2

Basic Biomedical Scientists

DEFINING THE WORKFORCE

The basic biomedical workforce has traditionally been defined as investigators holding Ph.D.s in fields related to human health and the basic biological mechanisms that underlie health,[1] for example, biochemistry, microbiology, molecular biology, and other related disciplines listed in Appendix E. Those who graduate from universities in the U.S. with Ph.D.s in these fields and seek careers in science and engineering in this country are considered part of the basic biomedical workforce until they retire, die, or leave science and engineering for another field of work.

This definition of the basic biomedical workforce encompasses M.D.-Ph.D.s and other dual-degree holders but not scientists without a Ph.D. Although many M.D.s and other investigators holding doctoral-level professional degrees (such as veterinarians and dentists) make major contributions to the basic biomedical sciences, their numbers are difficult to estimate. We were thus unable to include them in our analysis of the size and demographic characteristics of this workforce. Nonetheless, it is important to recognize that the basic biomedical workforce includes many who have not earned Ph.D.s and that their training follows a path that differs from traditional doctoral programs in the basic biomedical sciences.

[1] National Research Council. *Meeting the Nation's Needs for Biomedical and Behavioral Scientists*. Washington, D.C.: National Academy Press, 1994.

A PORTRAIT OF THE WORKFORCE

Since 1975 the basic biomedical workforce has more than doubled in size, increasing from just over 40,600 Ph.D.s to nearly 93,000 in 1997 (see Figure 2-1). The workforce grew at a steady pace over most of this period until 1995, when its growth escalated more rapidly.

This recent growth, however, should be interpreted with caution. A change in the survey methodology in 1993 may have affected subsequent estimates of workforce size by classifying individuals by occupation (e.g., scientist, professor, manager), rather than by the scientific field in which they worked. In addition, at least part of this reported workforce growth appears to have stemmed from a change in the analysis of survey responses by the National Opinion Research Center when it took over the management of the Survey of Doctorate Recipients in 1997.

As illustrated in Figure 2-1, the growth in the overall workforce was accompanied by increasing numbers of women entering the field. Between 1975 and 1997 the number of women in the basic biomedical workforce more than quadrupled, growing from 6,529 to 27,239. By 1997 women made up 29.3 percent of the workforce, up from 16.1 percent in 1975.

The number of underrepresented minorities in the basic biomedical workforce also increased dramatically, from 1,076 in 1975 to 3,943 in 1997 (see Table G-4). Still, minorities remain a small percentage of the overall workforce. In 1997, 4.2 percent of biomedical scientists were underrepresented minorities, compared to 2.6 percent in 1975.

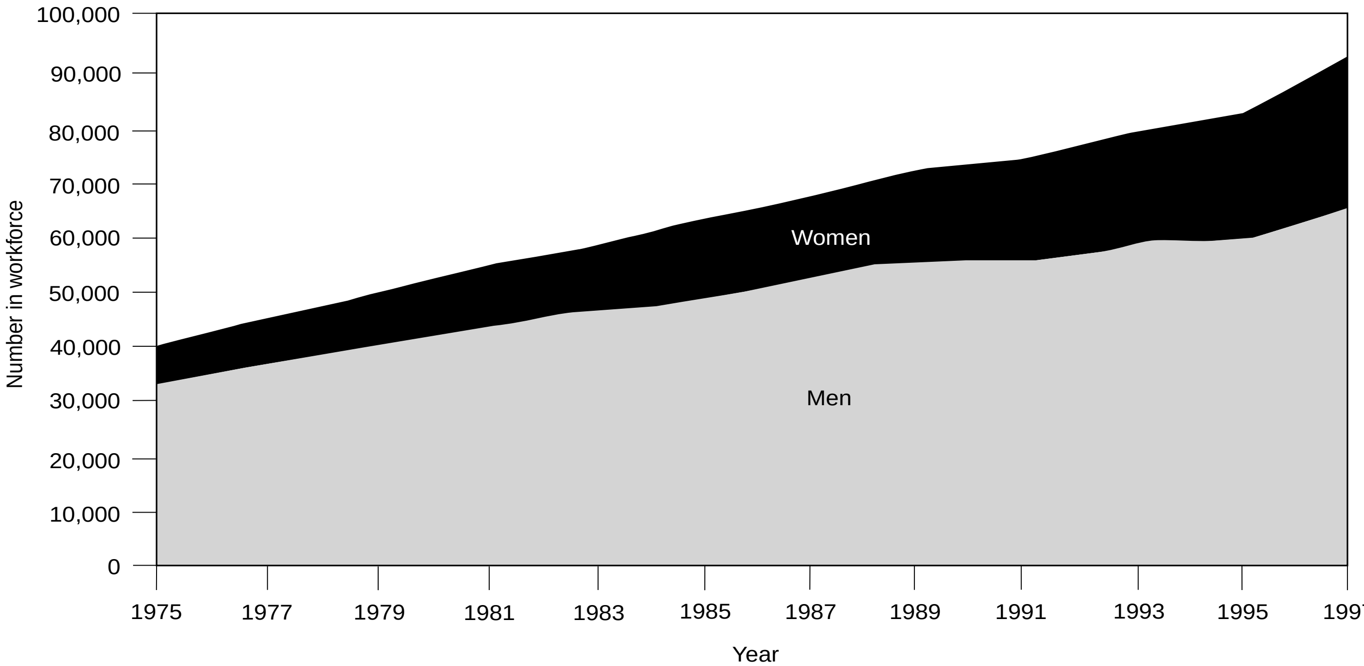

FIGURE 2-1 Gender composition of the basic biomedical workforce. SOURCE: Data are from the Survey of Doctorate Recipients (see Table G-4).

As a result of substantial increases in the numbers of Ph.D.s entering the basic biomedical workforce, the median age of the workforce has grown only modestly over the last decade, rising from 43 years in 1987 to 45.7 in 1997.[2] A demographic analysis of the workforce estimates that the median age of the basic biomedical workforce is likely to increase less than a year by 2005 to 46.2 (see Appendix D).

Unless there is a major departure from current trends in Ph.D. production and retirement, the basic biomedical workforce is projected to grow at a rate of 3.4 percent annually for the next several years. By 2005, women are expected to make up 36 percent of this workforce, which is likely to number more than 128,500 Ph.D.s.

TRENDS IN THE EDUCATION OF BASIC BIOMEDICAL SCIENTISTS

As shown in Figure 2-2, doctorate production in the basic biomedical sciences was relatively stable from 1975 to 1985 but began to increase at a rapid pace thereafter. By 1997 the number of Ph.D.s awarded in the biomedical sciences reached 5,420.

Over the course of the last two decades, the fraction of women among new Ph.D.s grew steadily, increasing from 23.9 percent overall in 1975 to 42.8 percent in 1997. International students have also become a growing component of new basic biomedical Ph.D.s. In 1975 students on temporary visas were 8.3 percent of new Ph.D.s (see Figure 2-3). By 1997 the fraction of students on temporary visas had risen to 21.6 percent.

In contrast, the proportion of underrepresented minorities earning Ph.D.s in the basic biomedical sciences has increased only gradually over the last few decades. In 1997, 4.7 percent of new Ph.D.s were from groups underrepresented in science, up from 2.4 percent in 1975. The absolute numbers represented by these percentages are small: in 1997 only 255 Ph.D.s in these fields were awarded to minorities (see Table G-1).

Between 1975 and 1990 the median time to degree in the basic biomedical sciences grew steadily from 6 years to 7.6 years, as measured from entry into postbaccalaureate study (see Table G-1). Since then the increase in time to degree has continued, though at a slower pace; Ph.D.s in 1997 spent a median of 7.8 years earning their degrees. As a result, median age at receipt

[2] Unpublished tabulation from the Survey of Doctorate Recipients; available from the archives of the Academies.

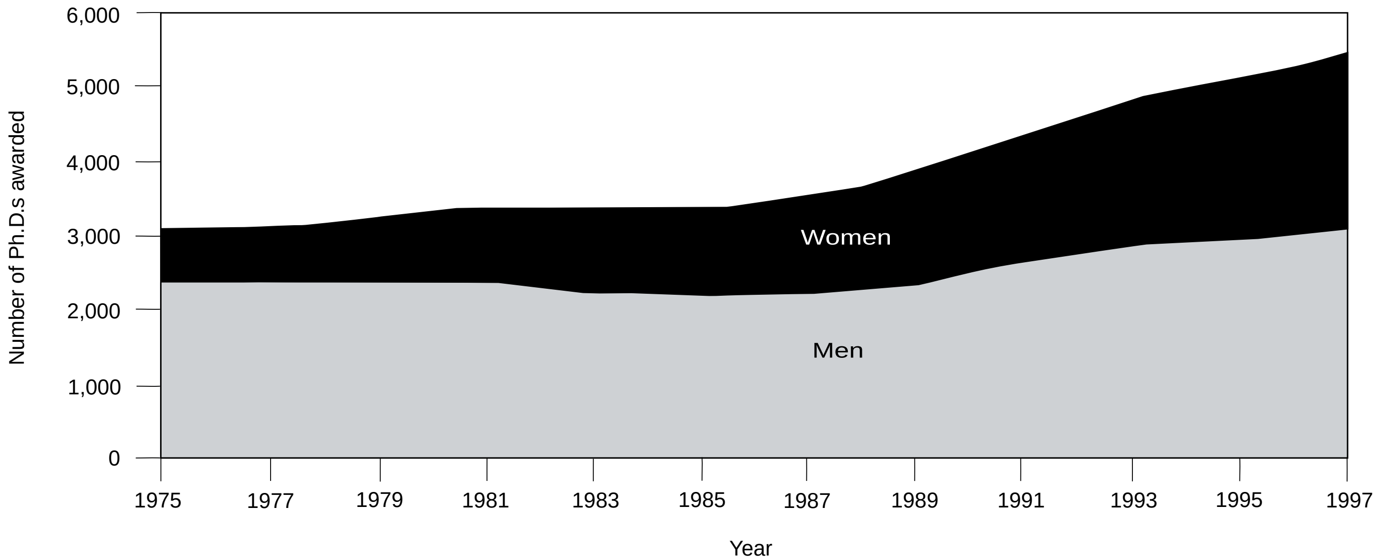

FIGURE 2-2 Ph.D.s awarded in the basic biomedical sciences in the United States by gender. SOURCE: Data are from the Survey of Earned Doctorates (see Table G-1).

of the Ph.D. also rose over this period, from 29.3 in 1975 to 30.9 in 1997.

Unlike many other fields, a period of temporary postdoctoral employment or study is a necessary step for most Ph.D.s in the basic biomedical sciences. Though the percentage of biomedical Ph.D.s planning to take a postdoctoral position after graduation has declined from its peak in 1993 (at nearly 75 percent), just over 65 percent of biomedical Ph.D.s receiving their degrees in 1997 reported plans for postdoctoral work

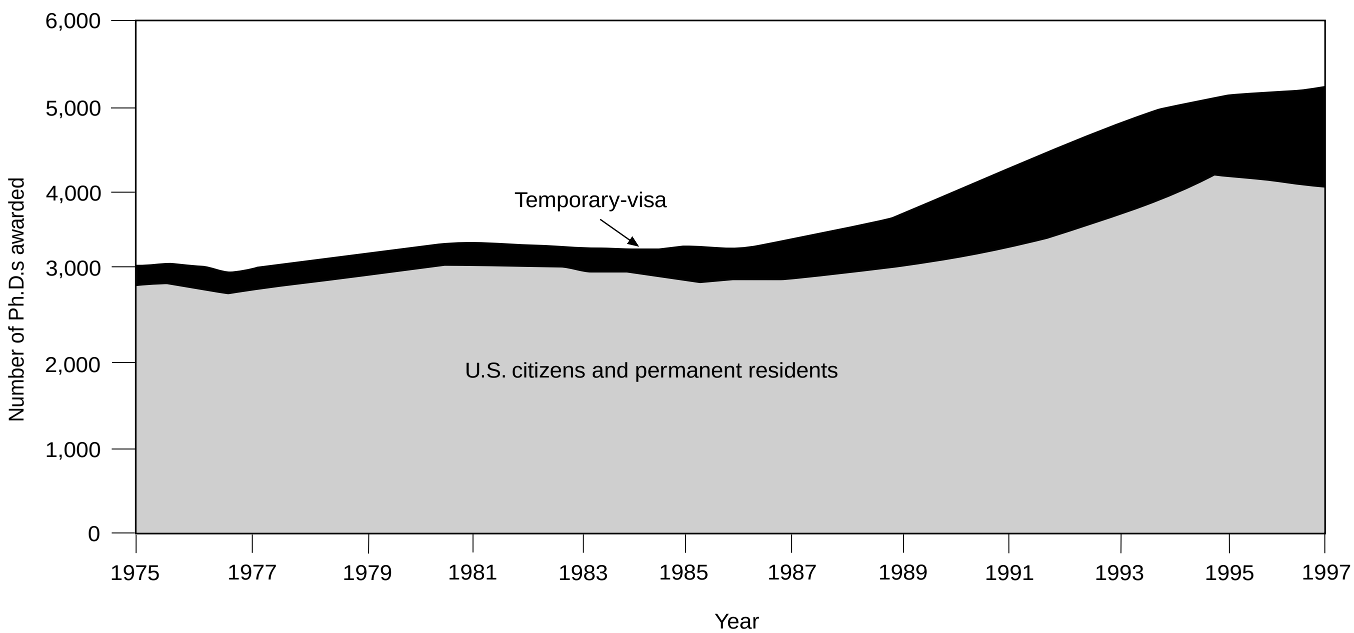

FIGURE 2-3 Ph.D.s awarded in the basic biomedical sciences in the United States by citizenship. SOURCE: Data are from the Survey of Earned Doctorates (see Table G-1).

or study (see Table G-1). Moreover, those who accept postdoctoral appointments spend increasing amounts of time in such positions. Among Ph.D.s graduating in the early 1970s who pursued postdoctoral work or study, 60.7 percent spent between two and four years in postdoctoral appointments, and 20.6 percent spent more than four years in such positions. In contrast, among Ph.D.s who received their degrees in the late 1980s and completed postdoctorates in the 1990s, 76.3 percent spent between two and four years in postdoctoral work or study and 39.8 percent spent more than four years in such appointments.[3]

TRENDS IN EMPLOYMENT

Upon completion of training, Ph.D.s in the basic biomedical sciences have traditionally worked in academic settings, and that remains the case for the majority of those in the workforce today. For the purposes of this analysis, those holding postdoctoral appointments are considered to be in the workforce and those who are self-employed are classified as working in industry. Over the last two decades, however, increasing numbers of basic biomedical scientists have pursued job opportunities in industry, and nearly one-quarter of the biomedical workforce can now be found in industrial settings (see Figure 2-4).

From 1975 to 1997 the number of biomedical scientists working in industry more than quadrupled (from 5,326 to 22,204) and the fraction of the biomedical workforce in that sector rose from 13.1 percent to 23.9 percent. The number of biomedical scientists in academia also grew but at a much more gradual pace, from 27,219 in 1975 to 53,026 in 1997. As a result, the portion of basic biomedical Ph.D.s working in academic settings dropped from 67 percent in 1975 to 57 percent in 1997. Over the same time period, biomedical scientists working in government more than doubled in number, rising to 8,649 in 1997; government scientists now represent 9.3 percent of the biomedical workforce.

While industrial employment has increased nationally, opportunities for such work vary widely by region. In 1997, for example, 65.2 percent of biomedical scientists working in New Jersey were employed in industry. The same was true of 39.3 percent of biomedical Ph.D.s working in Connecticut and 37.5 percent of those working in California. In Maryland, however, where the National Institutes of Health (NIH) and other

[3] Unpublished tabulation from the Survey of Earned Doctorates; available from the archives of the Academies.

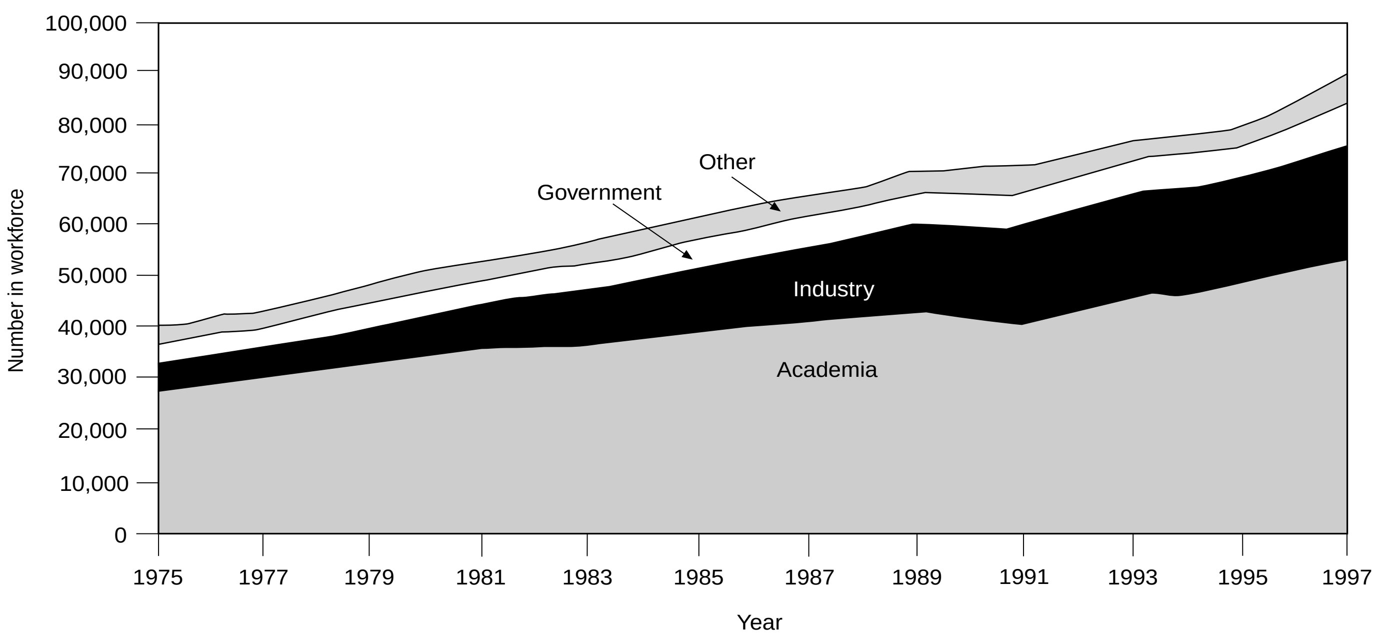

FIGURE 2-4 Employment of basic biomedical scientists by sector. SOURCE: Data are from the Survey of Doctorate Recipients (see Table G-4).

federal laboratories are the major employer, only 14.1 percent of biomedical Ph.D.s were employed in industry.[4]

Since the mid-1990s, the rate of growth in industrial employment has slowed. After steadily increasing throughout the 1980s and early 1990s, the overall fraction of biomedical scientists working in industry peaked at 25.1 percent in 1993. Subsequent reductions in the pace of hiring caused a modest decline in the fraction of the biomedical workforce employed in industry, which registered 23.9 percent in 1997.

In academic settings, where most biomedical Ph.D.s continue to find employment, the types of positions common today are markedly different from those available two decades ago. As shown in Figure 2-5, nearly all (81.7 percent) biomedical Ph.D.s in academia in the mid-1970s were tenured or tenure-track faculty members. Only 9.6 percent of biomedical Ph.D.s in academic institutions were employed in postdoctoral positions. By 1997, however, the fraction of biomedical Ph.D.s in academia who were tenured or were on tenure track had dropped to 55.3 percent, and those in postdoctoral positions had risen to 18.1 percent. Over the same period, the number of nontenure-track faculty increased more than tenfold, so that by 1997, 12.9 percent of biomedical Ph.D.s in academic institutions held such appointments. In addition, "other academic" positions (such as research associates and instructors) more than quadrupled in number, rising from 6.3 percent of the academic workforce in 1975 to 13.8 percent in 1997.

National surveys of the Ph.D. workforce supply less detail about the types of jobs held by government scientists, but the growth in postdoctorates in that sector has followed the same upward trend as in academia. From 1975 to 1997, the fraction of biomedical Ph.D.s employed in government who held postdoctoral positions increased from 6.1 to 16.6 percent (see Table G-4). Postdoctorates increased in industry as well but remained well below the levels found in government and academia: only 2.5 percent of biomedical Ph.D.s working in industry reported holding postdoctoral appointments in 1997.

As is the case for all highly educated workers, unemployment rates for Ph.D.s consistently register well below the overall national average, and biomedical scientists are no exception. In 1997 just 1.2 percent of biomedical Ph.D.s were unemployed.[5] The same year

[4] Unpublished tabulation from the Survey of Doctorate Recipients; available from the archives of the Academies.

[5] Ibid.

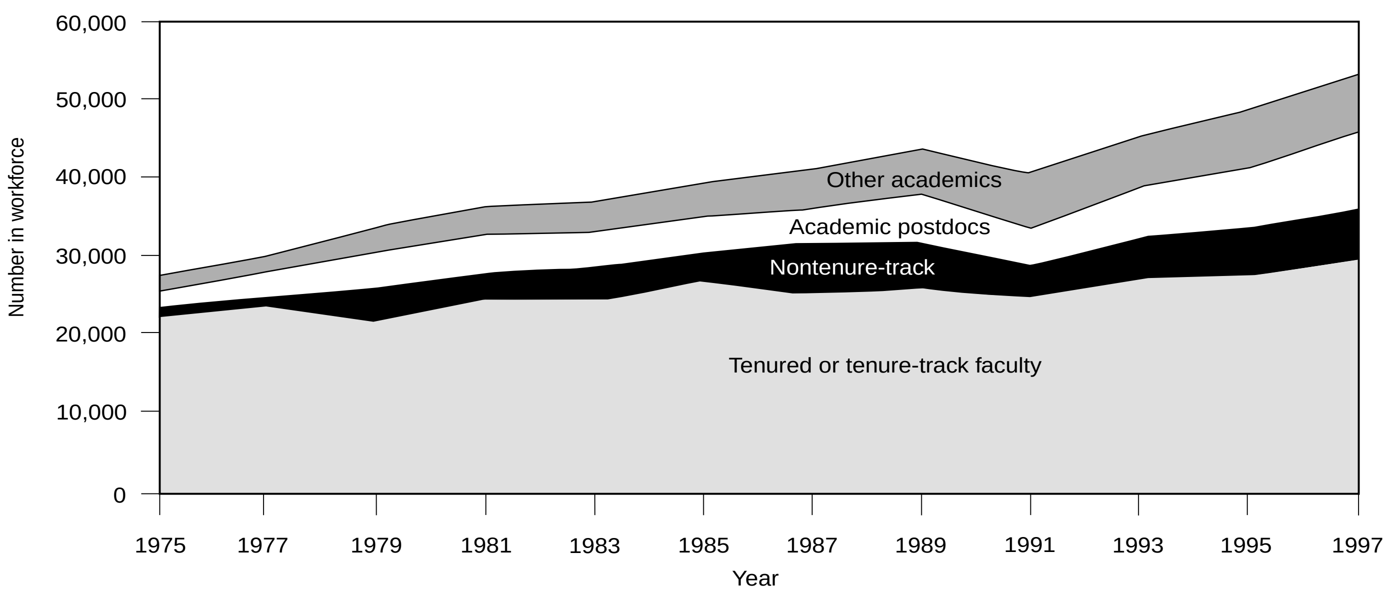

FIGURE 2-5 Employment of basic biomedical scientists in academia. SOURCE: Data are from the Survey of Doctorate Recipients (see Table G-4).

the fraction of new Ph.D.s planning postdoctoral study dropped to 65.1 percent, possibly signaling improved employment opportunities for newly minted Ph.D.s.

At the same time, there are signs that new Ph.D.s in the biomedical sciences continue to have difficulties finding suitable employment and establishing themselves professionally. Surveys conducted by microbiology and physiology societies found that more than 75 percent of newly minted Ph.D.s worked in postdoctoral or other temporary positions, and more than 40 percent reported doing so only because a suitable permanent position was not available.[6] The surveys of microbiologists found that more than twice as many Ph.D.s graduating in 1996 and 1997 viewed the job market as "bad" or "hopeless" (41 percent) than "good" or "excellent" (17 percent).[7] If they had to do it over again, 31 percent of those earning doctorates in cell biology in the 1990s reported that they "probably" or "definitely" would not pursue a Ph.D.[8]

The views of recent Ph.D.s responding to these surveys in regard to their profession and employment prospects highlight the consequences of changes in the conduct of science and the nature of its job market over the last few decades. Because the biomedical research agenda is increasingly dominated by questions that depend on teams of research personnel, many who were attracted to science for the opportunity to be "independent investigators" may find the field less satisfying than in the past.

With increasing numbers of new Ph.D.s entering the job market over the last decade and a half and comparatively few openings for independent investigators on university and medical school faculties and in government labs, Ph.D.s have increasingly taken on the day-to-day work of research—tasks that command lower salaries and in past years were often performed by technicians. This trend was noted in a 1993 study of staffing patterns for NIH grants, in which agency analysts found that "technical" and "other" support staff declined from fiscal years 1983 to 1990, while the role played by (less expensive) postdoctorates and graduate research assistants increased.[9] Consequently, some observers believe that biomedical research has two distinct job markets: one for independent investigators for whom demand is low and one for low-paid research workers for whom demand is high.

As part of the demographic analysis conducted for the committee, estimates were made of the number of graduates that would be needed from 1996 to 2005 if the biomedical research workforce grew at the same rate as the U.S. labor force as a whole (see Table D-7). Under those circumstances, the number of new biomedical science Ph.D.s that would have been needed in 1997 was estimated at 1,571—less than one-third of the actual number that year (5,420). As a result of increasing retirements and other departures from the workforce, the annual number of new Ph.D.s that will be needed is projected to rise to 3,031 by 2005. That figure still falls well below current levels of Ph.D. production.

THE ROLE OF PHYSICIANS IN THE WORKFORCE

Though often overlooked in assessments of this workforce, physician-scientists play an important role in basic biomedical research. In 1997, for example, more than one-fifth of NIH research grants for nonclincal research were awarded to M.D.s (18.2 percent) or M.D.-Ph.D.s (4.1 percent). In fact, since the NIH began to classify clinical research awards in 1996, it has become evident that both M.D.s and M.D.-Ph.D.s supported by the agency are more likely to conduct nonclinical than clinical research (see Table 4-1). Because many physician-investigators approach nonclinical research with the goal of understanding the mechanisms underlying a particular disease or disorder, their findings are often essential to improvements in human health.

Beyond the pool of NIH-funded investigators, information about the M.D. portion of the health research workforce is more difficult to obtain than about Ph.D.s (who are the subject of several national surveys sponsored by the National Science Foundation). The only data available on the national supply of physicians in

[6] Commission on Professionals in Science and Technology. *Employment of Recent Doctoral Graduates in S&E: Results of Professional Society Surveys.* Washington, D.C.: CPST, 1998.

[7] American Society for Microbiology. *Profile of Recent Doctoral Graduates in Microbiology: 1996 and 1997 Graduates.* Washington, D.C.: ASM, 1999.

[8] Marincola, Elizabeth, and Frank Solomon. "The Career Structure in Basic Biomedical Research: Implications for Training and Trainees." *Molecular Biology of the Cell* 9 (November 1998): 3003-6.

[9] National Institutes of Health, Office of Science Policy and Legislation. *Staffing Patterns of the National Institutes of Health Research Grants*. Bethesda, Md.: NIH, 1993.

research are collected by the American Medical Association, but they reveal little about the type of research conducted or whether it is carried out in a medical school, industry, or government laboratory.

According to the American Medical Association, the number of physicians active in research rose throughout the late 1970s and early 1980s and reached 22,945 by 1985.[10] Since then, however, the number of M.D.s and M.D.-Ph.D.s identifying research as their primary professional activity has steadily declined, dropping to 14,434 in 1997. If the fraction of this national pool of physician-investigators focusing on nonclinical research is similar to that supported by the NIH (66 percent), the basic biomedical workforce would have included 9,526 M.D.s and M.D.-Ph.D.s in 1997.

Though these data do not distinguish between physician-investigators holding the M.D. degree and those with M.D.-Ph.D.s, it is likely that an increasing proportion of physician-scientists hold two degrees. Since the first formal M.D.-Ph.D. training programs were introduced in 1964, opportunities for dual-degree training have steadily increased, and in 1998, 116 medical schools offered their students an opportunity to earn both degrees.[11,12] Because M.D.-Ph.D. investigators are more likely to concentrate on nonclinical research than M.D.s (see Table 4-1), this group can be expected to play an increasing role in the basic biomedical workforce in the years ahead.

As described in more detail in Chapter 4, many dual-degree students receive research training support from the NIH through National Research Service Award (NRSA) training grants and fellowships dedicated to M.D.-Ph.D. training. In addition, a number of medical schools support dual-degree training with funds from private or other sources.

On completion of their training, most M.D.-Ph.D.s enter the job market on better financial footing and with better job prospects than investigators with only one degree. Overall indebtedness levels reported by M.D.-Ph.D.s are about half those of their medical school classmates (see Table 4-3). Moreover, unlike their counterparts with a Ph.D., who often have difficulty obtaining faculty positions, M.D.-Ph.D.s are reportedly in great demand as medical school faculty members, particularly in clinical departments.

Despite such advantages, M.D.-Ph.D.s are subject to some of the same economic pressures as other medical school faculty. In competitive health care markets, they—like other junior faculty surveyed in a 1997 assessment of the activities of medical school faculty—may be more apt to be assigned to patient care duties and less likely to conduct research.[13] Indeed, by the latter half of the 1990s, M.D.-Ph.D.s emerging from some of the best-known training programs in the country were reporting difficulties identifying faculty positions that would allow them to perform research.[14]

THE CHANGING ROLE OF THE NATIONAL RESEARCH SERVICE AWARD PROGRAM

When the NRSA program began in 1975, 20,522 graduate students in the basic biomedical sciences received some form of financial assistance for their studies (see Figure 2-6). Of these, 42.9 percent (8,797) received federal funding, and more than half of those students (57.6 percent) were supported by NIH or other DHHS training grants and fellowships.

By 1997 the situation had changed dramatically. The overall number of graduate students receiving financial support in the basic biomedical sciences increased by two-thirds, to 33,873. Of these, the percentage supported by federal sources remained roughly the same (at 44.9 percent), but only 25.9 percent received funds from NIH or other DHHS training grants and fellowships. In 1997 nearly half (48.9 percent) of federal support to graduate students in the biomedical sciences took the form of research assistantships provided through NIH or other DHHS grants; another 25.1 percent of students received funds from other federal sources. In short, in just over two decades the pattern of federal support for graduate education in the biomedical sciences changed dramatically: the percentage of students receiving funds from NIH or other DHHS

[10] Pasko, Thomas, and Bradley Seidman. *Physician Characteristics and Distribution in the US, 1999.* Chicago: American Medical Association, 1999.

[11] National Institutes of Health, National Institute of General Medical Sciences. *The Careers and Professional Activities of Graduates of the NIGMS Medical Scientist Training Program*. Bethesda, Md.: NIH, September 1998.

[12] Association of American Medical Colleges. *Medical School Admissions Requirements, 2000-2001*. Washington, D.C.: AAMC, 1999.

[13] Campbell, Eric G., Joel S. Weissman, and David Blumenthal. "Relationship Between Market Competition and the Activities and Attitudes of Medical School Faculty." *JAMA* 278, no. 3 (1997): 222-26.

[14] Ledger, Kate. "Specialists for Hire." *Hopkins Medical News* (Spring-Summer 1996): 21-27.

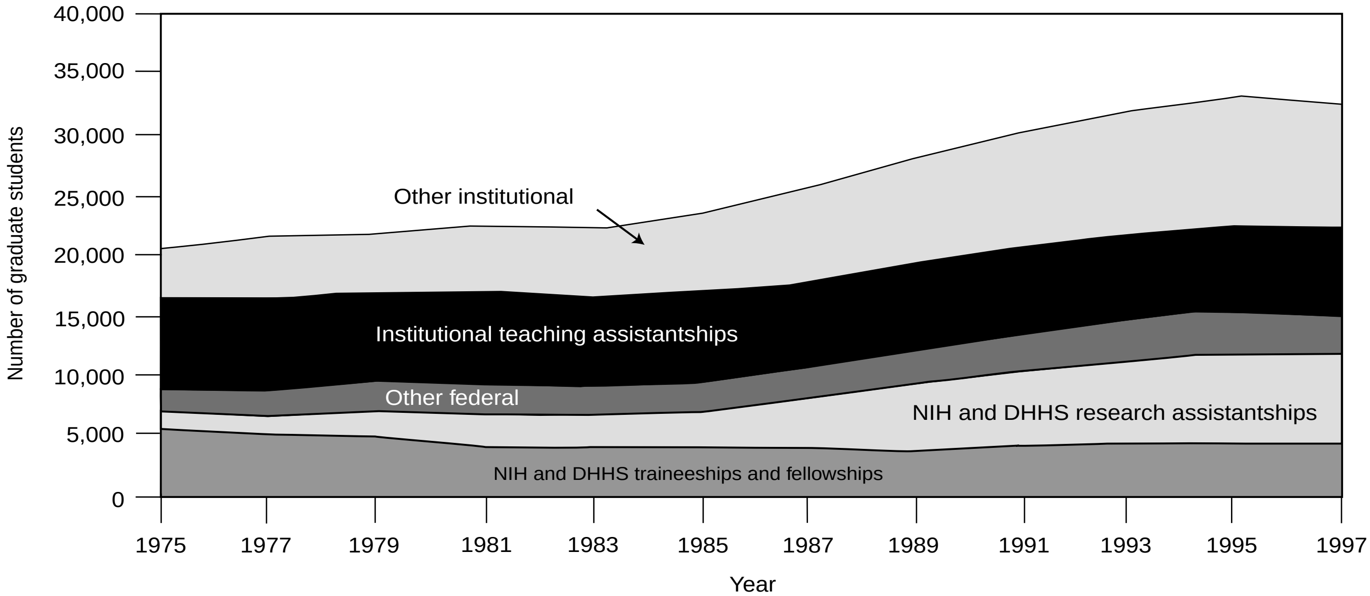

FIGURE 2-6 Trends in graduate students' primary source of support in the biomedical sciences. SOURCE: Data are from the Survey of Graduate Students and Postdoctorates in Science and Engineering (see Table G-7).

training grants and fellowships fell by more than half, while the percentage receiving funding through NIH or other DHHS research grants more than doubled.

Though the information available on funding patterns for postdoctorates in the basic biomedical sciences is much less detailed than that for graduate students, it is evident that the portion of federal funds devoted to training grants and fellowships has diminished at the postdoctoral level as well.[15] In the mid-1970s, 4,250 (77.2 percent) of the 5,506 university-based postdoctorates received federal funding for their training. Of these, 45.8 percent had federal fellowships or training grant appointments and 54.2 percent were employees on federal research grants. By 1997 the fraction of the 14,197 university-based postdoctorates receiving federal funds had declined slightly (to 71.9 percent), and a significant shift in the pattern of support had occurred. Of the 10,213 postdoctorates supported by federal funds that year, 22.3 percent had fellowships or training grant appointments, while 77.7 percent worked on research grants.

The source of this shift in the pattern of federal research training support can be found traced to a number of related trends. Over the last 25 years the number of research grants awarded by the NIH and other DHHS agencies has more than doubled.[16] Principal investigators have come to depend on graduate students and postdoctorates to carry out much of the day-to-day work of research. During the same period, both the number of universities awarding Ph.D.s in the basic biomedical sciences and the quantity of Ph.D.s awarded by existing programs have grown.[17] Federal funding policies, furthermore, have inadvertently provided universities an incentive to appoint students and postdoctorates to research assistantships instead of training grants or fellowships. As shown in Table 2-1, the NIH provides almost $9,000 more to research assistants and their institutions (largely in the form of indirect cost payments to universities) than to NRSA trainees or fellows.

As described in Chapter 1, the number of students and postdoctorates provided research training through NRSA training grants and fellowships has been deliberately limited over much of the last 25 years to ensure that the supply of investigators trained through the program would not exceed what the research enterprise could absorb. No similar federal effort has been under-

[15] Unpublished tabulation from the Survey of Graduate Students and Postdoctorates in Science and Engineering; available from the archives of the Academies.

[16] Unpublished tabulation from the NIH IMPAC System; available from the archives of the Academies.

[17] Unpublished tabulation from the Survey of Earned Doctorates; available from the archives of the Academies.

TABLE 2-1 Comparison of the Average Benefits Provided to NRSA Recipients and NIH-Supported Graduate Research Assistants, Fiscal Year 1999

NRSA Recipient		Graduate Research Assistant[a]	
Stipend	$14,688	Base salary	$16,000
Tuition benefit	8,600	Tuition reimbursement	8,400
Institutional allowance	1,500	Fringe benefits	1,600
Indirect costs	1,310	Indirect costs	8,800
Travel allowance	500		
Total cost	$26,598	Total cost	$34,800

NOTE: Comparison is based on the following assumptions:

- The average salary of graduate research assistants is $16,000.
- The fringe benefit rate for graduate research assistants is 10 percent.
- The average indirect cost rate for research grants is 50 percent and for NRSA training grants and fellowships is 8 percent.
- Institutions receive a $1,500 allowance for each predoctoral trainee; NRSA recipients may accrue some benefit from this allowance.
- The NRSA tuition benefit equals 100 percent of the first $2,000 and 60 percent of costs above $2,000; amount shown assumes that the average combined cost of tuition, fees, and health insurance is $13,000.

[a] Direct costs are capped at $26,000.

SOURCE: Data are from the NIH Office of Extramural Research.

taken thus far to ensure an adequate supply of technically prepared support staff in research, nor is there a system for regulating the number of research assistantships. Hence, as Massy and Goldman concluded in their 1995 analysis of science and engineering Ph.D. production, the size of doctoral programs is driven largely by departmental needs for research and teaching assistants, rather than by the labor market for Ph.D.s.[18]

Despite the shift in federal support, the fraction of eligible students in the biomedical sciences who receive NRSA funding during their predoctoral years has remained relatively constant over the last few decades. At some point during their training, one-third of qualifying doctoral students receive NRSA support.[19] The explanation for this seeming contradiction can be found in the eligibility requirements for NRSA awards: only U.S. citizens and permanent residents qualify for NRSA training grants and fellowships, and their number has grown at a much slower pace than that of foreign students pursuing degrees in the biomedical sciences.

This shift in the pattern of federal research training support may have long-term implications, as a result of several factors. Predoctoral NRSA training grants in the basic biomedical sciences generally take a "multidisciplinary" approach to research training, and students without benefit of such exposure may be limited in their future research activities. Moreover, evaluations of the NRSA program suggest that its participants complete their training faster than other students and go on to more productive research careers.

Since the beginning of the NRSA program, the NIH has required most predoctoral training grants in the basic biomedical sciences to be "multidisciplinary" in order to expose students to a range of biomedical fields. Though the effectiveness of multidisciplinary training undoubtedly varies from program to program, a training grant with the declared purpose of multidisciplinary training is more likely to achieve that goal than a research assistantship.

In the committee's view, the tradition of multidisciplinary training in the biomedical sciences has been valuable and could be fruitfully extended to a wider range of related fields. In spite of the efforts of

[18] Massy, William F., and Charles A. Goldman. *The Production and Utilization of Science and Engineering Doctorates in the United States.* Stanford Institute for Higher Education Research Discussion Paper. Stanford, Calif.: 1995.

[19] Unpublished tabulation from the Survey of Earned Doctorates and NIH Trainee and Fellow File; available from the archives of the Academies.

several targeted NRSA research training programs to encourage universities to integrate training in physics, chemistry, or mathematics with biology, the committee believes that too few doctoral students in the basic biomedical sciences have the opportunity to develop the breadth of knowledge that will allow them to interact effectively with investigators in related fields. Building on the rapidly increasing knowledge of molecular biology and genetics, for example, often requires work in fields outside the basic biomedical sciences. Similarly, the translation of basic biomedical discoveries into clinical applications may require collaborating with physicians and a working knowledge of such aspects of human biology as anatomy, physiology, and pharmacology.

The committee recognizes the challenge of expanding the breadth of research training without increasing time to degree, but progress in health research will be accelerated if basic biomedical scientists can readily relate their knowledge to other fields, including chemistry, mathematics, clinical medicine, and behavior. Examples of model approaches to research training that could be adopted more widely include the "Frontiers in Interdisciplinary Biosciences" course introduced at Stanford University in the fall of 1999, which brings together students from the biosciences, chemistry, physics, and engineering to evaluate cutting-edge research,[20] and the long-standing pathobiology course at the Tufts University Sackler School of Graduate Biomedical Sciences, which provides non-physician graduate students and postdoctoral fellows with grounding in human disease and the skills to collaborate with physicians.[21]

Evaluations of career outcomes suggest that NRSA participants complete training faster and go on to more successful research careers than classmates at the same institution or those graduating from universities without NRSA funding. The first of these assessments, completed in 1984, found that participants in NIH training programs completed their doctoral degrees faster and were more likely to go on to NIH-supported postdoctoral training than their counterparts who received funding from other mechanisms.[22] Moreover, those supported by the NIH during their predoctoral studies received NIH research grants more often, authored more articles, and were cited more frequently by their peers.

A more recent evaluation, conducted in the late 1990s, reported similar findings (see Figure 2-7). Basic biomedical Ph.D.s who received NRSA support for at least one academic year spent less time in graduate school. Nearly 57 percent of NRSA trainees and fellows received their doctorates by age 30, an accomplishment matched by 39 percent of their classmates and 32 percent in departments without NRSA support.[23]

After completing their studies, NRSA trainees and fellows were more likely to move into faculty or other research-intensive positions. Seven to eight years after receiving their degrees, 37 percent of former NRSA recipients held faculty appointments at institutions ranking in the top 100 in NIH funding. The same was true for 24 percent of their classmates without NRSA support and 16 percent of graduates from departments without NRSA funding. As a whole, 87 percent of former NRSA trainees and fellows reported that they were in research-related positions, in academia, industry, or other settings, compared to 77 percent of their former classmates and 72 percent of those from departments without NRSA support.

Former NRSA trainees and fellows were more likely to be successful in competing for grants. Of the 1981-1988 Ph.D. recipients who applied for NIH research grant support by 1994, the success rates were 67 percent for NRSA recipients, 55 percent for their former classmates, and 47 percent for those who graduated from departments without NRSA funding. Moreover, former trainees and fellows who completed their degrees in 1981-1982 had a median of eight and one-half publications by 1995, twice as many as Ph.D.s who graduated from departments without NRSA support, and much more than their former classmates, who published a median of five publications.

Such findings, of course, do not address the reasons

[20] Stanford University. Department of Biological Sciences. "Frontiers in Interdisciplinary Biosciences." Online. Stanford University. Available: http://cmgm.stanford.edu/biochem/biox/course.html. Accessed 23 February 2000.

[21] Arias, Irwin M. "Training Basic Scientists to Bridge the Gap Between Basic Science and Its Applications to Human Disease." *New England Journal of Medicine* 321, no. 14 (1989): 972-74.

[22] Coggeshall, Porter, and Prudence Brown. *The Career Achievements of NIH Predoctoral Trainees and Fellows.* Washington, D.C.: National Academy Press, 1984.

[23] Pion, Georgine, M. Office of Extramural Research, National Institutes of Health. *The Early Career Progress of NRSA Predoctoral Trainees and Fellows.* Bethesda, Md.: NIH, 2000.

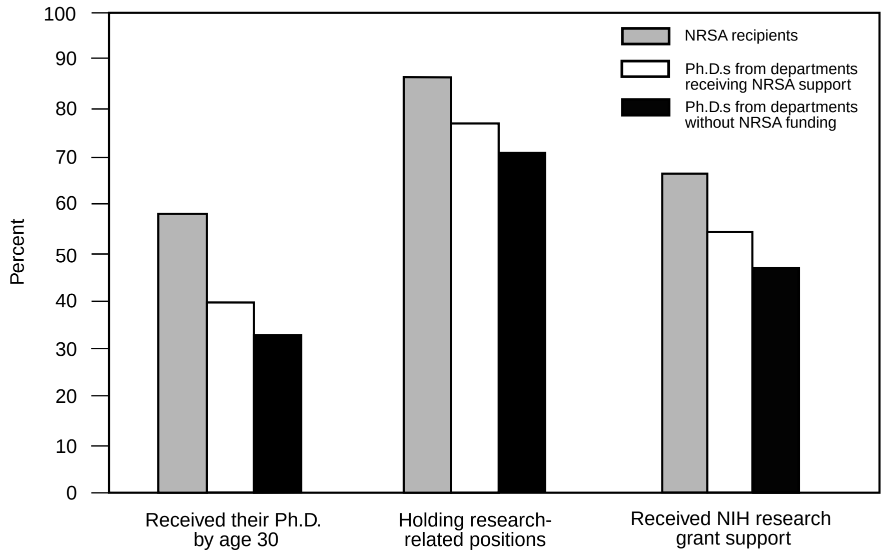

FIGURE 2-7 Selected career outcomes of basic biomedical Ph.D. recipients from 1981 to 1992 by nature of support. SOURCE: Data are from the NIH Office of Extramural Research, *The Early Career Progress of NRSA Predoctoral Trainees and Fellows,* 2000.

for the success of former NRSA trainees and fellows. The extent to which the differences in their educational and career outcomes reflect the foresight of training grant directors and fellowship reviewers in selecting the most promising candidates for NRSA funding and to what degree the outcomes are due to the training itself—or other factors—are not known. Nonetheless, it is clear that more NRSA participants go on to active and successful research careers.

IMPLICATIONS AND RECOMMENDATIONS

On the whole, the size of the basic biomedical workforce appears more than sufficient to meet national needs, and current levels of research training may be even higher than necessary to maintain the workforce. While the committee believes there are some areas of research training that should expand, overall Ph.D. production in biomedical sciences should not.

In light of the findings from the demographic analysis of the workforce conducted for the committee, some might suggest that the number of Ph.D.s awarded in biomedical science fields be reduced. Given the central role that graduate students and postdoctorates play in the conduct of basic biomedical research, however, a decrease in Ph.D. production could delay or disrupt research progress. Before considering any cutbacks, university administrators and federal policymakers must begin to address the ongoing demand for research support staff. The "nonreplicating" Ph.D.-level scientist (i.e., one who neither applies for grants nor trains students) proposed by Marincola and Solomon is one potential solution;[24] a permanent laboratory workforce of master's-level technicians and Ph.D.-trained research associates, as proposed by the NRC committee that prepared the 1998 report *Trends in the Early Careers of Life Scientists,* is another.[25]

Several steps should be taken to improve the quality of research training in the basic biomedical sciences. The committee believes that the tradition of multidisciplinary NRSA training would be even more effective if it were broadened to emphasize the connections between the biomedical sciences and other related fields. In addition, the committee is greatly concerned that the number of underrepresented minorities earning Ph.D.s in the biomedical sciences has increased at a very slow pace.

[24] Marincola, Elizabeth, and Frank Solomon, "The Career Structure in Basic Biomedical Research: Implications for Training and Trainees." *Molecular Biology of the Cell* 9 (November 1998): 3003-6.

[25] National Research Council. Trends in the Early Careers of Life Scientists. Washington, D.C.: National Academy Press, 1998.

Because of the successful career outcomes of its participants and its tradition of multidisciplinary training, the NRSA program should play a greater role in NIH's portfolio of research training and training-related activities than it does today. It is unlikely, however, that the NIH could readily return to its pattern of research training support of the mid-1970s, when the NRSA program was initiated and more than 70 percent of graduate students in the biomedical sciences with NIH or other DHHS support received funding through training grants or fellowships. Instead, the committee believes that the agency should strive for a middle ground: gradually expanding the NRSA program until it accounts for at least 50 percent of the agency's funding for graduate students in the basic biomedical sciences and correspondingly limiting research assistantships and other modes of graduate student support, to ensure that overall Ph.D. production does not increase. At the postdoctoral level, the NIH should also seek to provide advanced research training to a greater number of recent Ph.D.s through NRSA training grants and fellowships, rather than postdoctoral appointments on research grants.

Coordinating reciprocal increases in the NRSA program and reductions in other funding for graduate student support will undoubtedly require the NIH to consolidate its oversight of research training and training-related activities. Such a change in NIH policy and practice will also have implications for the ways in which universities administer federal research training funds, perhaps requiring more centralized control over graduate student enrollment. Moreover, if eligibility requirements for NRSA training grants and fellowships remain unchanged, a reduction in other forms of training-related support will likely reduce the number of foreign students seeking biomedical science Ph.D.s in the U.S. These and related issues are discussed in greater detail in Chapter 5.

Recommendation 2-1. There should be no growth in the aggregate number of Ph.D.s awarded in the basic biomedical sciences.

Given the current employment opportunities for basic biomedical scientists and the forecasted growth in the workforce, the present number of approximately 5,400 new basic biomedical Ph.D.s a year is more than sufficient to fulfill anticipated national needs at least until 2005.

Recommendation 2-2. Support for NRSA training grants and fellowships at the predoctoral and postdoctoral levels should be gradually increased. At the predoctoral levels, the NIH should seek to provide at least 50 percent of its research training support through training grants and fellowships.

The evidence suggests that training grants and fellowships are more effective in research career development than are research assistantships. Therefore, we recommend a gradual expansion in the numbers of students and postdoctorates supported in this fashion but only if accompanied by a concomitant decrease in training by research grants.

NIH and other federal sponsors of research training should consider options to assist graduate departments in restricting overall expansion of Ph.D. programs, including (1) encouraging universities to provide all entering graduate students with some form of financial support, such as a traineeship, that would allow them an opportunity for broad multidisciplinary education, (2) requiring graduate students to pass their qualifying exams before working as research assistants on federally funded projects, and (3) limiting the number of years graduate students may be employed as research assistants and postdoctorates may be employed in temporary appointments with federal funds.

Recommendation 2-3. The NIH should consider at least a small increase in dual-degree training in the basic biomedical sciences.

Because of the considerable success of the NRSA dual-degree training programs that prepare physicians to conduct basic biomedical research, we urge the NIH to consider at least a small increase in such programs. If it opts to expand dual-degree training, the NIH should assess the need for proportionate reductions in other forms of research training support, in order to prevent an increase in overall Ph.D. production in the basic biomedical sciences.

Recommendation 2-4. The NIH should expand its emphasis on multidisciplinary training in the basic biomedical sciences.

Since the NRSA program began, training grant awards in the basic biomedical sciences have emphasized multidisciplinary research training. Given current opportunities for basic biomedical Ph.D.s and continuing advances in science, the NIH should build on its tradition of multidisciplinary training by providing more students and fellows with the skills that will allow them to collaborate effectively with investigators in clinical medicine, the behavioral sciences, and such fields as mathematics, physics, and chemistry.

Recommendation 2-5. The NIH should increase its efforts to identify and support programs that encourage and prepare underrepresented minority students for careers in basic biomedical research.

Although there has been some increase in minority Ph.D.s in the basic biomedical sciences, their number is still low. The cause of this is likely not in graduate training but far earlier in the educational careers of students. There is a great need to evaluate and identify what works, which environments are especially successful, and where NIH interventions could make a difference.