Foreign postdocs: the changing face of biomedical science in the U.S.

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Progress in biomedical research depends upon the intellectual and physical effort of talented scientists. In the U.S., the composition of this essential resource has undergone substantial change over the past three decades. Postdocs have become the largest segment of the workforce in biomedical science and in recent years, foreign postdocs have accounted for all of the growth in the postdoctoral population. This workforce has helped fuel our extraordinary progress in biomedical research, but over-reliance on a temporary workforce may have far-reaching, negative consequences for our research enterprise.

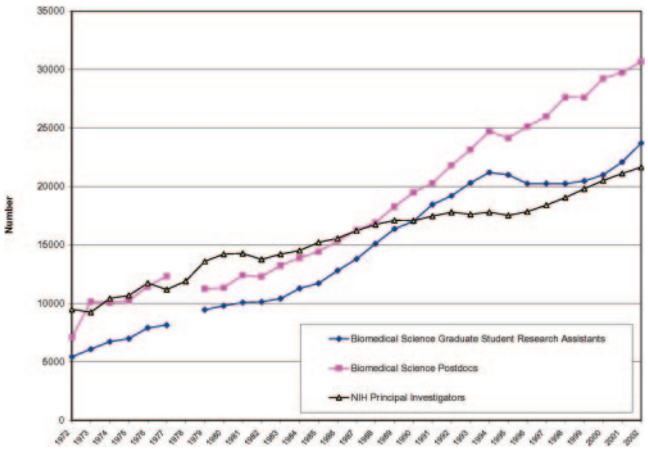

Figure 1. Biomedical science graduate research assistants, biomedical science postdocs and NIH principal investigators (1972–2002). Source: NSF-NIH survey of graduate students and postdoctorates; personal communication from Robert Moore, NIH.

Growth and change in composition of the workforce

The biomedical science (Note A) workforce has grown substantially over the past three decades (**Fig. 1**). Not surprisingly, this workforce growth parallels the increase in the NIH budget, as personnel costs are typically the largest budget item of NIH research grants. There has also been a change in the relative composition of the biomedical research workforce since 1972. In the early 1970s, the number of NIH principal investigators (PIs) was roughly equal to the number of biomedical postdocs and exceeded the number of biomedical graduate student research assistants (RAs) by more than 50%. From 1984 through 1994, the number of graduate student RAs and postdocs increased more rapidly than NIH PIs, and by 1994 the number of RAs exceeded the number of PIs by nearly 20%; the number of postdocs exceeded the number of PIs by almost 40% (Note B).

In 1972, there were 9492 NIH PIs holding one or more NIH grants. By 2002, the number of NIH PIs had more than doubled, reaching 21,643. During most of this period the expansion of the PI population was gradual, and for the past two decades the growth rate averaged 2% per year and exceeded 4% only twice. Even during the unprecedented "doubling" of the NIH budget (1998–2002), the annual growth rate for NIH PIs has averaged 3.3%.

While the number of NIH PIs doubled over the past three decades, the number of biomedical science graduate students paid as research assistants quadrupled, increasing from 5435 in 1972 to 23,697 in 2002. Unlike the steady growth in the number of NIH PIs, however, the graduate student RA population has undergone periods of both rapid and slow growth. Growth was greatest in the early 1970s and again in the late 1980s. During the period from 1984 through 1991, the average annual growth rate for graduate student RAs was 7.4%. In contrast, the population of graduate student RAs remained stable from 1995 through 2000, despite the increase in the NIH budget. The stabilization of the number of graduate student RAs in recent years cannot be viewed as the result of an increase in alternative funding sources for graduate students, as the number of predoctoral trainee and fellowship slots has not increased.

The population of biomedical postdocs also quadrupled during the past three decades, rising from 7097 in 1972 to 30,677 in 2002. For most of this period, the growth rate for biomedical postdocs was parallel to that for biomedical graduate student RAs. The growth patterns diverged sharply, however, in the late 1990s. While the population of both postdocs and graduate student RAs dropped in 1995, the postdoc population—unlike the graduate student RA population—

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continued to grow in each of the subsequent years. The overall growth in the postdoctoral population is especially notable considering the declining rate at which new U.S. biomedical Ph.D. recipients have been entering postdoctoral appointments immediately after earning their doctorates. This percentage decreased from 63% in 1995 to 54% in 2001 (1).

Increased dependence on foreign postdocs

Foreign postdocs on temporary visas are the fastest growing segment of the biomedical postdoc population (**Table 1**). Over a 25 year period, foreign scientists increased from 27% to 55% of the total postdoctoral pool. In 1977, there were 8967 U.S. postdocs (Note C) and 3372 foreign postdocs in the biomedical sciences at doctorate granting universities in the U.S. By 1992, foreign postdocs had reached numerical parity with U.S. postdocs. Rates of growth for U.S. and foreign postdocs were similar from 1992 through 1998. After 1998, however, the growth rates diverged again. The number of U.S. postdocs declined in two of the next four years, and by 2002 there were fewer of them than there were in 1998. In contrast, the number of foreign postdocs continued to increase during this period, and as a result foreign postdocs have accounted for all of the recent growth in the biomedical science postdoc population. By 2002, foreign postdocs outnumbered U.S. postdocs by 23% (16,890 to 13,787).

It appears that most of the increase in the number of foreign postdocs is comprised of individuals who earned their doctorate degrees in other countries and came to the U.S. to work. The expansion is not due to an increase in the number of foreign Ph.D. students or

TABLE 1. *Graduate Students, Doctorate Recipients from U.S. Schools, and Postdocs in the Biological and Medical Sciences (1972–2002) and NIH Principal Investigators*

	Biol. and Med. Sci. Grad Stds. (1)			Biological and Medical Sci. Ph.D. Recipients (2)					Biol. and Med. Sci. Postdocs (3)			
Year	US Citizens and Perm. Res.	Temp. Res.	R.A.s	U.S. Citizens and Perm. Residents	Temporary Residents	Unknown Citizenship	Total Known	Total	Temp. Res.	U.S. Citizen and Perm. Res.	Total	NIH PIs (4)
1972			5,435	3,370	336	92	3,706	3,798			7,097	9,492
1973			6,088	3,431	348	78	3,779	3,857			10,158	9,244
1974			6,725	3,151	386	182	3,537	3,719			10,063	10,423
1975			6,999	3,293	349	86	3,642	3,728			10,253	10,684
1976			7,911	3,364	353	108	3,717	3,825			11,441	11,740
1977			8,144	3,247	348	96	3,595	3,691	3,372	8,967	12,339	11,180
1978				3,324	325	96	3,649	3,745				11,914
1979			9,453	3,481	336	100	3,817	3,917	2,949	8,301	11,250	13,593
1980			9,801	3,656	345	81	4,001	4,082	3,157	8,185	11,342	14,215
1981			10,078	3,688	325	105	4,013	4,118	3,698	8,716	12,414	14,271
1982			10,135	3,696	395	125	4,091	4,216	3,637	8,665	12,302	13,762
1983			10,413	3,551	387	97	3,938	4,035	3,856	9,390	13,246	14,207
1984			11,282	3,674	415	135	4,089	4,224	4,249	9,649	13,898	14,524
1985			11,722	3,522	499	139	4,021	4,160	4,817	9,618	14,435	15,213
1986			12,804	3,500	469	205	3,969	4,174	5,442	9,917	15,359	15,569
1987			13,804	3,415	562	237	3,977	4,214	6,339	9,904	16,243	16,223
1988			15,108	3,618	642	264	4,260	4,524	6,958	9,955	16,913	16,739
1989			16,375	3,598	704	244	4,302	4,546	7,881	10,386	18,267	17,105
1990			17,026	3,694	977	106	4,671	4,777	8,795	10,700	19,495	17,069
1991			18,453	3,855	1,174	76	5,029	5,105	9,700	10,589	20,289	17,459
1992			19,198	3,912	1,333	86	5,245	5,331	10,782	11,020	21,802	17,799
1993			20,305	4,096	1,399	115	5,495	5,610	11,354	11,796	23,150	17,621
1994	47,590	14,666	21,200	4,504	1,200	63	5,704	5,767	12,144	12,558	24,702	17,802
1995	48,449	14,083	20,990	4,712	1,122	97	5,834	5,931	11,644	12,494	24,138	17,526
1996	47,686	13,428	20,245	4,759	1,403	134	6,162	6,296	12,376	12,759	25,135	17,842
1997	47,600	13,092	20,252	4,599	1,480	255	6,079	6,334	12,834	13,157	25,991	18,402
1998	48,156	13,508	20,243	4,717	1,490	219	6,207	6,426	13,454	14,167	27,621	19,046
1999	49,586	13,530	20,459	4,536	1,447	206	5,983	6,189	14,289	13,320	27,609	19,799
2000	48,428	14,232	20,987	4,719	1,549	250	6,268	6,518	15,622	13,609	29,231	20,510
2001	49,453	15,079	22,087	4,671	1,414	249	6,085	6,334	16,706	13,045	29,751	21,105
2002	52,471	16,962	23,697	4,519	1,485	360	6,004	6,364	16,890	13,787	30,677	21,643

1. National Science Foundation: NSF-NIH Survey of Graduate Students and Postdoctorates in S&E. Biological and Medical Sciences Graduate Students in Doctorate Granting Departments.

2. National Science Foundation; Survey of Earned Doctorates/Doctorate Records File.

3. National Science Foundation: NSF-NIH Survey of Graduate Students and Postdoctorates in S&E; Biological and Medical Sciences Postdoctorates in Doctorate Granting Departments.

4. Personal Communication from Robert Moore, NIH, December 22, 2004.

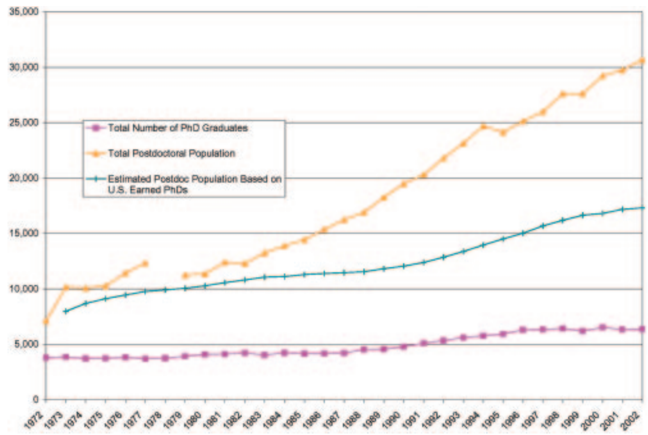

Figure 2. Biomedical Ph.D.s, number of biomedical postdocs, and estimated number of postdocs without foreign-earned doctorates. Source: NSF survey of earned doctorates/doctorate records file; survey of graduate students and postdoctorates, and authors' calculations.

their propensity to stay in the U.S. The number of U.S. biomedical Ph.D.s earned by foreign students is stable (Table 1) and is only one-tenth the size of the total foreign postdoc population. The fraction of foreign students remaining in the U.S. after earning Ph.D.s in the life sciences from U.S. schools (the "stay rate") has been relatively constant at ~75 percent (2). Thus, it is clear that the growth in the postdoctoral population cannot be attributed to an increased number of new U.S.-educated Ph.D. recipients and must reflect recruitment of doctorate-level scientists from abroad.

The extent of our dependence on doctorate-level scientists from abroad can be estimated using data from NSF surveys. In recent years, ~70% of the individuals earning biological science Ph.D.s from U.S. institutions had definite plans for postdoctoral positions (3). This percentage was similar for U.S. citizens, permanent residents, and temporary residents. In the biological sciences, the median time spent in postdoctoral positions is approximately four years (4). Assuming that these relationships for the biological sciences hold for the biomedical sciences as well, we can estimate the number of biomedical science postdocs who earned their doctorates at U.S. institutions from the NSF data on doctorates awarded by U.S. institutions. Comparing the estimated postdoctoral yield of U.S. institutions with the actual postdoctoral pool (**Fig. 2**), it is apparent that this estimated number currently comprises only one half of the entire postdoctoral population. The rest, we can safely assume, enter the U.S. postdoctoral marketplace with a doctorate earned outside the U.S.

DISCUSSION

Over the past three decades, the biomedical science workforce has grown steadily. There continues to be a strong demand for biomedical researchers, and the most rapid growth has been in the postdoc population. Since 1998, all of the growth in this group has been due to the increased number of foreign postdocs.

While foreign scientists now comprise the majority of the postdoctoral pool, there is no evidence that they are taking permanent jobs from U.S. citizens. For example, the percentage of medical school faculty with degrees earned in foreign countries has increased only slightly (5). From 1980 to 1984, 17.5% of the newly hired, full-time medical school faculty had one or more doctoral degrees from institutions outside the U.S. (H. Yamagata, personal communication, February 24, 2004). From 1995 to 1999, the comparable figure was 21.3%. A bigger constraint facing U.S. scientists seeking careers in academia, however, is the slow growth in number of faculty positions. At U.S. medical schools, which award approximately one-half of the nation's biomedical science Ph.D. degrees, the number of full-time basic science faculty with Ph.D. degrees rose by only 2499 in the period from 1980 to 1999 (6). Full-time Ph.D. faculty in clinical departments grew by 5,656 during the same time period. Moreover, the turnover of existing faculty positions has also slowed as attrition rates for Ph.D.s in both basic and clinical departments dropped from the early 1980s to the late 1990s.

Clearly, our progress in biomedicine is becoming increasingly dependent on foreign scholars with temporary visas. As a magnet for the best and brightest researchers from around the world, we have been enriched by their talent and productivity. A recent report of foreign scholars published by the National Academies concluded that, in order to maintain its dominance in science and technology, the U.S. must continue to recruit the best and brightest international students while continuing to improve the training of domestic students (7).

However, our ability to attract scholars from other nations may be changing. We are beginning to hear reports about increased international competition for students and researchers (8). Some European and Asian nations are beginning to increase their production of science and engineering doctorates (9) and this may already be having an effect on U.S. enrollments. Surveys conducted by the Council of Graduate Schools indicate that applications for graduate study from foreign students in the life sciences declined by 24% between 2003 and 2004 and by an additional one percent between 2004 and 2005 (10). The number of first-time foreign graduate student enrollments in the life sciences declined by 10% in 2004 (11). At the same time as the sizeable decline in first-time foreign graduate student enrollments, there has also been a modest decline (2%) in the number of first-time enrollments of U.S. students. Will the factors that led to the decline in foreign graduate students also erode the number for foreign postdocs? If the threat to our supply of talented foreign scientists materializes, we could lose a critical segment of our biomedical research workforce.

International collaborations and exchanges of scientific personnel are extremely valuable endeavors and must be preserved. Virtual dependence on foreign labor for any expansion in the biomedical science workforce, however, is an altogether different matter. Economist Richard Freeman suggests that changes in the global market for scientists and engineers are eroding U.S. dominance in research and development and our relative advantage in high tech industries (12). A concerted effort to boost the number of U.S. citizens entering the profession is one possible response, but this may not be an effective solution without strong steps to ensure rewarding career opportunities for highly trained scientists.

From the supply side, it is easy to appreciate why foreign scientists would want to work in the U.S. We are the world leader in biomedical science and, until recently, we have provided research opportunities that were not available in many other countries. Our position is still strong. For the time being, we are able to attract bright people from other nations who are looking for a way to advance their careers. For these individuals, the temporary status of a postdoc position is not a huge obstacle, and in comparison to wages in many other nations the salary may still be good.

For young U.S. scientists, the situation may not be as attractive. The long years of preparation are a drawback. Low pay and limited employment benefits are also a disincentive, especially as the length of training increases and in light of discouraging forecasts about the academic job market for biomedical Ph.D.s (13). A recent article listed academic research scientists as one of the "big jobs that pay badly" (14). Perhaps most discouraging for prospective U.S. scientists are the temporary nature of postdoctoral positions, the shortage of opportunities for permanent academic positions and the diminishing prospects for establishing an independent, funded research program. Efforts to reverse this trend, including those suggested in the National Academies' *Bridges to Independence Study*, deserve serious consideration (15).

Technological advances, increasingly complex research designs and interdisciplinary collaborations will increase the number of very large research projects. With the expansion of large-scale research projects in the biomedical sciences, the number of PIs will grow at a slower rate than the total number of scientists working in the field. If these team positions do not have an appropriate reward structure (salary, job security, benefits, professional respect, and opportunities to advance), then it will be even more difficult to recruit skilled individuals to fill them (16).

For the continued health of our biomedical research enterprise, we need to begin the transition to a laboratory staffing model that is capable of attracting and retaining our brightest young scientists. New models should include research technicians with bachelor's degrees and "non-replicating" staff scientists (17, 18). With the judicious employment of technicians, along with the proper balance of graduate students and postdoctoral researchers and staff scientists, we could have productivity, efficiency, and the foundations for future progress. Over-reliance on a mobile, temporary workforce of postdocs, most of who are from other countries, has huge risks for this nation. If left unchanged the situation will deteriorate, and the U.S. scientist will become a dangerously scarce resource. FJ

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NOTES:

A. In this paper, we use the standardized NSF definition for biological sciences and medical sciences fields and use the term "biomedical" interchangeably with the combined totals for biological sciences and medical sciences. "Biological sciences" include anatomy, biochemistry, biology, biometry/epidemiology, botany, biophysics, cell biology, ecology, entomology/parasitology, genetics, microbiology, immunology, and virology, nutrition, pathology, pharmacology, physiology, zoology, and biosciences not elsewhere classified. The "medical sciences" are comprised of anesthesiology, cardiology, endocrinology, gastroenterology, hematology, neurology, obstetrics and gynecology, oncology/cancer research, ophthalmology, otorhinolaryngology, pediatrics, preventive medicine/community health, psychiatry, pulmonary disease, radiology, surgery, and clinical medicine not elsewhere classified.

B. The RA and postdoc statistics are from the National Science Foundation Survey of Graduate Students and Postdocs and include individuals funded by any sponsor, federal or other. While NIH PIs do not represent all of the biomedical science PIs in the academic sector (a small number may be funded only by industry, other federal agencies or nonprofit foundations), NIH PIs clearly represent the "mainstream."

C. This figure includes both U.S. citizens and foreign citizens with permanent U.S. visas.

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