Education and Employment Patterns of U.S. Ph.D.'s in the Biomedical Sciences

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ABSTRACT **During most of the 1970s and 1980s, the number of biomedical Ph.D.'s conferred in the United States was fairly constant. From 1987 to 1995, however, there was an increase of almost 50% in the number of biomedical Ph.D.'s awarded by U.S. institutions; nearly 70% of this increase can be accounted for by the increase in the number of noncitizens receiving a Ph.D. in the U.S. Although unemployment among U.S. citizens with biomedical Ph.D.'s is now extremely low—less than 2.0%—there have been some important changes in the job market for biomedical Ph.D.'s. The total number of biomedical scientists has grown, whereas the number of faculty positions has remained stable, causing a deline in faculty positions as a percentage of total employment for biomedical scientists. Jobs in industry have increased, and in the future might surpass academic jobs as the most prevalent form of employment for U.S. biomedical scientists.—Garrison, H. H., Gerbi, S. A. Education and employment patterns of U.S. Ph.D.'s in the biomedical sciences. *FASEB J.* 12, 139–148 (1998)**

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THERE HAS BEEN INCREASING CONCERN in recent years about employment and career opportunities available to young biomedical scientists. Some of this concern may have been sparked by growing unemployment rates in other fields of science (1); some may have been generated by shifts in the pattern of research funding for young investigators and more subtle shifts in career contingencies (2). The problem has been examined in reports (3), studies (4), and conferences at the national level (5), and by local studies and symposia (6). By using survey data collected by the National Research Council (NRC),[2] we examine trends in production and employment of Ph.D.'s in the biomedical sciences.

PRODUCTION OF BIOMEDICAL Ph.D.'s

The number of biomedical[3] Ph.D.'s awarded in the U.S. remained fairly constant during most of the 1970s and 1980s. From 1972 through 1978, the number of new biomedical Ph.D.'s was approximately 3500 (**Table 1** and **Fig. 1**). An increase in 1980 led to a new equilibrium: the number of new Ph.D.'s ranged between 3800 and 3900 during the early and middle 1980s. In 1988, however, the number rose to

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[2] Abbreviations: NRC, National Research Council; NIH, National Institutes of Health; NSF, National Science Foundation; SDR, Survey of Doctorate Recipients.

[3] In this report, statistical tabulations from the NSF and NRC data sources on doctoral scientists were generated for the 'biomedical sciences.' This classification consists of biology disciplines frequently involved in medical research. It is often used in NRC studies, including the congressionally mandated NRC studies of NIH training programs. The biomedical science fields also correspond closely with the disciplines represented by the FASEB Societies: anatomy, biochemistry, biophysics, cell biology, developmental biology, immunology, molecular biology, nutritional science, pathology, pharmacology, and physiology. In 1995, individuals with Ph.D. degrees in these fields comprised 50% of the biomedical scientists in the two NRC survey samples used in this report: the Survey of Doctorate Recipients and the Survey of Earned Doctorates. Doctorate degree holders in bioengineering, genetics, microbiology, neuroscience, and toxicology comprised another 20% of the biomedical scientists. For a full listing of fields in the biomedical sciences category, see ref 7.

TABLE 1. *Number of biomedical science Ph.D.'s awarded by U.S. institutions, by nationality, 1972–1995*[a]

Year	Total	U.S. citizens[b]	Non-U.S. citizens[b]
1972	3,449	2,806	552
1973	3,516	2,879	556
1974	3,410	2,665	572
1975	3,509	2,881	535
1976	3,576	2,939	524
1977	3,457	2,835	519
1978	3,518	2,940	472
1979	3,644	3,071	467
1980	3,823	3,242	502
1981	3,845	3,285	460
1982	3,960	3,317	506
1983	3,788	3,175	503
1984	3,904	3,240	521
1985	3,791	3,050	587
1986	3,865	3,077	578
1987	3,975	3,018	719
1988	4,369	3,254	831
1989	4,433	3,287	887
1990	4,620	3,325	1,171
1991	4,968	3,478	1,402
1992	5,203	3,537	1,580
1993	5,594	3,749	1,713
1994	5,680	3,726	1,886
1995	5,878	3,746	2,031

[a] Source: National Research Council, Survey of Earned Doctorates. [b] Subtotals include only those individuals reporting citizenship status.

4369, and continued to rise to 5878 in 1995, increasing by 47.9% the number of biomedical Ph.D. recipients from 1987 to 1995. This growth, however, was not uniform across all institutions. Between 1970 and 1994, the number of new life science Ph.D.'s remained fairly constant (2254 and 2665, respectively) at the top 27 schools (ranked by 1970 Ph.D. standards); the percentage of the total Ph.D. degrees bestowed by these 27 schools, however, dropped from 50.5% to 36.1% (8). Schools that historically turned out fewer Ph.D. graduates had increased their percentage of life science Ph.D.'s during that 24-year period.

Massey and Goldman (9) claim there is a link between the need for teaching and/or research assistants and the growth in the number of Ph.D. recipients. Clearly, there is a symbiotic relationship among teaching, research, and graduate education. The activities of graduate assistants provide important benefits for faculty members and their institutions, and offer graduate students unique and valuable experience. Many schools hire graduate teaching assistants to help in undergraduate courses that often have a laboratory component. But this cannot be a universal factor driving the number of students admitted into biomedical Ph.D. programs, since this particular workforce need is usually absent in medical school settings, where about half of the biomedical Ph.D.'s are trained (10).

Another influence on the number of graduate students is today's need for research assistants—an important part of the workforce that carries out research supervised by faculty mentors. This apprenticeship, in turn, serves to train students in how to perform research, and is therefore a mutually beneficial arrangement. The stipends and tuition for research assistants are paid either from federal sources (training grants, individual fellowships, or wages from research grants) or by the school (including state funds at publicly supported schools). Financial arrangements reflect the synergism of the relationship: the research grant pays the student's salary and tuition while the research project benefits from the student's contributions.

The workforce needs of an institution are translated into their modes of support for graduate students. In 1994, an estimated 37.0% of the biomedical graduate students who trained in medical schools received institutional support; 29.5% were research assistants paid from research grants; and 17.2% had traineeships from the National Institutes of Health (NIH) (10).

Data from National Science Foundation (NSF) surveys of graduate student enrollment and support indicate that the increase in the number of biomedical Ph.D.'s correlates with growth in number of research assistantships, suggesting that certain workforce needs are associated with an increased production of Ph.D.'s. The number of biomedical science Ph.D.'s rose by 53.8% between 1980 and 1995 (Table 1), during which there were sizable declines in the number of NIH traineeship and fellowship positions and small declines in the number of biological science graduate students with teaching assistantships and 'self support' (**Table 2**). However, the number of biology graduate students with research assistantships (from NIH, nonfederal sources, and all other sources) increased dramatically—doubling between 1980 and 1995. Although

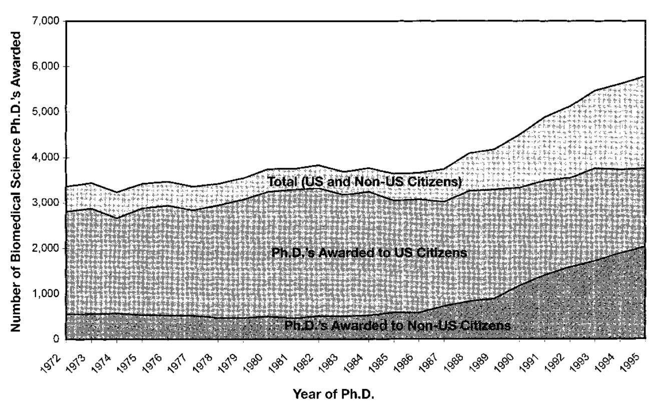

Figure 1. Number of biomedical science Ph.D.'s awarded by U.S. institutions to U.S. and non-U.S. citizens, by year (also see Table 1). Source: National Research Council, "Survey of Earned Doctorates."

TABLE 2. *Sources of support for biology[a] graduate students, 1972–1995*

Year	NIH predoctoral trainees and fellows[b]	Teaching assistants[c]	Self support[c]	NIH, Biology R.A.'s[c]	Non-Federal R.A.'s[c]	All biological R.A.'s[c]
1972	12,047	6,832	5,329	1,321	2,344	5,140
1973	8,788	7,779	5,524	1,436	2,833	5,834
1974	9,427	8,383	7,032	1,588	3,098	6,467
1975	15,197	8,717	9,011	1,702	3,182	6,738
1976	14,131	8,936	8,816	2,058	3,487	7,676
1977	13,196	8,997	8,719	2,136	3,737	7,959
1978	13,152	n.a.	8,100	n.a.	n.a.	n.a.
1979	12,682	8,798	7,153	2,630	4,196	9,187
1980	12,280	9,016	6,834	2,745	4,193	9,488
1981	12,364	8,923	6,522	2,955	4,445	9,793
1982	8,401	9,085	6,276	2,857	4,608	9,753
1983	8,194	8,818	5,969	2,959	4,706	9,929
1984	8,010	8,815	5,795	3,230	5,202	10,707
1985	7,585	8,781	5,424	3,410	5,194	11,015
1986	7,385	8,441	5,429	3,924	5,639	11,884
1987	7,861	8,136	5,004	4,288	5,923	12,759
1988	7,947	8,053	4,813	4,908	6,464	13,930
1989	8,246	8,341	4,561	5,505	6,839	14,997
1990	9,053	8,166	4,289	5,624	7,195	15,572
1991	9,828	8,237	4,575	6,025	7,634	16,634
1992	10,027	8,295	4,983	6,374	7,932	17,390
1993	9,960	8,473	5,467	6,916	8,302	18,579
1994	10,077	8,741	5,561	7,021	8,574	19,143
1995	9,811	8,647	6,011	7,053	8,452	18,894

[a] These tabulations refer to the NSF ''biology'' classification, a category that is much larger and not directly comparable to the NRC ''biomedical'' category used in the other tables. [b] NIH predoctoral trainees anf fellows (excl T35, T35, and T36). Source: NIH IMPAC ORE/OD. [c] Full-time graduate students in biological sciences in doctorate granting institutions. Source: NSF Survey of Graduate Students.

the field specifications differ between Table 1 ('biomedical' Ph.D.) and Table 2 ('biological science graduate student'), the increase in Ph.D. production at the same time that the number of research assistantships was expanding points to the possibility of a direct connection between the two trends.

STUDENTS FROM OTHER NATIONS

The small increase in the number of U.S. citizens obtaining biomedical Ph.D.'s apparently has not been sufficient to meet the workforce needs of schools. At the same time, an increased number of citizens of other nations have obtained Ph.D.'s in the U.S.

From the early 1970s to the middle 1980s, Ph.D. production was stable, with approximately 3400 to 3900 degrees awarded each year. Only 500 to 550 of these new Ph.D.'s were earned by people who identified themselves as non-U.S. citizens (Table 1 and Fig. 1). In the middle 1980s, however, the number of degrees awarded to non-U.S. citizens began to increase steadily. In 1985, the 587 Ph.D. degrees awarded to non-U.S. citizens represented 16.1% of the 3637 degrees awarded to individuals reporting citizenship.[4] In 1995, 2031 degrees were earned by non-U.S. citizens, comprising 35.2% of the 5777 degrees awarded to individuals reporting citizenship (Table 1). The growth in the number of Ph.D.'s awarded to non-U.S. citizens—from 587 in 1985 to 2031 in 1995—represents an increase of 246%. The 1444 additional Ph.D.'s awarded to non-U.S. citizens account for 67.5% of the total growth in U.S. citizen plus non-U.S. citizen Ph.D. conferment from 1985 to 1995. Some of the sharp increase in the number of degrees earned by students from other nations reflects, in part, unique political events (especially in China and the Soviet Union) that are unlikely to recur, and it is unclear how long the rise in the percentage of degrees earned by noncitizens will continue.

Have noncitizens displaced U.S. citizens from graduate schools in the biomedical sciences? There was a slight increase of 421 U.S. citizens obtaining a biomedical Ph.D. from 1990 to 1995, which is the same period when the numbers of biomedical Ph.D.'s. awards to noncitizens doubled (Table 1). One interpretation of these trends is that the need for biomed-

[4] This number may be an underestimate, as each year a small fraction of survey respondents decline to report citizenship status.

TABLE 3. *Unemployment for biomedical scientists, 1973–1995[a] (U.S. citizens only)*

	Survey Year							
	1973	1977	1981	1985	1989	1991	1993	1995
Total labor force	1.0	1.6	1.3	1.1	0.9	1.9	1.4	1.8
1–2 years post-Ph.D.	1.8	2.3	1.7	1.4	1.3	1.2	0.9	2.1
3–4 years post-Ph.D.	1.3	2.3	1.7	1.6	0.9	1.6	0.4	2.0
5–6 years post-Ph.D.	0.8	1.9	2.1	0.8	1.2	1.3	1.4	1.2
7–8 years post-Ph.D.	1.1	1.5	0.9	1.0	0.5	1.4	0.7	1.5
9–10 years post-Ph.D.	0.7	1.2	1.7	1.2	1.2	1.9	1.0	0.9
More than 10 years post-Ph.D.	0.8	1.1	0.9	0.9	0.9	2.2	1.8	1.9

[a] Data shown are weighted estimates from sample surveys. The first line contains estimates for all biomedical scientists; succeeding lines present estimates for components of the population classified according to number of years since receipt of the doctorate. Changes in survey methodology complicate some of the comparisons over time. In 1991, a significant effort was made to improve accuracy of the survey estimates by increasing the response rate. Additional activities to contact nonrespondents were used to increase the reliability of the surveys, and these procedures were maintained in the 1993 and 1995 surveys. Although the data yield more accurate estimates, it is not possible to determine whether changes between surveys pre- and post-1991 are due to methodological practices or substantial developments in the experiences of scientists. Trend data for this period, therefore, need to be interpreted cautiously. As part of the more intensive follow-up program, the data collection period for the survey was pushed further back in the academic year for many survey respondents. It is possible that, for some respondents, the change in the timing of the survey had an effect on the information reported. In addition, changes were made in the survey questionnaire in 1993. These modifications, implemented to collect more precise information, may have affected the reporting practices of the respondents, and as a result, created an additional (but unmeasurable) impediment to comparisons over time. Source: National Research Council, Survey of Doctorate Recipients.

ical predoctoral students cannot be met by qualified U.S. citizens, and noncitizens are recruited to fill the void. This trend continues at the postdoctoral level, where the need for postdoctorals outstrips the supply of Ph.D.'s from U.S. institutions, so noncitizens trained in other countries are recruited (11). It may be that a greater number of qualified U.S. undergraduates do not choose to pursue predoctoral biomedical training because they hear how difficult it is to obtain academic jobs and research grants; these considerations may be of less concern to noncitizens when weighed against other factors shaping their choices. As stated earlier, the data suggest that workforce needs for research assistants may be driving Ph.D. production.

EMPLOYMENT TRENDS FOR BIOMEDICAL PH.D.'s

How have the growth in the number of persons earning Ph.D.'s and immigration affected job prospects for U.S. Ph.D.'s? Some perspective on this question can be gained from the ''Survey of Doctorate Recipients'' (SDR), a longitudinal study of employment outcomes for a statistically selected sample of Ph.D. recipients conducted by the NRC under contract to the NSF. The SDR responses are tabulated and weighed to depict employment of the entire population of Ph.D. recipients.

The statistical data tabulations from the SDR presented below are limited to U.S. citizens. The number of non-U.S. citizens in the SDR biomedical science sample is small, and estimates for U.S. citizens are virtually the same as those for the entire biomedical Ph.D. sample.[5] The SDR sample is representative of the entire population of U.S. citizen Ph.D.'s, but not representative of noncitizen Ph.D.'s, as it includes only those noncitizens with Ph.D.'s from U.S. schools who indicated, when they completed their doctoral dissertation, that they had plans to remain in the U.S. However, not all have firm plans, and it is unclear—often even to the noncitizens themselves—whether they will remain in the U.S. Moreover, noncitizens who obtained their Ph.D. in other countries (a sizable part of the postdoctoral pool) are not captured in the SDR sample.

These and other limitations (chiefly the lag time between data collection and reporting) notwithstanding, the survey data demonstrate that unemployment and 'out-of-field' employment remain low. In other ways, however, the employment conditions of biomedical scientists have undergone substantial change. Somewhat longer periods of postdoctoral appointments, the emergence of postdoctoral positions in industry, no growth in the number of academic positions, and expansion of career positions in industry pose new challenges and opportunities for young scientists and their mentors.

Unemployment

The percentage of U.S. citizen biomedical science Ph.D.'s who are unemployed is extremely small: 1.0% in 1973 and 1.8% in 1995 (**Table 3**). Unemployment wavered between 0.9% and 1.9% during the intervening years, with no discernable pattern.

[5] Tabulations for the latter group are available from the authors upon request.

TABLE 4. *Percentage of employed biomedical Ph.D.'s who were postdoctorals, 1973–1995[a] (U.S. citizens only)*

	1973	1977	1981	1985	1989	1991	1993	1995
				All postdoctoral[b]				
Total employed[c]	5.7	8.7	9.6	8.3	8.9	7.3	9.1	9.7
1–2 years post-Ph.D.	26.5	43.9	52.0	50.1	56.9	42.6	49.5	58.0
3–4 years post-Ph.D.	7.3	14.7	23.6	24.0	28.0	24.9	32.0	32.1
5–6 years post-Ph.D.	2.2	5.4	8.9	11.3	13.2	6.3	14.9	15.5
7–8 years post-Ph.D.	1.5	3.4	3.3	2.5	6.1	5.4	6.4	7.7
9–10 years post-Ph.D.	0.3	1.5	0.9	2.3	1.7	1.8	4.0	3.1
More than 10 years	0.1	0.4	0.4	0.4	0.4	0.4	0.6	0.8
				Academic postdoctoral				
Total employed[c]	4.5	7.0	8.0	6.3	7.1	5.6	6.8	7.1
1–2 years post-Ph.D.	20.7	35.8	44.1	39.7	45.9	32.6	36.8	42.2
3–4 years post-Ph.D.	6.2	11.7	19.2	18.8	22.6	19.0	24.7	23.3
5–6 years post-Ph.D.	1.8	4.3	7.0	7.5	10.2	4.8	11.1	12.0
7–8 years post-Ph.D.	1.0	2.3	3.0	1.5	4.6	4.7	4.6	5.5
9–10 years post-Ph.D.	0.3	1.5	0.5	1.5	1.4	1.2	2.8	2.4
More than 10 years	0.1	0.3	0.3	0.2	0.3	0.3	0.4	0.6
				Nonacademic postdoctoral				
Total employed[c]	1.2	1.7	1.6	2.0	1.8	1.7	2.3	2.6
1–2 years post-Ph.D.	5.8	8.1	7.9	10.4	11.0	10.0	12.7	15.8
3–4 years post-Ph.D.	1.1	3.0	4.4	5.2	5.4	5.9	7.3	8.8
5–6 years post-Ph.D.	0.4	1.1	1.9	3.8	3.0	1.5	3.8	3.5
7–8 years post-Ph.D.	0.5	1.1	0.3	1.0	1.5	0.7	1.8	2.2
9–10 years post-Ph.D.	n.a.	n.a.	0.4	0.8	0.3	0.6	1.2	0.7
More than 10 years	0.0	0.1	0.1	0.2	0.1	0.1	0.2	0.2

[a] See footnote *a* to Table 3. [b] A detailed definition of postdoctoral appointment was provided for the first time in the 1979 Survey of Doctorate Recipients. Differences in survey results obtained before and after this date may reflect changes in questionnaires as well as temporal trends. [c] The numbers shown for each of the "years post-Ph.D." represent the percentage of postdoctorals in the degree cohort. The numbers shown for "Total employed" are weighted averages of each of the entries below it, adjusting for the size of each cohort. Source: National Research Council, Survey of Doctorate Recipients.

Underemployment

Underemployment is only one of several labor market outcomes, and the term 'underemployment' has been coined to refer to those individuals who do not find jobs appropriate to their education or experience. In an effort to measure certain aspects of underemployment, NSF has begun reporting an 'involuntarily out-of-field rate' (R_{IOF}), which is interpreted as the ratio of those who are working part-time but seeking full-time jobs (E_{PTS}), or who are working outside of their degree field when a science and engineering position would be preferred (E_{NSP}), to total employment (E_T): $R_{IOF} = (E_{PTS} + E_{NSP})/E_T$. Thus, in 1995, 3.3% of the biological and health scientists were employed 'involuntarily out-of-field.' This represents a slight decrease from the 1993 value of 3.5% (12). Unlike most statistical data contained in this report, these rates refer to all fields of biology and include both U.S. citizens and noncitizens. In addition, individuals working full-time in their degree field in positions that are not meeting their career goals—for example, senior postdoctorals who have not yet acquired permanent employment—are not indexed by this measure.

Postdoctoral positions

Postdoctoral research allows individuals to expand their expertise; indeed, some delve into areas outside their predoctoral field. The duration of the postdoctoral experience varies with the amount of advanced training desired and other circumstances unique to the individual. Postdoctorals also represent a pool of applicants for permanent jobs. As these jobs become harder to secure, students remain longer in postdoctoral positions. In the past two decades, the percentage of U.S. Ph.D.'s working as postdoctorals has increased (**Table 4**).

In the early 1970s, postdoctoral positions were held by a minority of the new Ph.D.'s: in 1973, a fourth of the new biomedical Ph.D. population went on to postdoctoral positions, almost always in academia. The pattern changed in the late 1970s and early 1980s: by the beginning of the 1980s, about half of the recent graduates found themselves in postdoctoral positions. Measuring the exact degree of growth is complicated by changes in survey questions and other differences in survey methodology. For example, during the 1970s, the definition of 'postdoctoral' used in the SDR was altered, and some of the change during this period may reflect differences in the respondents' interpretations of the questions asked. Moreover, enhancements in survey methodology between 1989 and 1991 increased the response rate in the survey sample, which resulted in more accurate data but changed the timing of reporting for many respondents, and may also have affected the comparability of survey statistics to those of earlier years.

Despite the methodological caveats, a pattern of somewhat longer postdoctoral study is evident. In 1981, 23.6% of employed U.S. biomedical Ph.D.'s were postdoctoral associates 3–4 years after receiving their degree. In 1995, 32.1% of this group were postdoctoral associates. Increases in the percentage of scientists employed as postdoctoral associates are found at every level of experience. Whereas some of the percentages and increases are small—for example, the percentage of biomedical scientists in postdoctoral positions 9–10 years post-Ph.D. rose from 0.9% in 1981 to 3.1% in 1995—the general pattern clearly indicates lengthening periods of postdoctoral study.

The expansion of the postdoctoral pool is even greater than that shown in Table 4, as these data do not include the influx of doctorates from other nations (11). The latter are not accounted for in the tabulations derived from the SDR, nor is it known whether the length of time they spend as postdoctorals is the same as that for U.S. citizens with biomedical Ph.D.'s. As we know little about their career paths, it is a subject ripe for further analysis.

In addition to the trend toward more and longer postdoctorals, there is the growth in the number of 'nonacademic' postdoctorals (e.g., positions in industry). In the early 1980s, only a small fraction of U.S. biomedical Ph.D.'s held nonacademic postdoctoral positions. For those 1–2 years beyond their Ph.D. in 1981, the percentage was 7.9%; for those who were 3–4 years post-Ph.D., the comparable percentage was 4.4%. But by 1995, the percentage in nonacademic postdoctoral positions doubled for both groups, and similar trends were recorded for more experienced individuals (Table 4).

Academic positions

According to estimates from the SDR, the number of U.S. biomedical Ph.D.'s employed in academic positions in 1981 was 35,917. This number rose by more than 4000 in 4 years and remained about the same for the next decade (**Table 5**). This stability in employment notwithstanding, there were substantial changes both in the types of positions held and in the fraction they occupied of total number of Ph.D.'s employed.

In 1981, 24,442 U.S. biomedical science Ph.D.'s were in tenured or tenure-track academic positions, a number comparable to the 24,082 in these positions in 1995. However, the number of tenure-track faculty 9–10 years post-Ph.D. has more than doubled since 1981. Because biomedical Ph.D.'s are remaining longer as postdoctoral associates, perhaps not as many are tenured 10 years post-Ph.D. Nonetheless, the total number of tenure-track plus tenured positions has been relatively constant.

An important change in academic employment is the 64.4% increase in 'other academic' personnel, from 7,047 in 1981 to 11,586 in 1995. This may include non-tenure-track teaching or research faculty positions and/or senior postdoctorals who are given other titles.

The stability in total academic positions occurred over a period when the total number of U.S. biomedical Ph.D.'s was increasing, resulting in a drop in the percentage of employed U.S. biomedical Ph.D.'s in academic (and tenured academic) positions (**Table 6**). The fraction of U.S. biomedical Ph.D.'s with academic positions declined steadily from the late 1970s (when it was just under two-thirds) to the early 1990s (when it leveled off at just over half). So academia is still a major employer of U.S. biomedical Ph.D.'s, representing about half of their employment but providing jobs for a decreasing fraction of the employed Ph.D.'s.

Positions in industry

The percentage of biomedical Ph.D.'s employed in industry (including the pharmaceutical and biotechnology industries) has doubled in 14 years, with 31.9% of biomedical scientists in 1995 employed in this sector 9–10 years after receiving their Ph.D. compared to 15.6% employed in this sector in 1981 (Table 6). A major spurt in industrial employment occurred between 1981 and 1989. In absolute numbers, 852 biomedical scientists 9–10 years post-Ph.D. were employed in industry in 1981, and this grew to 1906 in 1995 (13). Thus, the importance of industry as a major employer of biomedical scientists, in both relative and absolute terms, has increased (**Fig. 2**).

Positions in government

The percentage of biomedical scientists employed in government has not changed substantially since 1973, and has remained around 10% (Table 6). These jobs include research in government laboratories, science policy positions, and science administration responsibilities.

Other positions

Employment in jobs other than those noted above has remained a small part of the total, i.e., less than

TABLE 5. *Number of biomedical Ph.D.'s employed in academic positions, 1981[a]–1995[b] (U.S. citizens only)*

	1981	1985	1989	1991	1993	1995
All academic						
Total employed	35,917	40,176	40,283	34,376	38,275	41,190
1–2 years post-Ph.D.	4,296	3,827	4,061	3,491	3,738	4,265
3–4 years post-Ph.D.	3,930	3,561	3,213	3,269	3,498	3,559
5–6 years post-Ph.D.	3,613	3,626	3,040	3,094	3,060	3,340
7–8 years post-Ph.D.	3,640	3,498	3,160	2,843	3,081	3,107
9–10 years post-Ph.D.	3,469	3,459	3,119	2,790	2,791	3,129
More than 10 years	16,969	22,205	23,690	18,889	22,107	23,789
Tenured						
Total employed	17,713	20,377	18,599	14,067	15,691	16,306
1–2 years post-Ph.D.	73	142	23	56	80	30
3–4 years post-Ph.D.	139	191	81	56	101	121
5–6 years post-Ph.D.	582	412	276	207	164	199
7–8 years post-Ph.D.	1,518	828	536	454	443	400
9–10 years post-Ph.D.	1,794	1,562	987	769	643	580
More than 10 years	13,607	17,242	16,696	12,525	14,260	14,978
Tenure-track						
Total employed	6,729	7,068	5,635	6,900	7,015	7,776
1–2 years post-Ph.D.	817	534	522	550	530	518
3–4 years post-Ph.D.	1,723	1,132	769	1,049	837	850
5–6 years post-Ph.D.	1,403	1,477	1,021	1,435	1,242	1,187
7–8 years post-Ph.D.	1,119	1,567	1,082	1,148	1,251	1,507
9–10 years post-Ph.D.	610	1,027	895	1,058	1,048	1,407
More than 10 years	1,057	1,331	1,346	1,660	2,107	2,306
Academic postdoctoral						
Total employed	4,428	4,250	5,062	3,745	4,893	5,522
1–2 years post-Ph.D.	2,621	2,353	2,740	1,877	2,204	2,613
3–4 years post-Ph.D.	1,107	1,170	1,263	1,120	1,471	1,445
5–6 years post-Ph.D.	402	479	588	279	646	719
7–8 years post-Ph.D.	175	90	281	266	263	327
9–10 years post-Ph.D.	30	92	82	72	157	143
More than 10 years	93	66	108	131	152	276
Other academic						
Total employed	7,047	8,491	10,987	9,663	10,676	11,586
1–2 years post-Ph.D.	785	798	776	1,008	924	1,105
3–4 years post-Ph.D.	961	1,068	1,100	1,044	1,087	1,144
5–6 years post-Ph.D.	1,226	1,258	1,155	1,173	1,008	1,235
7–8 years post-Ph.D.	828	973	1,261	975	1,124	873
9–10 years post-Ph.D.	1,035	778	1,155	891	1,943	1,000
More than 10 years	2,212	3,566	5,540	4,573	5,588	6,229

[a] Prior to 1981, data on tenure-track appointments were not collected. [b] See footnote to Table 3. Source: National Research Council, Survey of Doctorate Recipients.

10%. For employed biomedical scientists 9–10 years after receiving their Ph.D., this category represented 6.4% of all biomedical Ph.D. holders employed in 1973 and 7.0% in 1995 (Table 6). This has significant implications for proposals to prepare students for careers outside academia, industry, or government.

CONCLUSION, RECOMMENDATIONS, AND QUESTIONS FOR FUTURE RESEARCH

In the last decade, there has been a substantial increase both in the number of biomedical science graduate students working as research assistants and the number of biomedical science Ph.D.'s awarded

TABLE 6. *Percentage of employed biomedical Ph.D.'s in academic, industry, government, and other positions, 1973–1995*[a] *(U.S. citizens only)*

	1973	1977	1981	1985	1989	1991	1993	1995
				All academic[b]				
Total employed	66.5	66.2	64.7	60.0	56.8	51.3	52.9	53.2
1–2 years post-Ph.D.	70.6	71.9	72.3	64.5	68.0	60.6	62.4	69.0
3–4 years post-Ph.D.	72.5	65.1	68.3	57.2	57.5	55.4	58.7	57.4
5–6 years post-Ph.D.	67.8	66.5	62.5	56.6	52.8	53.0	52.7	55.7
7–8 years post-Ph.D.	67.4	67.7	61.9	58.7	51.8	50.1	54.1	52.8
9–10 years post-Ph.D.	66.8	67.5	63.6	57.1	52.9	47.6	49.2	52.4
More than 10 years	62.7	64.1	63.6	61.1	56.9	49.8	51.1	50.5
				Industrial[b]				
Total employed	13.9	14.3	17.0	21.8	25.6	29.4	30.5	29.9
1–2 years post-Ph.D.	8.2	8.9	11.4	15.8	12.5	16.2	18.2	12.6
3–4 years post-Ph.D.	9.8	12.3	15.5	23.9	24.3	22.8	22.7	24.5
5–6 years post-Ph.D.	12.7	13.4	17.6	25.3	30.2	28.2	28.0	27.6
7–8 years post-Ph.D.	15.1	12.9	19.6	23.6	30.5	34.6	29.3	28.8
9–10 years post-Ph.D.	15.4	14.5	15.6	24.7	30.6	34.5	33.4	31.9
More than 10 years	17.0	17.1	18.2	21.1	25.6	31.1	33.4	33.0
				Government[b]				
Total employed	11.9	10.5	9.6	9.3	9.8	9.7	10.5	10.4
1–2 years post-Ph.D.	10.5	9.7	6.9	7.1	10.6	11.8	12.2	11.9
3–4 years post-Ph.D.	9.1	9.4	8.7	7.9	10.2	11.8	10.1	10.6
5–6 years post-Ph.D.	11.8	10.8	10.1	10.7	8.1	8.8	12.5	9.0
7–8 years post-Ph.D.	10.1	10.3	9.2	9.1	9.4	7.6	10.1	11.6
9–10 years post-Ph.D.	11.5	11.2	13.3	9.0	9.5	8.7	11.3	8.6
More than 10 years	13.7	10.9	9.6	9.8	10.0	9.6	10.0	10.5
				Other				
Total employed	7.7	9.0	8.7	8.8	7.8	9.6	6.1	6.5
1–2 years post-Ph.D.	10.8	9.5	9.5	12.6	8.9	11.5	7.2	6.5
3–4 years post-Ph.D.	8.6	13.2	7.6	11.0	8.0	10.1	8.5	7.4
5–6 years post-Ph.D.	7.7	9.4	9.8	7.5	8.8	10.1	6.8	7.7
7–8 years post-Ph.D.	7.3	9.1	9.3	8.6	8.3	7.8	6.6	6.8
9–10 years post-Ph.D.	6.4	6.9	7.5	9.2	7.0	9.2	6.2	7.0
More than 10 years	6.7	7.9	8.6	8.1	7.5	9.5	5.5	6.1

[a] See footnote to Table 3. [b] Percentages include postdoctoral associates. Source: National Research Council, Survey of Doctorate Recipients.

by U.S. institutions. Most of the growth in the number of Ph.D.'s has been the result of a rapid increase in the number of degrees awarded to non-U.S. citizens. Unemployment and measured underemployment for U.S. citizens, however, have been extremely low. Nonetheless, there have been some important changes in employment opportunities for U.S. Ph.D.'s in the biomedical sciences, including growth of jobs in industry while academic positions have remained stable.

Students and faculty should be made aware of the spectrum of jobs open to individuals with biomedical Ph.D.'s, and job expectations of predoctoral students and postdoctoral associates should be informed by the current trends in employment. Faculty mentors should encourage students to consider a wide range of employment goals, encouraging them to consider their individual interests and abilities. Our nation thrives on the creativity of its citizens, and challenging job opportunities exist in academia, industry, and other settings. Biomedical scientists should be encouraged to explore new areas and create new niches of employment where they can use their training in biomedical research. These recommendations are congruent with those of COSEPUP in its earlier report (3).

The data presented in this report reveal trends in biomedical Ph.D. numbers and job opportunities, but also raise questions for future discussions. For example, what changed and what forces were at play in

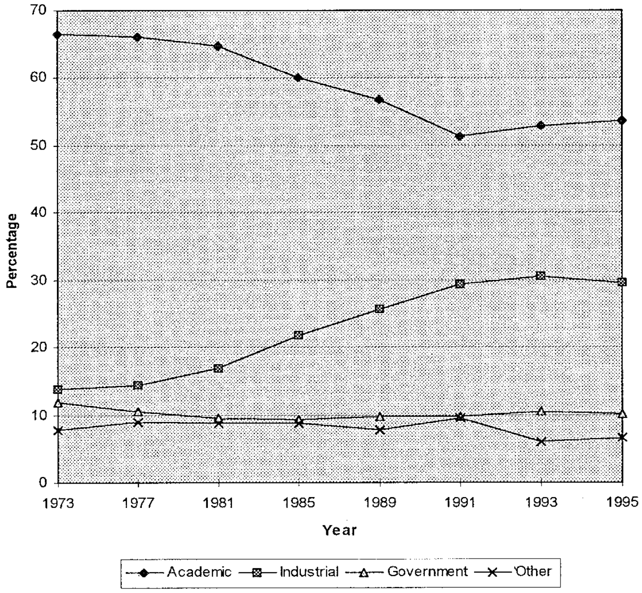

Figure 2. Percentage distribution of employed biomedical scientists, by sector (U.S. citizens): 1973–1995. Source: National Research Council, "Survey of Doctorate Recipients."

1982–1983 that led to the beginning of the continued rise in biomedical Ph.D. degrees conferred from 1988 onward? Financial resources are not infinite; when will the level of resources constrain increases in biomedical Ph.D. production? The data suggest that the workforce demand for research assistants is driving up the number of students accepted into biomedical Ph.D. programs. We believe that the selection of an applicant to graduate school should be based on past performance and potential for success rather than on institutional needs for research or teaching assistants. Alternate ways to fill workforce needs should be considered, and this will require more creative solutions.

Only 5% of biomedical Ph.D.'s are unemployed or underemployed, but there is a trend toward longer postdoctoral appointments. Does this trend reflect the abilities of the biomedical students entering the postdoctoral pool, making additional training necessary? Has the greater number of Ph.D.'s led to a decline in quality? Do longer periods of postdoctoral study reflect the limited employment options? Is the increased length of postdoctoral appointments due to an insufficient number of jobs that meet the expectations of individuals in this pool? Although there has not been appreciable change in the number of tenured and tenure-track jobs in academia, 'other' jobs in academia have increased, the nature of which deserves further analysis. Are these positions filled by senior postdoctorals with another title? What is the effect on academia of the lack of mandatory retirement? Are schools replacing tenured faculty who retire or leave with nontenure-track 'other' personnel to gain the flexibility of yearly contracts? The absolute number of tenured and tenure-track jobs has held constant, but there has been an increase in jobs in the industrial sector. Although the rise of the latter has leveled off, will it grow again?

We strongly reaffirm the conclusions and recommendations reached in collaboration with our colleagues in the recent FASEB report on graduate education (14). Historical trend data can be a useful guide, but many changes can occur during the 10-year period from the onset of predoctoral study to the completion of a postdoctoral. Therefore, applicants to Ph.D. programs should realize that the job market may look quite different when they are ready to enter it than it does when they begin graduate study. Research in the biomedical sciences is exciting. There is tremendous potential, but no one can predict the impact of biomedical research advances on the job market. Since future employment demand for biomedical Ph.D.'s cannot be determined precisely, it is inappropriate to limit the number of Ph.D.'s granted on the basis of guesses about the future job market. Adjustments should be made at the local level in the programs themselves; quality in predoctoral education should not be sacrificed for quantity. FJ

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