs finding permanent employment in academe.

The committee examined several approaches to stabilizing the total number of PhDs produced by life-science departments beyond the first and obvious approach of individual action on the part of graduate programs to constrain growth in the number of graduate students enrolled. Some might argue that this solution is expecting unreasonably altruistic behavior on the part of established investigators and training-program directors and that graduate programs will continue to accept large numbers of students simply to meet their faculties' need for instructors and laboratory workers. The committee urges life-science faculties to seek alternatives to these workforce needs by increasing the number of permanent laboratory workers. As the increases over the last decade have been fueled almost entirely by the increased availability of federal and institutional support for research assistants, consideration might be given to restricting the numbers of graduate students supported through the research-grant mechanism.

The committee believes the most prudent way to reasonably reduce the rate of increase in the number of PhDs awarded annually and perhaps to achieve a gradual reduction in the numbers being trained is to help students to make informed decisions about their career choices.

To be effective, such decisions must be based on relevant and up-to-date information about both the quality of the training available in particular graduate programs and in the job opportunities of a given field. Equally importantly, this information must be used by individual graduate programs and mentors in determining the numbers of trainees they accept and in assessing the effectiveness of their programs. It is our expectation that such information will have the salutary effect of letting market forces control the rate of entry into the profession *before* young people have invested ten and more years in training.

Recommendation 2: Dissemination of Accurate Information on the Career Prospects of Young Life Scientists

The committee recommends that accurate and up-to-date information on career prospects in the life sciences and career outcome information about individual training programs be made widely available to students and faculty. Every life science department receiving federal funding for research or training should be required to provide to its prospective graduate students specific information regarding all predoctoral students enrolled in the graduate program during the preceding 10 years.

With the most accurate information available, students will be able to make informed decisions about their careers.

Recommendation 3: Improvement of the Educational Experience of Graduate Students

There is no clear evidence that career outcomes of persons supported by training grants are superior to those of persons supported by research grants. However, the committee, which included members with direct experience with training grants, concluded that training grants are pedagogically superior to research grants and result in a superior educational climate in which students have greater autonomy. First, training grants are pedagogically superior because they provide a mechanism for stringent peer review of the training process itself, something that is not considered in the review of a research project. Second, they improve the educational climate because they minimize the potential conflicts of interest that can arise between trainers and trainees. Although the student-mentor relationship is ordinarily healthy and productive for both partners, it can be distorted by the conditions of the mentor's employment of the student and limit the ability of students to take advantage of opportunities to broaden their education. Third, training grants provide the federal government with information that it needs to evaluate the level of its investment in graduate life-science education with the aim of developing a funding framework for graduate education that contributes to the long-term stability and well-being of the research enterprise.

The committee encourages all federal agencies that support life-science education and research to invest in training grants and individual graduate fellowships as preferable to research grants to support PhD education. Agencies that lack such programs should look for ways to start them, and agencies that already have them should seek ways to sustain and in some instances expand them.

This recommendation should not be pursued at the expense of scientific and geographic diversity. Rather, we encourage the establishment of small, focused training-grant programs for universities that have groups of highly productive faculty in important specialized fields, but might not have the number of faculty needed for more traditional, broad-based training grants.

It is true that the current regulations governing NIH training grants bring universities some financial disadvantages because of restricted overhead recovery. Furthermore, NIH training grants cannot support foreigners on student visas, and so this recommendation places at disadvantage programs that depend on foreign students for research or teaching. These disadvantages are outweighed, in the committee's view, by the salutary effect that the training-grant peer-review process brings to the members of a department faculty, leading them to examine and reflect on how, as an entity, they are providing for the education and training of their graduate students.

Our endorsement of training grants and fellowships is not intended to result in the training of more PhDs. Rather we advocate a shift from support by research grants to training grants. We anticipate improvements in the quality and oversight of graduate education in the life sciences. The federal government is already heavily invested in life-science education; greater reliance on support of graduate students on training grants ensures that taxpayers are receiving the best return on their investment.

The committee is also concerned that the length of time spent in training has become too long at a median of 8 years elapsed time from first enrollment to PhD for all life sciences (though field differences exist). We believe that the time should be about 5–6 years. However, an immediate effort to shorten the time to degree would increase the number of PhDs produced. Efforts to shorten the time to degree should be undertaken when the effort to restrain growth in the number of PhDs has shown positive effects.

Recommendation 4: Enhancement of Opportunities for Independence of Postdoctoral Fellows

While the length of graduate training has been increasing, so too have the extent and duration of postdoctoral training. Prolonged tenure as a postdoctoral fellow provides a person with valuable research experience, but it carries some real costs. In most cases, fellows are not independent of their mentors so they cannot pursue their own research. We recognize the many good reasons for prolonged tenure as a postdoctoral fellow but we believe that tenures longer than 5 years are not in the best interest of either the individual fellow or the scientific enterprise.

Because of its concern for optimizing the creativity of young scientists and broadening the variety of scientific problems under study in the life sciences the committee recommends that public and private funding agencies establish "career-transition" grants for senior postdoctoral fellows. The intent is to identify the highest-quality scientists while they are still postdoctoral fellows and give them financial independence to begin new scientific projects of their own design in anticipation of their obtaining fully independent positions.

The committee recommends a goal of 200 federal and private grants awarded annually, representing about 1% of the postdoctoral pool. That number of people supported would be quite small but the program might provide an important opportunity for the most promising postdoctoral fellows and serve as both example and incentive to many more. We make this recommendation with the knowledge that it is possible that the money for a new federal grant program probably would come from existing federal funds. In our view, the benefits of increased intellectual independence and improved motivation of talented midcareer postdoctoral fellows justify such a reallocation of funds. Private funders might establish new programs or enlarge existing programs that support career-transition grants.

Recommendation 5: Alternative Paths to Careers in the Life Sciences

As traditional research positions in academe, industry, and government have become more difficult to obtain, positions in "alternative careers"—such as law, finance, journalism, teaching, and public policy have been suggested as opportunities for PhDs in the life sciences.

The idea of highly trained scientists investing their talents in nontraditional careers seems at first glance attractive. Scientists have analytical skills and a work ethic to bring to any position, and the placement of highly trained scientists in diverse jobs in the workforce would lead to an increase in general science literacy. As the committee's review of alternative opportunities concludes, however, most of the possibilities are less available or less attractive than they might at first glance appear. Many "alternative" careers are also heavily populated, and competition for good positions is stiff. Others require special preparation or certification, or offer unattractive compensation, and none makes full use of the PhD's hard won life-science research skills. The committee believes that the idea of alternative careers should not be oversold to PhD candidates.

The interest in alternative careers for PhD scientists has inevitably raised the question of whether preparation for the degree should be changed from its current narrow focus on training for the conduct of scientific research to embrace a broader variety of educational goals that would connect to alternative career paths. The committee has discussed that question extensively.

The committee recommends that the PhD degree remain a research-intensive degree, with the current primary purpose of training future independent scientists.

At the same time, the committee recognizes that not all students who begin graduate school intending to pursue a research career maintain that desire as they progress through training. Graduate programs should expand their efforts to help students learn about the diversity of career opportunities open to them, and university departments should examine possible alternatives to the research PhD.

One alternative to broadening the PhD program is to strengthen the Master's degree, which may be a more appropriate end point for students who determine early enough in their training that PhD training is not necessary for the career goals they have selected. There has been a decline in the number of Master's-degree programs in the life sciences and with it a growing perception that the Master's degree has become a consolation prize for those who do not complete a PhD program. This devaluation of the Master's degree effectively limits the number of choices for college graduates who are interested in a career in the life sciences, although not necessarily careers in directing laboratories conducting fundamental research. For example, the college graduate who is interested in teaching in secondary school or two-year colleges, would benefit from formal and focused Master's-degree programs that do not require long periods of research-intensive graduate and postdoctoral training. Master's degree programs would not only be more appropriate but also be preferable to the PhD for this type of employment and these students.

We recommend that universities identify specific areas of the biological and biomedical sciences for which Master's level training is more appropriate, more efficient and less costly than PhD training. We recommend that focused Master's programs be established in those areas.

A vigorous Master's-degree program that produces highly skilled laboratory technicians for industry, government, and academe could potentially contribute to righting the imbalance between PhD training and the labor market. When the committee recommended constraint in further growth in training in recommendation 1, it was fully aware that graduate students are needed in the labor-intensive life-science research enterprise and to teach undergraduates. One way to resolve this dilemma is to effect a modest shift toward a more permanent laboratory workforce by replacing some fraction of the existing training positions with permanent employees such as MSc-level technicians and PhD-level research associates.

The Impact of Foreign Nationals

This report has documented that the majority of the recent increase in the number of PhD trainees and postdoctoral fellows are foreign nationals, not US citizens. The number of foreign nationals reflects the international nature of modern science and the central place that the US plays in this international arena. Furthermore, foreign nationals have traditionally contributed to the excellence of US science, as suggested by the fact that of the 732 members of the National Academy of Sciences who are life scientists, 21.2% are foreign born and 12.4% obtained their PhD training abroad. Foreign nationals' important contributions to US scientific leadership are reflected in their representation as department chairs (25%) and their inclusion as "outstanding authors" in life sciences (26.4%). Foreign students and fellows are welcome participants in the research enterprise, provided they are of high quality and competitive with American applicants.

We believe it would be unwise to place arbitrary limitations on the number of visas issued for foreign students. But we do not believe that US institutions should continue to enroll unlimited numbers of foreign nationals. As decisions are made on ways to constrain further growth, the measures adopted should apply equally to all students regardless of nationality.

If, as we hope, implementation of our recommendations results in constraining further growth in PhDs awarded in the life sciences, we urge our colleagues on graduate admissions committees to resist the temptation to respond by simply increasing the number of foreign applicants admitted.

Responsibility for Effecting Change

This report has documented several dramatic changes in career trends in the life sciences over the last several decades. The rapid growth in the academic scientific establishment in the 1960s and the early 1970s set in place a training infrastructure that was built on the premise that there would be continued growth. When the inevitable slowdown in resources to support that growth occurred, it was not accompanied by a commensurate adjustment in the rate of training. The impact of the imbalance between the number of aspirants and the research opportunities is now being felt by a generation of scientists trained in the last 10 years who are finding it increasingly difficult to find permanent positions in which their hard-accumulated skills in research can be used. Unless steps are taken to put the system more in balance, the difference between students' expectations and the reality of the employment market will only widen and the workforce will become more disaffected. Such an occurrence would damage the life-science research enterprise and all the participants in it.

The training of life scientists is a highly decentralized activity. Notwithstanding the heavy dependence on federal funds, the most important decisions affecting the rate of production of life scientists are made locally by the universities and their faculties. The numbers and qualifications of students admitted to graduate study, the allocation of institutional funds for their tuition and stipends (which account for half or more of the total expenditures for graduate-student support), the requirements for the degree—all are local decisions. As a consequence, a large portion of the responsibility for implementing our recommendations falls on the shoulders of established investigators, their departments and universities, professional scientific organizations, and students themselves. Students must take the responsibility of making informed decisions about graduate study, but they must be provided accurate career information on which to base their decisions. Individual faculty members must be willing to set aside their short-term self-interest in maintaining the high level of staffing of their laboratories for the sake of the long-term stability and well-being of the scientific workforce. Directors of graduate programs must be willing to examine the future workforce needs of the scientific fields in which they train, not just the current needs of their individual departments for research and teaching assistants.

The recommendations in this report are offered as first steps to improve the overall quality of training and career prospects of future life scientists. We hope that the information in this report will be used to begin discussions within the life-science community on the best ways to prepare future scientists for exciting careers in the profession and to protect the vitality of the life-science research enterprise.

APPENDIX

Committee on Dimensions, Causes, and Implications of Recent Trends in the Careers of Life Scientists

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