Responses to Changing Conditions for Doctorate Recipients and Post-doctoral Researchers in the U.S.

A Report to NEDO

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EXECUTIVE SUMMARY

This report focuses on the changing conditions that face doctorate recipients and post-doctoral researchers in science and engineering in the U.S. We use the term “post-doc” to mean either a post-doctoral fellowship or the individual who holds such an appointment.

Between 2001 and 2011 (the latest year for which data are available), the following three trends can be observed:

- The number of PhD scientists and engineers trained in the U.S. has grown steadily. For degrees in life sciences, physical sciences and engineering, the increase is 42.57 percent over this ten-year period.
- The number of researchers with post-doctoral fellowships has also grown dramatically, for reasons that are not entirely understood. Its increase is about 45% during the period.
- While the numbers of doctorate recipients have increased, the number of professor-level jobs in U.S. universities has not increased as much. As a result, a decreasing percentage of doctorate recipients find jobs as professors. In addition, some parts of U.S. industry have cut the number of scientists and engineers that they hire. This is particularly true in the American pharmaceutical industry. As result, young PhD recipients increasingly must look for other types of jobs.

While the decision to seek and accept a post-doc is an individual matter, there seem to be three types of motivational situations that apply:

- The “traditional” reason is to deepen or broaden their academic skills and knowledge.

- A second reason may be that other jobs, particularly jobs as professors or in corporate research laboratories, are not available. Thus a post-doc position may serve as a "bridge" or "buffer" between graduate school and, one hopes, a regular research job in later years.

- A third set of reasons may be that post-doctoral fellowships offer new PhDs valuable job flexibility, such as allowing an individual to remain at his or her university while a spouse finishes graduate school. Here, too, the fellowship serves as a "bridge" or "buffer," but the young PhD takes the position happily, for the flexibility it provides.

Whatever the motivation for a post-doc, the reality is that most recent doctorate recipients and post-dos face an uncertain employment situation. Less than one quarter of recent doctorate recipients obtain a regular university faculty position. Industry is decreasing its hiring of PhDs, particularly in the life sciences. Some analysts see the rise in post-docs as primarily a response to these employment phenomena. Few analysts expect the situation to ameliorate, given Federal budget cuts and changes in the climate for university education (e.g. on-line coursework) that may reduce the demand for new PhDs.

The changing circumstances of PhDs and post-docs over the last ten years have produced three main criticisms:

- Over at least the past 10 years, U.S. research universities have accepted more graduate students and given more PhDs than they should, given that there are not good jobs – particularly academic jobs – available for students who want them. This problem of "over-supply" is particularly serious in the life sciences.

- Post-doctoral fellowships can provide valuable apprenticeships, but they are often poorly compensated and poorly mentored. More specifically, many post-docs have low salaries and minimal benefits; and little career guidance for the next stage.

- Given that most doctoral recipients today will not have faculty positions, and may not want them, graduate programs should provide more training and more advice regarding non-academic positions, particularly in industry and government. Current career training, critics say, is poor. In addition, post-doctoral researchers should receive more training in the practical aspects of leading and running research programs.

These criticisms have been most fully explored in the life sciences in the report of a 2012 NIH "working group."

The challenges facing doctoral education and the post-doctoral experience in the U.S. have by no means gone unnoticed or unaddressed. Initiatives have been mounted by funding agencies, foundations, universities, private companies, professional associations, and students. They are of three main types:

- Those that broaden the horizons of graduate students to help them better prepare for careers other than traditional academic positions.
- Those that help make doctoral and post-doctoral students more employable by giving them a wider array of skills that are useful in the academic workplace.
- Those intended to improve the conditions of work for advanced students, especially for those in post-doctoral positions.

The following specific examples (discussed in more detail in the full text) are particularly worth noting.

- The Preparing Future Faculty (PFF) program
- Engineering Research Centers at NSF
- The Keck Graduate Institute Program in Applied Life Sciences
- Graduate Student Internships at the University of California, San Francisco

- The NIH training program in “responsible conduct of research.”
- The National Postdoctoral Association Postdoctoral Core Competencies Toolkit
- The NIH Biomedical Research Working Group
- The University of Southern California Office of Postdoctoral Affairs
- Formal post-doctoral programs in large industrial firms
- The Professional Science Master’s coordinated by the Council on Graduate Schools.

While these initiatives appear to be numerous, in fact, almost all of them are small in scale and scope. Most view the problem as a mismatch of skills and needs, and few propose major change. The NIH Working Group Report to the NIH Director was perhaps most candid in suggesting that the imbalance in the biomedical field might be addressed by shifting NIH financial support to universities toward greater use of full-time, non-faculty research staff and less dependence on graduate students and post-docs.

With few voices urging a slowing or reversal of graduate enrollment in science and engineering, an excess supply of PhDs and post-docs relative to demand is likely to continue.

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PREFACE

The study underlying this report was commissioned by the Washington, D.C., office of Japan's New Energy and Industrial Technology Development Organization (NEDO).

The report's authors, working together as the firm of Technology Policy International (TPI), have undertaken the study as independent consultants, although it should be noted that each has other professional affiliations and activities (see "About the Authors"). The opinions expressed in this report do not necessarily reflect the views of NEDO or the institutions with which the authors are affiliated.

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1. INTRODUCTION: OPPORTUNITIES FOR DOCTORATE RECIPIENTS AND POST-DOCTORAL RESEARCHERS

Holders of doctoral degrees represent an important resource for the progress of science and technology. Having been granted degrees at the highest level possible, these individuals operate at the forefront of new knowledge. Since most doctorate recipients are still young, their career trajectories will have impacts over a long period of years.

One common stage in the career of doctoral recipients is an immediate postdoctoral research appointment – typically called a "post-doc" in the U.S.[1] A post-doc position is an interim situation, allowing newly minted PhDs the chance both to build on the research that earned the degree and to make a first foray into professional life. In some fields – notably, the life sciences – post-doc jobs are routine. In others – such as most of the engineering disciplines – they are considerably less common. Post-docs may occur in universities, research institutes, or industry. They are generally assumed to be temporary appointments, with a limited term and purpose before the individual who has the post-doc proceeds to permanent, long-term employment.

The overall situation of PhDs and post-docs is not without controversy, either in the U.S. or Japan. While it is an undisputed fact that the number of

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[1] In the United States, the term "post-doc" can refer to either a post-doctoral fellowship (which is a type of research job) or to an individual who holds such an appointment (also known as a "post-doctoral fellow"). This report uses the term in both ways, although usually to refer to the fellowships themselves. The report uses the terms "doctorate recipient" or, more informally, "PhD" for someone who has received a PhD degree or another science and technology doctoral degree. Of course, post-doctoral fellows are also doctorate recipients, but not all PhDs in the U.S. take a post-doctoral position. Also, one can write either "post-doctoral fellow" with a hyphen between "post" and "doctoral" or "postdoctoral fellow" without a hyphen. This report uses the version with the hyphen, but some of the papers and articles quoted here use "postdoctoral."

PhDs and post-docs has grown considerably in the U.S. since 2000, it is far from clear whether this is a positive trend – either for society or for the degree-holders themselves. Some commentators even refer to a PhD "glut"[2] -- meaning a situation in which there may be too many PhDs overall, and especially in some fields, with consequent under-utilization of this highly-developed talent.

Irrespective of the quantity of PhDs, there is also the question of the appropriateness of their training. The patterns of academic life in PhD programs change very slowly – certainly more slowly than the progress of technology – sometimes producing doctoral recipients whose training may not correspond to societal needs. In particular, are universities training them well for the non-academic jobs that many of these young people will take? Some argue that there is a "mismatch" between what students are taught and the skills they need in industry and other non-academic institutions. While this "mismatch" of course raises issues for how academic institutions train doctoral students, it also casts the post-doc experience in a new light. That is, is it in fact a period when new PhDs can and should refocus their training and open new opportunities?

This issue – the relationship between the capabilities of doctoral recipients and post-docs and the needs of society, particularly in industry – is the focus of this report. The following chapters explore three different aspects of the PhD and post-doc situation in the U.S. today. First, in Chapter 2, we look at data that show trends in the numbers and employment of PhDs, as well as post-docs. Next, Chapter 3 explores the current criticisms of the American system of PhD education as well as post-doctoral fellowships. Chapter 4 offers some examples

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[2] See Jordan Weissmann, "The PhD Bust – American's Awful Market for Young Scientists," *The Atlantic*, February 20. 2013.

of ways these criticisms are being addressed in specific circumstances. In addition, Chapter 5 provides a brief conclusion.

2. DOCTORAL RECIPIENTS AND POST-DOCTORAL RESEARCHERS IN THE UNITED STATES

2.1 Chapter Introduction

This chapter provides data about the numbers of doctorate recipients and post-doctoral researchers in the U.S. It also provides data about the types of jobs these scientists and engineers receive.

This chapter makes three main points:

- The number of PhD scientists and engineers trained in the U.S. has grown steadily since 2000.
- The number of researchers with post-doctoral fellowships has also grown dramatically, for reasons that are not entirely understood.
- While the numbers of doctorate recipients have increased, the number of tenured and tenure-track jobs in U.S. universities has not increased as much. As a result, a decreasing percentage of doctorate recipients find jobs as professors. In addition, some parts of U.S. industry have cut the number of scientists and engineers that they hire. This is particularly true in the American pharmaceutical industry. As result, young PhD recipients increasingly must look for other types of jobs.

2.2 Growth in the Number of U.S. Doctorate Recipients

The number of doctorate recipients in the United States (individuals with PhDs or similar doctoral degrees) has risen in recent years.

In 2001, 40,744 people received doctorate degrees in the United States. Of these, 19,744 were in the fields of life sciences, physical sciences, and engineering. (The remaining awards were in the social sciences, education, and the humanities.) In 2011 – ten years later – 49,010 individuals received doctoral degrees, of which 28,149 were in life sciences, physical sciences, and engineering. So the number of doctoral degrees in these three areas of science and engineering grew by 42.57 percent – a large increase.[3]

Table 1 provides details about these degrees, as well as providing data back to 1981.[4]

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[3] National Center for Science and Engineering Statistics, National Science Foundation, "Science and Engineering Doctorates: 2011," 2013, http://www.nsf.gov/statistics/sed/2011/data_table.cfm.

[4] Some other NSF reports give a much larger number of "doctoral degrees" than those provided in Table 1. See, for example, Appendix table 2-27 in Science and Engineering Indicators 2012, which lists a total of 61,730 doctoral degrees earned in the U.S. in 2009. However, Appendix table 2-27 states, this larger number is based on an expanded definition of doctoral degrees: it includes medical doctors and lawyers ("doctor of jurisprudence") as well as PhD's and similar degrees. In this report, we use the traditional, narrow definition of doctorates.

TABLE 1. Doctorate recipients, by major field of study: Selected years, 1981–2011

Field of study	1981		1986		1991		1996		2001		2006		2011	
	Number	Percent	Number	Percent	Number	Percent	Number	Percent	Number	Percent	Number	Percent	Number	Percent
All fields	31,355	100.0	31,897	100.0	37,530	100.0	42,437	100.0	40,744	100.0	45,622	100.0	49,010	100.0
Life sciences	5,665	18.1	5,767	18.1	6,967	18.6	8,337	19.6	8,368	20.5	9,703	21.3	11,467	23.4
Agricultural sciences, natural resources	1,205	3.8	1,191	3.7	1,277	3.4	1,289	3.0	1,134	2.8	1,146	2.5	1,209	2.5
Biological, biomedical sciences	3,803	12.1	3,807	11.9	4,649	12.4	5,724	13.5	5,694	14.0	6,651	14.6	8,135	16.6
Health sciences	657	2.1	769	2.4	1,041	2.8	1,324	3.1	1,540	3.8	1,906	4.2	2,123	4.3
Physical sciences	4,116	13.1	4,772	15.0	6,244	16.6	6,592	15.5	5,866	14.4	7,464	16.4	8,678	17.7
Chemistry	1,612	5.1	1,903	6.0	2,194	5.8	2,149	5.1	1,982	4.9	2,364	5.2	2,439	5.0
Computer and information sciences	232	0.7	399	1.3	800	2.1	920	2.2	830	2.0	1,453	3.2	1,711	3.5
Earth, atmospheric, and ocean sciences	529	1.7	554	1.7	801	2.1	724	1.7	660	1.6	757	1.7	856	1.7
Mathematics	728	2.3	729	2.3	1,038	2.8	1,122	2.6	1,010	2.5	1,325	2.9	1,607	3.3
Physics and astronomy	1,015	3.2	1,187	3.7	1,411	3.8	1,677	4.0	1,384	3.4	1,565	3.4	2,065	4.2
Social sciences	6,317	20.1	6,082	19.1	6,378	17.0	7,053	16.6	7,025	17.2	7,125	15.6	8,120	16.6
Anthropology	369	1.2	381	1.2	341	0.9	397	0.9	410	1.0	472	1.0	555	1.1
Economics	824	2.6	859	2.7	885	2.4	1,008	2.4	927	2.3	1,029	2.3	1,124	2.3
Political science	445	1.4	414	1.3	434	1.2	622	1.5	658	1.6	616	1.4	686	1.4
Psychology	3,358	10.7	3,126	9.8	3,250	8.7	3,495	8.2	3,401	8.3	3,260	7.1	3,594	7.3
Sociology	605	1.9	491	1.5	465	1.2	517	1.2	566	1.4	579	1.3	656	1.3
Other social sciences	716	2.3	811	2.5	1,003	2.7	1,014	2.4	1,063	2.6	1,169	2.6	1,505	3.1
Engineering	2,528	8.1	3,375	10.6	5,213	13.9	6,308	14.9	5,510	13.5	7,186	15.8	8,004	16.3
Aerospace/aeronautical	97	0.3	118	0.4	206	0.5	287	0.7	202	0.5	238	0.5	261	0.5
Chemical engineering	296	0.9	476	1.5	621	1.7	681	1.6	636	1.6	799	1.8	826	1.7
Civil engineering	287	0.9	387	1.2	509	1.4	600	1.4	501	1.2	655	1.4	636	1.3
Electrical/electronics	0	0.0	705	2.2	1,206	3.2	1,501	3.5	1,346	3.3	1,786	3.9	1,891	3.9
Industrial/manufacturing	66	0.2	101	0.3	165	0.4	259	0.6	206	0.5	234	0.5	263	0.5
Materials science engineering	113	0.4	187	0.6	361	1.0	472	1.1	448	1.1	583	1.3	662	1.4
Mechanical engineering	282	0.9	442	1.4	762	2.0	947	2.2	878	2.2	1,045	2.3	1,084	2.2
Other engineering	1,387	4.4	959	3.0	1,383	3.7	1,561	3.7	1,293	3.2	1,846	4.0	2,381	4.9

Education	7,497	23.9	6,649	20.8	6,454	17.2	6,785	16.0	6,356	15.6	6,122	13.4	4,691	9.6
Education administration	1,659	5.3	1,638	5.1	1,913	5.1	2,165	5.1	2,077	5.1	2,051	4.5	926	1.9
Education research	3,168	10.1	2,725	8.5	2,354	6.3	2,699	6.4	2,637	6.5	2,751	6.0	2,453	5.0
Teacher education	639	2.0	490	1.5	408	1.1	371	0.9	296	0.7	250	0.5	205	0.4
Teaching fields	1,437	4.6	1,142	3.6	973	2.6	864	2.0	723	1.8	707	1.5	808	1.6
Other education	594	1.9	654	2.1	806	2.1	686	1.6	623	1.5	363	0.8	299	0.6
Humanities	3,575	11.4	3,271	10.3	3,872	10.3	4,884	11.5	5,385	13.2	5,326	11.7	5,214	10.6
Foreign language and literature	576	1.8	445	1.4	498	1.3	605	1.4	620	1.5	615	1.3	646	1.3
History	692	2.2	563	1.8	663	1.8	857	2.0	1,031	2.5	973	2.1	1,066	2.2
Letters	1,052	3.4	957	3.0	1,204	3.2	1,493	3.5	1,493	3.7	1,457	3.2	1,515	3.1
Other humanities	1,255	4.0	1,306	4.1	1,507	4.0	1,929	4.5	2,241	5.5	2,281	5.0	1,987	4.1
Other[a]	1,657	5.3	1,981	6.2	2,402	6.4	2,478	5.8	2,234	5.5	2,696	5.9	2,836	5.8
Business and management	624	2.0	902	2.8	1,163	3.1	1,279	3.0	1,064	2.6	1,311	2.9	1,328	2.7
Communication	240	0.8	258	0.8	332	0.9	389	0.9	390	1.0	510	1.1	651	1.3
Fields not elsewhere classified	793	2.5	821	2.6	907	2.4	810	1.9	780	1.9	871	1.9	857	1.7
Unknown field	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	4	*	0	0.0

* = value < 0.05%.

[a] Non-science and engineering fields not shown separately.

NOTES: Major field of study definitions are detailed in appendix A. Due to rounding, percentages may not sum to 100.

SOURCE: NSF, "Science and Engineering Doctorates: 2011," Table 12, http://www.nsf.gov/statistics/sed/2011/pdf/tab12.pdf

Data from NSF/NIH/USED/USDA/NEH/NASA, Survey of Earned Doctorates.

Why has the number of U.S. S&E doctoral awards increased so much since 2001? We do not fully know why. However, several factors are important.

First, U.S. universities depend heavily on graduate students to help conduct research, and some of the money in most federal research grants is used to hire and pay graduate-student research assistants. Therefore, if federal research funding increases, professors and their universities have an incentive to recruit and train larger numbers of graduate students. They need those students to help carry out their research. (In many large universities, graduate students also often become "teaching assistants" and help teach undergraduate students; this is another reason why many universities want large numbers of graduate students.)

In 2009, according to NSF, research assistantships were the primary mechanism for support for 40.1 percent of full-time engineering graduate students and 29.0 percent of full-time graduate students in the natural sciences.[5]

If the amount of research money for universities increases, it is likely that the number of research assistantships offered by professors will also increase. And between 1999 and 2009, for example, the amount of academic R&D expenditures increased in real (that is, inflation-adjusted) terms – especially in biology and medicine. See Figure 1, below.

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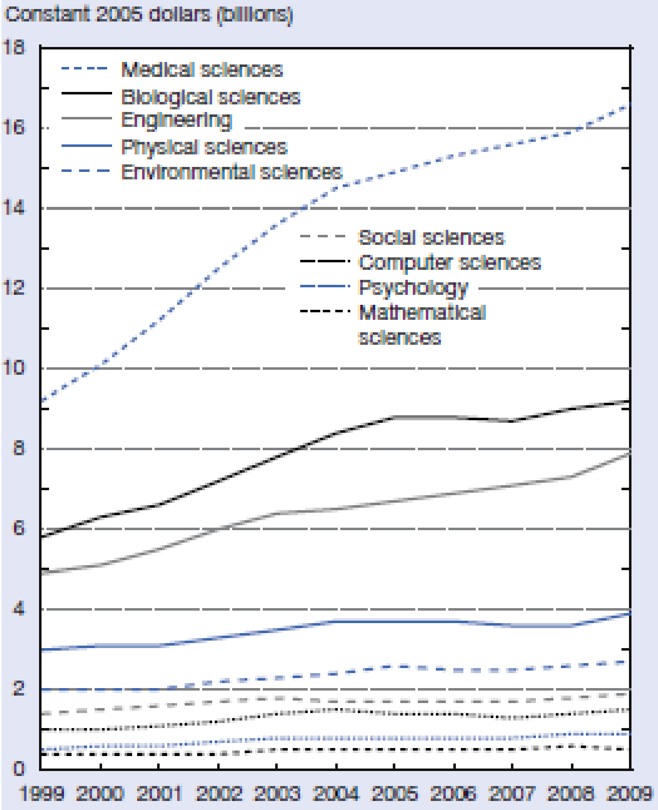
[5] National Science Board, National Science Foundation, *Science and Indicators 2012,* Appendix table 2-5. In U.S. universities, more doctoral students are supported by research assistantships than by fellowships or by traineeships or by teaching assistantships. Many students, a third or more, provided their own support, through their savings, loans, or family contributions.

Figure 1

Academic R&D expenditures, by S&E field: 1999–2009



NOTE: See appendix table 4-1 for gross domestic product implicit price deflators used to convert current dollars to constant 2005 dollars.

SOURCE: National Science Foundation, National Center for Science and Engineering Statistics, Survey of Research and Development Expenditures at Universities and Colleges. See appendix table 5-6.

Science and Engineering Indicators 2012

Given that academic research funding rose in the 2000's and given that U.S. academic research depends heavily on graduate students, it is reasonable to assume that universities wanted to increase the number of doctoral students during that decade.

Second, the number of U.S. young people interested in science and engineering has apparently also increased. In particular, more U.S. women and "under-represented minorities" (blacks, Hispanics, and American Indians/Alaska

Natives) are going to graduate school than in previous decades. NSF gives this summary about women: "The number of U.S. citizen and permanent resident women earning doctorates in S&E increased from 8,700 in 2000 to 15,000 in 2009, while the number earned by men increased from 10,700 to 12,800 in the same time interval…."NSF also reports that individuals from under-represented minorities accounted for 7 percent of all S&E doctorates earned in 2009, up from 6 percent in 2000.[6] More women and minorities apparently see science and engineering as good occupations and perhaps also have a greater opportunity than in the past to attend graduate school.

Along with U.S. women and minorities, the number of foreign graduate students has also increased. NSF provides this summary:

> Foreign students earned 57% of all engineering doctorates [in 2009], 54% of all computer science degrees, and 51% of physics doctoral degrees. Their overall share of S&E degrees was one-third.
>
> After a 64% growth from 2002 to 2008, the number of temporary residents [that is, foreign students with temporary visas] earning S&E degrees declined by about 4% in 2009, to 13,400.[7]

All of these points discussed above lead to an overall conclusion: it is likely that a combination of faculty wanting more doctoral students and more young interested in studying S&E accounts for the increase in the number of U.S. doctorate degrees in science and engineering over the past decade. Whether or not jobs exist for all of these doctorate recipients is another question – one discussed later in this chapter.

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[6] *Science and Engineering Indicators 2012,* page 2-27.

[7] *Science and Engineering Indicators 2012,* page 2-5.

2.3 Growth in the Number of U.S. Post-doctoral Researchers

The number of post-doctoral fellows at U.S. universities has also increased greatly over the past decade. If one uses a broad definition of post-doctoral researchers – one that includes medical doctors as well as scientists and engineers – then the total number of post-docs at U.S. universities was 66,415 in 2010. However, excluding medical doctors and related health professionals the total number of academic science and engineering post-docs that year was 44,051. This was approximately a 45 percent increase over 2000. Of the 44,051, 20,419 were U.S. citizens or permanent residents and 23,632 (53.6 percent) were foreign researchers (that is, individuals with temporary visas). Not all of the foreign researchers had received their doctoral degrees in the United States; many received degrees in their home countries.[8]

Table 2, from NSF, provides additional details about these university post-doctoral researchers.

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[8] National Center for Science and Engineering Statistics, National Science Foundation, “Graduate Enrollment in Science and Engineering Grew Substantially in the Past Decade but Slowed in 2010,” NSF 12-317, May 2012.

TABLE 2. POST-DOCTORAL APPOINTEES IN SCIENCE, ENGINEERING, AND HEALTH FIELDS BY SEX, CITIZENSHIP, AND FIELD: 2000–10

													% change	
Characteristic	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007 old**[a]	**2007 new**[a]	**2008**	**2009**	**2010**[b]	**2000 –10**[c]	**2009 –10**
All survey fields	43,115	43,311	45,034	46,728	47,240	48,555	49,343	50,712	50,840	54,164	57,805	63,415	45	9.7
Science and engineering	30,224	30,196	31,937	33,666	34,065	34,456	34,887	35,894	36,223	38,203	40,804	44,051	45	8.0
Male	21,296	20,941	21,807	22,882	23,080	23,227	23,361	24,412	24,631	25,119	26,647	28,752	35	7.9
Female	8,928	9,255	10,130	10,784	10,985	11,229	11,526	11,482	11,592	13,084	14,157	15,299	70	8.1
U.S. citizens and permanent residents	12,627	12,073	13,524	13,542	13,969	14,078	14,111	14,903	15,107	16,274	18,175	20,419	60	12.3
Temporary visa holders	17,597	18,123	18,413	20,124	20,096	20,378	20,776	20,991	21,116	21,929	22,629	23,632	35	4.4
Science	26,911	27,044	28,371	29,856	30,116	30,290	30,245	30,986	31,281	32,741	34,388	37,095	40	7.9
Agricultural sciences	822	833	963	1,054	959	1,007	927	948	985	1,147	1,083	1,195	45	10.3
Biological sciences	16,734	17,032	17,640	18,625	18,716	18,747	18,807	19,218	19,109	19,827	20,159	21,537	30	6.8
Computer sciences	344	336	356	355	384	406	467	516	456	493	594	748	115	25.9
Earth, atmospheric, and ocean sciences	1,155	1,049	1,129	1,182	1,263	1,364	1,495	1,322	1,250	1,339	1,424	1,760	50	23.6
Mathematical sciences	385	353	395	449	468	500	579	621	624	723	737	756	95	2.6
Physical sciences	6,270	6,223	6,619	6,829	7,059	7,011	6,703	6,760	6,719	6,885	7,447	7,703	25	3.4
Psychology	730	809	815	960	902	884	873	1,106	1,088	1,077	1,219	1,077	50	-11.6
Social sciences	471	409	454	402	365	371	394	495	483	508	561	646	35	15.2
Other sciences[a,d]	ne	ne	ne	ne	ne	ne	ne	ne	567	742	1,164	1,673	-	43.7
Engineering	3,313	3,152	3,566	3,810	3,949	4,166	4,642	4,908	4,942	5,462	6,416	6,956	110	8.4
Aerospace engineering	111	128	140	141	141	153	165	178	178	154	168	191	70	13.7
Architecture[a]	ne	ne	ne	ne	ne	ne	ne	ne	5	11	22	10	-	-54.5
Biomedical engineering	220	262	284	388	425	477	591	640	640	710	960	1,036	370	7.9
Chemical engineering	703	574	758	686	689	702	735	758	790	880	1,084	1,092	55	0.7
Civil engineering[a]	295	268	342	300	313	384	458	419	417	465	535	570	95	6.5
Electrical engineering	525	436	613	646	654	689	721	885	884	987	1,025	1,097	110	7.0
Industrial engineering	48	21	43	45	50	51	51	73	71	115	109	163	240	49.5
Mechanical engineering	480	501	441	543	514	562	644	725	722	784	948	1,009	110	6.4
Metallurgical/materials engineering	507	479	507	539	567	578	571	555	564	605	758	835	65	10.2
Other engineering	424	483	438	522	596	570	706	675	671	751	807	953	125	18.1

Health	12,891	13,115	13,097	13,062	13,175	14,099	14,456	14,818	14,617	15,961	17,001	19,364	50	13.9
Clinical medicine[a,e]	11,555	11,663	11,582	11,445	11,477	12,323	12,584	12,805	12,472	13,837	14,601	16,610	45	13.8
Other health	1,336	1,452	1,515	1,617	1,698	1,776	1,872	2,013	2,145	2,124	2,400	2,754	105	14.8

ne = not eligible; data were not collected for this field before 2007. - = not calculable.

[a] In 2007 survey was redesigned and five fields were added or reclassified to improve reporting. 2007new shows data as collected in 2007; 2007old shows data as they would have been collected in prior years. Due to methodological changes, counts should be used with caution for trend analysis. See http://www.nsf.gov/statistics/nsf10307/ for more detail.

[b] In 2010 postdoc section of survey was expanded and significant effort was made to ensure that appropriate personnel were providing postdoc data (see http://www.nsf.gov/statistics/gradpostdoc/ for more detail). As a result, it is unclear how much of increase reported in 2010 represents growth in postdoctoral appointments and how much results from improved data collection. More information will be forthcoming on improved data collection and changes in postdoc data.

[c] "% change 2000–10" shows growth from 2000 to 2010 and is rounded to nearest 5% to reflect potential imprecision of this estimate due to methodological changes in 2007.

[d] Includes communication, family and consumer sciences/human sciences, neuroscience, and multidisciplinary/interdisciplinary studies. These fields were added in 2007, although some programs reported within them had been reported prior to 2007 within other fields.

[e] Includes postdoctoral appointees in anesthesiology, cardiology, endocrinology, gastroenterology, hematology, neurology, obstetrics/gynecology, oncology/cancer research, ophthalmology, otorhinolaryngology, pediatrics, preventive medicine/community health, psychiatry, pulmonary disease, radiology, surgery, and clinical medicine, not elsewhere classified.

SOURCE: National Center for Science and Engineering Statistics, National Science Foundation, “Graduate Enrollment in Science and Engineering Grew Substantially in the Past Decade but Slowed in 2010,” NSF 12-317, May 2012, Table 3, http://www.nsf.gov/statistics/infbrief/nsf12317/.

Data from National Science Foundation/National Center for Science and Engineering Statistics, NSF-NIH Survey of Graduate Students and Postdoctorates in Science and Engineering.

Industry and non-profits also offer some post-doctoral fellowships, but not in large numbers.[9]

Why has the number of U.S. university post-doctoral researcher positions increased so much in recent years? NSF says that the answer is not clear:

> Neither the reasons for this growth nor its effect on the health of science are well understood. Increases in competition for tenure-track academic research jobs [that is, jobs as university professors], collaborative research in large teams, and need for specialized training are possible factors explaining this growth….
>
> Among holders of U.S. SEH [science, engineering, and health] doctorates received before 1972, 31% reported having had a postdoc position earlier in their careers…. This proportion has risen over time to 46% among 2002-05 graduates and has increasingly involved fields in which, formerly, only a small number of doctorate recipients went on to postdoc positions. In traditionally high-postdoc fields such as the life sciences (from 46% to 60% [before 1972 to 2002-05]) and the physical sciences (from 41% to 61%), most doctorate recipients now have a postdoc position as part of their career path. Similar increases were found in mathematical and computer sciences (18% to 30%), and engineering (14% to 38%)….
>
> In 2006, former postdoc position holders reported reasons for accepting their appointment that are consistent with the traditional intent of a postdoc position as a type of apprenticeship…. However, 10% of [survey] respondents in a postdoc position in October 2008 reported that they took their current postdoc position because "other employment was not available…."
>
> In 2006, most former postdocs reported that their most recent postdoc appointment had enhanced their career opportunities….[10]

This discussion from NSF focuses on why recent doctorate recipients might want to take post-doctoral positions. The recession that began in 2008 might also help explain why young PhDs in recent years have sought these

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[9] We can find no recent report that provides data about the number of industrial post-doctoral fellowships in the United States. Anecdotal evidence suggests that the numbers are small – although, as Chapter 4 of this report shows, some companies continue to offer these fellowships.

[10] *Science and Engineering Indicators 2012,* pages 3-36 to 3-39.

positions. In addition, it is possible that as federal research funding rose in the 2000's, professors running laboratories wanted post-docs as well as graduate students to help them carry out their research projects. So professors may have offered more post-doctoral positions than in the past.

2.4 A Further Look at Why Young Doctorate Recipients Seek Post-doctoral Appointments

2.4.1 Three Situations

As the NSF statement on the previous page says, no one knows for certain why so many young PhDs now seek and accept post-doctoral fellowships. But three sets of reasons seem particularly important:

- The "traditional" reason is to deepen and/or broaden their academic skills and knowledge.
- A second reason may be that other jobs, particularly jobs as professors or in corporate research laboratories, are not available. Thus a post-doc position may serve as a "bridge" or "buffer" between graduate school and, one hopes, a regular research job in later years.
- A third set of reasons may be that post-doctoral fellowships offer new PhDs valuable job flexibility, such as allowing an individual to remain at his or her university while a spouse finishes graduate school. Here, too, the fellowship serves as a "bridge" or "buffer," but the young PhD takes the position happily, for the flexibility it provides.

This section of the report examines each of these situations and presents relevant data, when data are available.

2.4.2 Additional Points about the Traditional Post-doctoral Experience

Traditional reasons for taking a post-doctoral fellowship include the following:

- Deepening the new PhD’s knowledge and skills in the field of the doctoral degree.
- Broadening the new PhD’s range of scientific or engineering knowledge through engagement in research in a field different from the doctoral degree field.
- Giving the new PhD a range of experiences in research leadership, self-direction, scientific communication, and teaching others that prepares him or her to assume the responsibilities of an independent faculty investigator in a tenure-track position.
- Providing a “new culture” to PhDs who, during the course of their graduate work, have discovered that they have interests other than academic research, in such areas as business, entrepreneurship, public policy, and international affairs.

Each of these purposes is intended to open new horizons to the recent PhD and to strengthen his or her base of professional skills.

The first two purposes listed above, in particular, have been the principal rationale for societal and personal investment in post-doctoral education and training. New PhDs who are motivated by these purposes have typically been among the top performers in their graduate programs. They have often been on the “fast track” to prestigious academic appointments in leading universities. Generally, these top performers have sought post-doctoral appointments under the mentorship of the leading academics in their chosen field, whether it is the field of their doctorate or an entirely new field. This kind of post-doctoral experience has been a feature of academia in Europe and North America for decades.

As research has become increasingly interdisciplinary, a post-doctoral appointment is not only a way to deepen an individual's skills and knowledge in his or her principal field but also as an effective way for students to develop a second field of recognized strength in such hybrid fields as bio-informatics, chemical-physics, or aero-chemical engineering.

The latter two of the traditional purposes—professional skills development and a "new culture" —have emerged more recently in the West. They are concerned less with strengthening the doctoral graduate's array of "hard" skills in the sciences, *per se,* and more with strengthening the "soft" skills that are increasingly recognized as being central to high performance and success, not only in careers in business or the public sphere, but even in academia itself.

Some anecdotal evidence suggests that recently post-doctoral positions have become not only a way to deepen skills but also a kind of "test" to see if young PhDs can show themselves to be successful academic researchers. Post-doctoral fellows who show that they can design and conduct new research projects, help train students, and – very importantly – get their own research grants demonstrate that they would make successful professors, thus increasing their chances of getting regular faculty jobs. There are no quantitative data on this phenomenon, but it may be one reason why even engineering PhDs increasingly take post-doc positions.

2.4.3 Additional Points about Which Jobs Are and Are Not Available to Young Doctorate Recipients

The second situation that may lead young PhDs to seek and accept post-doc positions is to get temporary professional employment when they have not been able to locate a satisfactory permanent position, owing either to short-term dislocations in the employment market or to long-term imbalances of supply and demand for doctoral degree holders in academia, industry and government laboratories.

Many of the foreign students who earn S&E doctorates in the United States return to their home countries after completing their studies. However, how often do those doctorate recipients – U.S. citizens, permanent residents, and foreigners – who remain in the United States find jobs and the jobs they want and were trained for?

U.S. political leaders and various organizations sometimes say that the United States needs to increase its supply of "STEM" professionals – individuals in science, technology, engineering, and mathematics. But in fact the growing numbers of S&E doctorate recipients find themselves competing for a limited number of jobs, particularly jobs as university professors.

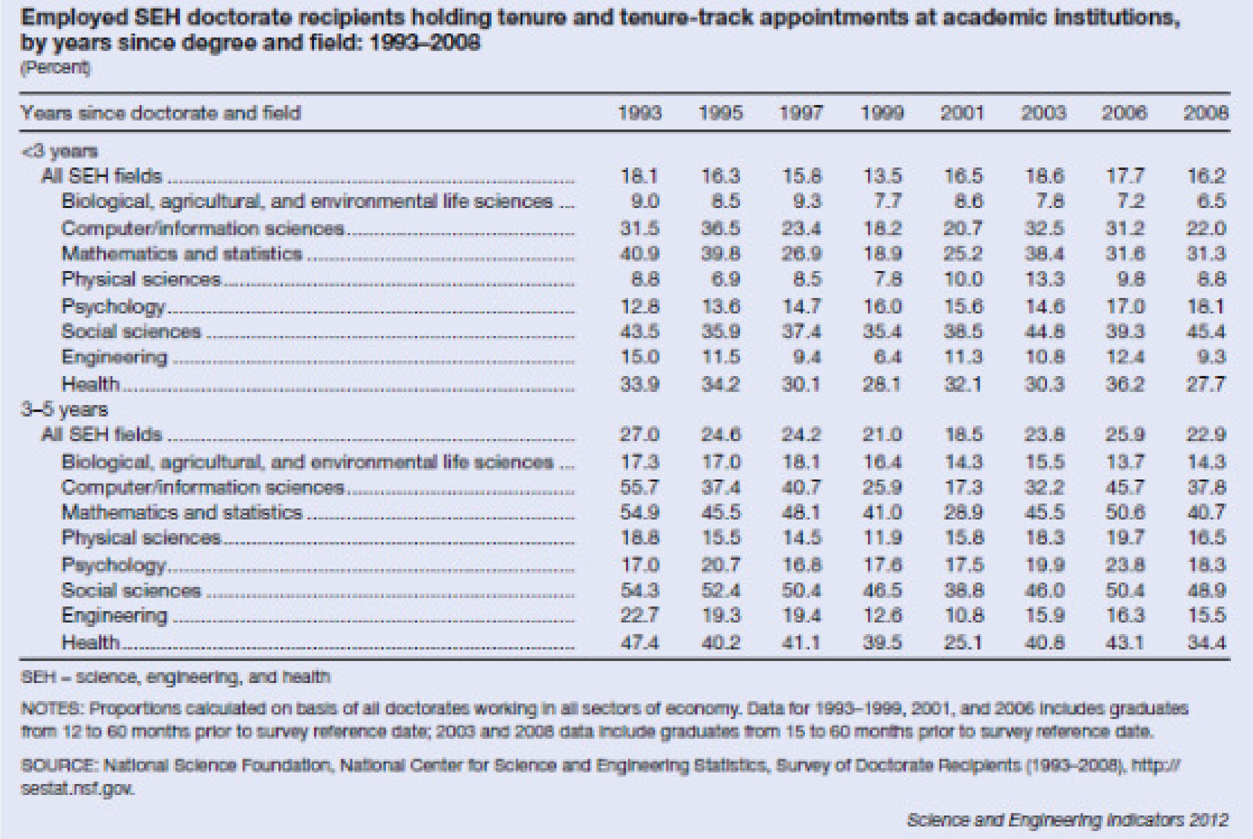
NSF reports that relatively few doctorate recipients receive a regular faculty appointment – either what we call a "tenure-track job" (typically an assistant professor job that offers the possibility of a permanent faculty position) or a tenured job (typically an associate or full professor with a permanent position).

> In 2008, the proportion of SEH [science, engineering, and health] doctorates with tenure or tenure-track appointments who were less than 3

> years [after] completing their doctorate was 16.2%; for those who had been in the labor market for 3 to 5 years, the comparable rate was 22.9%.[11]

That means that less than one quarter of recent doctorate recipients have a regular university faculty position. Of course, not every doctorate recipient wants an academic job, but many do. Table 3 (Table 3-20 in *Science and Engineering Indicators 2012*) provides additional details. Note that in 2008 the percentage of doctorate recipients who had tenured or tenure-track academic positions three to five years after they received their degrees was particularly low in the biological, agricultural, and environmental life sciences (14.3 percent).

Table 3



Employed SEH doctorate recipients holding tenure and tenure-track appointments at academic institutions, by years since degree and field: 1993–2008

(Percent)

Years since doctorate and field	1993	1995	1997	1999	2001	2003	2006	2008
<3 years								
All SEH fields	18.1	16.3	15.8	13.5	16.5	18.6	17.7	16.2
Biological, agricultural, and environmental life sciences	9.0	8.5	9.3	7.7	8.6	7.8	7.2	6.5
Computer/information sciences	31.5	36.5	23.4	18.2	20.7	32.5	31.2	22.0
Mathematics and statistics	40.9	39.8	26.9	18.9	25.2	38.4	31.6	31.3
Physical sciences	8.8	6.9	8.5	7.8	10.0	13.3	9.8	8.8
Psychology	12.8	13.6	14.7	16.0	15.6	14.6	17.0	18.1
Social sciences	43.5	35.9	37.4	35.4	38.5	44.8	39.3	45.4
Engineering	15.0	11.5	9.4	6.4	11.3	10.8	12.4	9.3
Health	33.9	34.2	30.1	28.1	32.1	30.3	36.2	27.7
3–5 years								
All SEH fields	27.0	24.6	24.2	21.0	18.5	23.8	25.9	22.9
Biological, agricultural, and environmental life sciences	17.3	17.0	18.1	16.4	14.3	15.5	13.7	14.3
Computer/information sciences	55.7	37.4	40.7	25.9	17.3	32.2	45.7	37.8
Mathematics and statistics	54.9	45.5	48.1	41.0	28.9	45.5	50.6	40.7
Physical sciences	18.8	15.5	14.5	11.9	15.8	18.3	19.7	16.5
Psychology	17.0	20.7	16.8	17.6	17.5	19.9	23.8	18.3
Social sciences	54.3	52.4	50.4	46.5	38.8	46.0	50.4	48.9
Engineering	22.7	19.3	19.4	12.6	10.8	15.9	16.3	15.5
Health	47.4	40.2	41.1	39.5	25.1	40.8	43.1	34.4

SEH = science, engineering, and health

NOTES: Proportions calculated on basis of all doctorates working in all sectors of economy. Data for 1993–1999, 2001, and 2006 includes graduates from 12 to 60 months prior to survey reference date; 2003 and 2008 data include graduates from 15 to 60 months prior to survey reference date.

SOURCE: National Science Foundation, National Center for Science and Engineering Statistics, Survey of Doctorate Recipients (1993–2008), http://sestat.nsf.gov.

Science and Engineering Indicators 2012

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[11] *Science and Engineering Indicators 2012,* page 3-36.

Is industry hiring large numbers of young doctorate recipients? This answer seems to vary among different fields in science and engineering. Here, too, the situation is particularly dire for young PhD recipients in the life sciences. A 2011 article in *Nature* summarizes the situation: "The problem is most acute in the life sciences, in which the pace of PhD growth is biggest, yet pharmaceutical and biotechnologies industries have been drastically downsizing in recent years."[12]

Another news article cites a report that says that since the year 2000 U.S. pharmaceutical firms have slashed 300,000 jobs. These cuts affect chemists as well as biologists. The article adds this point:

> Although the overall unemployment rate of chemists and other scientists is much lower than the national average, those figures mask an open secret: Many scientists work outside their chosen field.
>
> "They'll be employed in something," said Michael S. Teitelbaum, a senior advisor to the Alfred P. Sloan Foundation who studies the scientific workforce. "But they go and do other things because they can't find a position that they spent their 20s preparing for."

The article does say that physicists and physicians have lower unemployment levels than other scientists.[13]

Therefore, the very rapid growth in post-doctoral appointments in recent years can be seen as a mechanism through which the sciences and engineering, especially the life sciences, have dealt with the problem of an excess supply of new PhDs relative to demand for them in the workforce.

And this problem may get worse in the future. While the science and engineering faculties of U.S. colleges and universities have not recently experienced the declining roles of full-time faculty that has been the norm in the

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[12] David Cyranoski, et al., "The PhD Factory," *Nature,* Vol 472, 276-279, 21 April 2011.

[13] Brian Vastag, "U.S. pushes for more scientists, but the jobs aren't there," *The Washington Post,* July 7, 2012.

humanities and social sciences over the past few decades, those faculties now face a new and potentially much more serious competitor in the rapid emergence of on-line university courses and degrees. This mode of education may be especially well-matched to the skills-based offerings of engineering and applied sciences curricula, and this may further undercut job opportunities for new PhDs in these fields in academia. When combined with budget-inspired cuts in federal research funds for universities and government laboratories in fiscal year 2013 and likely in years ahead, the job prospects for new U.S. PhDs in R&D in every sector are bleak indeed.

2.4.4 Post-doctoral Positions That Provide Job Flexibility

However, it also true that post-doctoral positions can sometimes offer young PhDs employment flexibility that they like and prefer. In particular, post-docs can be attractive for three reasons.

First, post-doc positions can provide temporary and valuable employment for young people who have completed their PhDs but must wait several months before they can begin tenure-track positions.[14] In these cases, an individual may ask for short-term, "informal" post-docs in his or her professor's laboratory, until the time comes to apply for or start a regular job.

Second, post-doc positions can also help recent PhDs who do not want to move immediately away from their graduate schools because of family concerns. For example, there are individuals whose spouses or "significant others" have not yet completed their own academic degrees, so the new PhDs want to remain where they are and yet do work that is productive and worthwhile. So they will

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[14] In the U.S. system, new faculty members typically start their positions at the beginning of the academic year, but it is customary for students to complete their doctoral studies at any time of the year.

seek regular post-doc appointments or informal, short-term positions until their spouses are ready to enter the job market. Or the spouse might have a local job that he or she wants to keep for an additional year or two.

Finally, anecdotal evidence suggests that some people like the job of being a full-time professional researcher. Even though many post-doc positions pay low salaries, some positions do offer good pay and benefits and give PhDs the opportunity to become valued and productive members of research teams. They may not only design and conduct research projects but may also enjoying supervising graduate students. Some post-docs find this kind of life very satisfying and are willing to work in academia as full-time research scholars. At some institutions, it is increasingly difficult to draw the line between post-doctoral students and full-time non-teaching research staff.

Any particular post-doctoral program or activity may be driven by a mix of the purposes discussed above; for example, one way to deal with the mismatch of supply and demand for PhDs in a certain field is to help them develop additional skills in a more marketable field by offering post-doctoral opportunities in the second field. Similarly, recent PhDs who have developed broader personal horizons during their time in graduate school may be grateful for post-doctoral opportunities in industry, in policy-making agencies of government, or even in teaching children in schools.

It will help us understand and appreciate the different sorts of initiatives in post-doctoral education and training programs discussed in Chapter 4 if we keep in mind the disparate purposes of such programs.

2.5 Problems That Lead to Criticisms

These problems – the large numbers of new doctorate recipients, the difficulties many face in getting academic jobs, job cuts in some parts of industry, and the possibility that some people take post-doctoral positions because they cannot get other jobs – have led some observers to criticize the way in which the United States trains graduate students and treats post-doctoral researchers. These criticisms are discussed in the next chapter of this report.

3. CRITICISMS OF U.S. GRADUATE EDUCATION AND POST-DOCTORAL POSITIONS

3.1 Chapter Introduction

The U.S. system for training doctoral students is generally seen as a great strength for America. U.S. research universities produce well-trained young people who have world-class skills and knowledge and can conduct their own scientific and engineering research. The fact that so many foreign students want to come to the United States for graduate training and post-doctoral fellowships is one indication of how good the system is.

However, the problems discussed in Chapter 2 have led some analysts to make three related criticisms of how the current system trains doctoral students in science and engineering and treats post-doctoral researchers. This chapter summarizes the three criticisms. The next chapter discusses some current and proposed initiatives that try to help.

These are the three main criticisms, although not all critics agree with all three points:

- Over at least the past 10 years, U.S. research universities have accepted more graduate students and given more PhDs than they should, given that there are not good jobs – particularly academic jobs – available for students who want them. This problem of "over-supply" is particularly bad in the life sciences.
- Post-doctoral fellowships can provide valuable apprenticeships, but they are often poorly paid and poorly mentored.
- Given that most doctoral recipients today will not have faculty positions, and may not want them, graduate programs should provide more training and more advice regarding non-academic

> positions, particularly in industry and government. Current career training, critics say, is poor. In addition, post-doctoral researchers should receive more training in the practical aspects of running research programs.

3.2 Is the U.S. Training Too Many Doctoral Students?

The *Nature* article cited earlier contains a comment that is representative of those analysts who believe that the U.S. is training more doctorate recipients than the number of good jobs available for them:

> To Paula Stephan, an economist at Georgia State University in Atlanta who studies PhD trends, it is "scandalous" that US politicians continue to speak of a PhD shortage. The United States is second only to China in awarding science doctorates … and production is going up. But Stephan says no one should applaud this trend, "unless Congress wants to put money into creating jobs for these people rather than just creating supply."[15]

As discussed earlier in this report, part of the problem is that the number of doctoral students and PhD recipients in STEM fields in the United States is largely based on the numbers of research assistants and teaching assistants that university departments want. The numbers of students they recruit are not based on estimates of how many jobs are available for the students who complete their degrees.[16] And in the 1900's and early 2000's, university research budgets in the United States were growing – giving universities an incentive to recruit and train more students. At the same time, though, it is not accurate to say that universities are solely to blame for this situation. For example, there were also many students who wanted to enter graduate school, including women and minority students who saw that S&E careers were more open to them than in past decades. What

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[15] David Cyranoski, et al.

[16] In the United States at the present time, there is no formal labor-market mechanism in place to ensure that the number of students who graduate is linked to their job prospects.

we can say is that for several reasons the numbers of graduate students rose sharply, particularly in the life sciences, and that many of the resulting doctorate recipients did not find faculty jobs or research jobs in large established companies.

Two further questions arise about the numbers of doctorate recipients trained in the U.S. First, to what degree will this problem of perceived "over-production" diminish as federal R&D funding becomes level or perhaps even declines in future years? Part of the problem in the life sciences is that the years of growth in the budget of the National Institutes of Health (NIH) during the 1990's and 2000's led universities to expand research and doctoral programs, but the growth of NIH funding leveled off just as these young people received their PhDs, reducing the number of new grants and perhaps reducing the number of new faculty jobs. So there was an imbalance over the past decade between supply and demand for new PhDs. But what will happen in the future? In particular, are the numbers of doctoral students in the life sciences and other fields currently going down, reflecting the fact that both new university jobs and company positions are relatively low?

NSF collects data on the total number of S&E graduate students – students studying for master's degrees as well as doctorates – but apparently does not present data just on graduate students pursuing doctorates. So we do not know whether the number of S&E PhD students in the U.S. is declining or not. However, NSF's data about overall U.S. graduate students suggest that the number of science students did not decrease between 2008 and 2010; it grew slightly. Does this mean that the numbers of doctorate recipients will remain relatively high in coming years? Perhaps it does, so the problem of "over-production" may not correct itself automatically. The number of engineering graduate students has grown more than the number of science students, but there may be more jobs in the future for these individuals.[17]

Table 4 summarizes these data on graduate enrollment.

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[17] In interpreting these data, it is important to keep in mind that enrollment in graduate programs in the United States, especially at the masters level, is sensitive to the state of the economy—in good times, students opt for employment; in bad times they opt to enroll in graduate programs while they wait for better job prospects.

TABLE 4. GRADUATE ENROLLMENT IN SCIENCE, ENGINEERING, AND HEALTH FIELDS, BY FIELD: 2000–10

Field	2000	2001	2002	2003	2004	2005	2006	2007 old[a]	2007 new[a]	2008	2009	2010	% change 2000 –10[b]	% change 2009 –10
All survey fields	493,311	509,607	540,404	567,121	574,463	582,226	597,643	607,823	619,499	631,489	631,645	632,652	30	0.2
Science and engineering	413,536	429,229	454,834	474,645	475,873	478,275	486,287	502,375	516,199	529,275	545,685	556,532	35	2.0
Science	309,424	319,736	335,166	347,268	352,307	357,710	363,246	372,120	384,523	391,419	401,008	407,291	30	1.6
Agricultural sciences	12,023	12,235	12,698	13,197	13,445	13,123	13,016	13,222	13,528	14,153	15,200	15,656	30	3.0
Biological sciences	56,282	57,639	61,088	64,701	66,565	68,479	69,941	71,663	71,932	72,666	73,304	74,928	35	2.2
Computer sciences	47,350	52,196	55,269	53,696	50,016	47,978	47,653	48,959	48,246	49,553	51,161	51,546	10	0.8
Earth, atmospheric, and ocean sciences	13,941	13,841	14,240	14,620	15,131	14,836	14,920	14,675	14,100	14,389	14,839	15,655	10	5.5
Mathematical sciences	15,650	16,651	18,163	19,465	19,931	20,210	20,815	21,335	20,975	21,400	22,226	23,136	50	4.1
Physical sciences	30,385	31,038	32,341	34,298	35,761	36,375	36,901	37,111	36,824	37,319	38,149	38,973	30	2.2
Psychology[c]	50,466	50,454	51,152	52,162	54,126	57,282	57,653	60,284	59,617	58,991	56,184	53,419	5	-4.9
Social sciences	83,327	85,682	90,215	95,129	97,332	99,427	102,347	104,871	103,150	103,384	107,820	109,220	30	1.3
Other sciences[a,d]	ne	ne	ne	ne	ne	ne	ne	ne	16,151	19,564	22,125	24,758	-	11.9
Engineering	104,112	109,493	119,668	127,377	123,566	120,565	123,041	130,255	131,676	137,856	144,677	149,241	45	3.2
Aerospace engineering	3,407	3,451	3,685	4,048	4,089	4,170	4,482	4,616	4,616	4,902	5,266	5,540	65	5.2
Architecture[a]	ne	ne	ne	ne	ne	ne	ne	ne	4,601	5,905	6,804	6,795	-	-0.1
Biomedical engineering	3,197	3,599	4,338	5,301	5,807	6,067	6,482	6,881	6,904	7,339	7,904	8,497	165	7.5
Chemical engineering	7,056	6,913	7,414	7,516	7,452	7,173	7,261	7,383	7,584	7,892	8,188	8,668	25	5.9
Civil engineering[a]	16,451	16,665	17,713	18,890	18,561	18,114	17,802	19,867	16,071	16,931	18,638	19,559	20	4.9
Electrical engineering	33,611	36,100	39,948	41,763	38,995	37,450	38,265	40,207	40,588	41,164	41,218	41,336	25	0.3
Industrial engineering	12,119	12,940	14,033	14,313	13,852	13,650	13,829	14,290	14,474	15,692	15,825	15,205	25	-3.9
Mechanical engineering	15,235	15,852	17,139	18,393	17,852	17,373	17,919	18,366	18,347	19,585	21,243	22,509	50	6.0
Metallurgical/materials engineering	4,377	4,721	4,992	5,131	5,059	5,160	5,268	5,365	5,314	5,539	5,863	6,274	45	7.0
Other engineering	8,659	9,252	10,406	12,022	11,899	11,408	11,733	13,280	13,177	12,907	13,728	14,858	70	8.2
Health	79,775	80,378	85,570	92,476	98,590	103,951	111,356	105,448	103,300	102,214	85,960	76,120	-5	-11.4
Clinical medicine[a,e]	16,407	17,363	19,166	20,574	20,866	21,414	23,441	24,616	22,751	23,939	24,125	25,699	55	6.5
Other health[c]	63,368	63,015	66,404	71,902	77,724	82,537	87,915	80,832	80,549	78,275	61,835	50,421	-20	-18.5

ne = not eligible; data were not collected for this field before 2007. - = not calculable.

[a] In 2007 survey was redesigned and five fields were added or reclassified to improve reporting. "2007new" shows data as collected in 2007; "2007old" shows data as they would have been collected in prior years. Due to methodological changes, counts should be used with caution for trend analysis. See http://www.nsf.gov/statistics/nsf10307/ for more detail.

[b] "% change 2000–10" is rounded to nearest 5% to reflect potential imprecision of this estimate due to methodological changes in 2007.

[c] Counts in psychology and other health declined in 2008, 2009, and 2010, potentially due to more rigorous follow-up with institutions regarding the exclusion of practitioner-oriented graduate degree programs. These decreases may not reflect changes in actual enrollments, and care should be used when examining trends.

[d] Includes communication, family and consumer sciences/human sciences, neuroscience, and multidisciplinary/interdisciplinary studies. These fields were added in 2007, although some programs reported within them had been reported prior to 2007 within other fields.

[e] Includes research-oriented graduate students in anesthesiology, cardiology, endocrinology, gastroenterology, hematology, neurology, obstetrics/gynecology, oncology/cancer research, ophthalmology, otorhinolaryngology, pediatrics, preventive medicine/community health, psychiatry, pulmonary disease, radiology, surgery, and clinical medicine, not elsewhere classified.

SOURCE: NSF 12-319, May 2012, Table 1, http://www.nsf.gov/statistics/infbrief/nsf12317/.

Based on data from National Science Foundation/National Center for Science and Engineering Statistics, NSF-NIH Survey of Graduate Students and Postdoctorates in Science and Engineering.

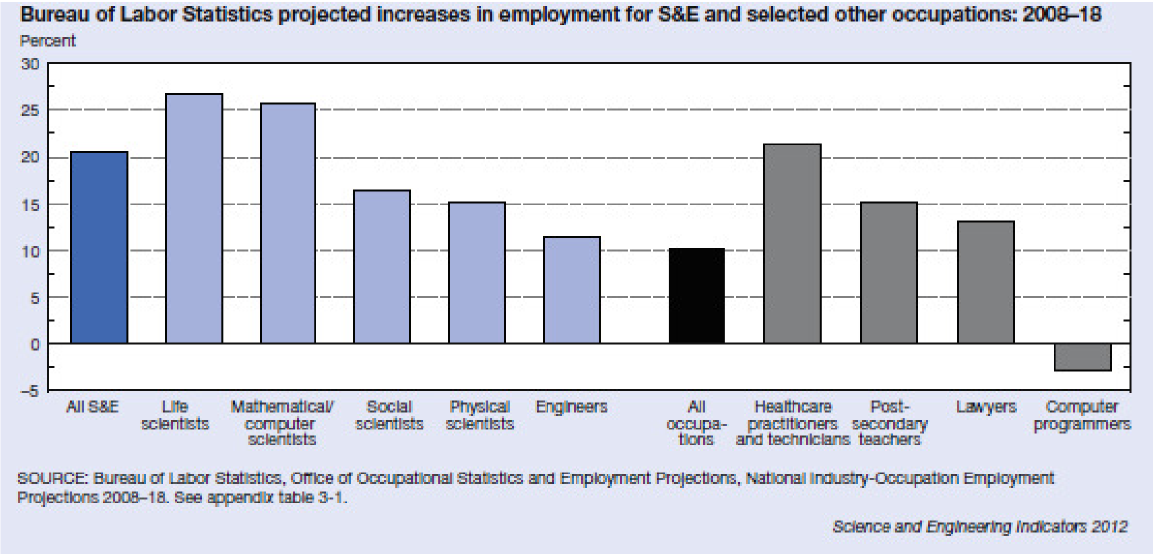
The second question is related: even if many S&E doctorate recipients today have difficulty finding the type of jobs they trained for, especially in the life sciences, will the employment situation improve in the future? That is, will the United States have a greater number of science and engineering jobs in the future?

Here NSF relies on projections from the U.S. Bureau of Labor Statistics, a unit of the Department of Labor. It is difficult to make reliable projections. However, NSF cites the following:

> The most recent Bureau of Labor Statistics (BLS) occupational projections, for the period 2008-18, suggest that total employment in occupations that NSF classifies as S&E will increase at more than double the overall growth rate for all occupations….[18]

NSF then provides a chart that summarizes BLS's projections for specific S&E fields, along with several non-S&E careers. That chart is below, as Figure 2.

Figure 2.



Bureau of Labor Statistics projected increases in employment for S&E and selected other occupations: 2008–18

SOURCE: Bureau of Labor Statistics, Office of Occupational Statistics and Employment Projections, National Industry-Occupation Employment Projections 2008–18. See appendix table 3-1.

Science and Engineering Indicators 2012

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[18] *Science and Engineering Indicators 2012*, page 3-12. Please note that these BLS projections were made before 2008 and therefore before the recession.

However, the BLS projections do not differentiate among the likely future demand for bachelor's level scientists and engineers (individuals with first degrees), master's degrees, and doctoral degrees. It remains difficult to know if the United States is training more S&E doctorate recipients than the numbers of jobs available now and in the future.

3.3 Problems with Post-doctoral Positions

Post-doctoral positions have benefits for both researchers and laboratories. The researchers get additional experience and training; it is a type of apprenticeship. And laboratories in both universities and industry get skilled, well-trained young people to help them conduct research.

However, critics raise two concerns about the current U.S. post-doc system. First, there are concerns about low pay and poor benefits (health insurance, pension contributions, paid vacations, time off when sick, child care, etc.) for both American post-doctoral researchers and foreign post-docs and, furthermore, that that the poor treatment of post-docs may discourage some young people from pursuing science careers. NSF provides a useful summary of this topic:

> Low pay and fewer benefits for postdocs are frequently raised as concerns by those worried about the effect of the increasing number of postdoc positions on the attractiveness of science careers. The median academic postdoc salary is 44% less than the median salary for non-postdocs up to 5 years after receiving their doctorates…. Among engineering doctorates, academic postdocs are paid half of the salary of those who are not in postdoc positions up to 5 years after receiving their doctorate….

> Across all S&E fields, 90% of postdocs reported having medical benefits and 49% reported having retirement benefits. It is not possible to know from [NSF's surveys] how extensive medical benefits may be or how transferable retirement benefits are.[19]

Second, some critics believe that the federal government and universities are not doing enough to help post-doctoral researchers move into permanent positions. This is a matter of both training (are they getting good career guidance and training while serving as post-docs?) and financial incentives (for example, is there sufficient grant money to help new investigators establish their own research programs?).

In the field of life sciences, a detailed critique of the post-doc situation comes from a 2012 "working group" at the National Institutes of Health. Princeton University President Shirley Tighman and NIH Deputy Director Salley Rockey chaired the group. The report notes that there is little good information about the numbers of American and foreign post-docs working in U.S. laboratories or the length of their fellowships. But the report does reach some important conclusions about both the training issue and the pay and benefits issue:

> Although a post-doctoral fellow is considered a trainee, in many laboratories fellows receive little additional preparation for their future careers, even for those in academic research. For example, few postdoctoral fellows receive instruction in grant writing, laboratory and personnel management, and teaching, all skills that are necessary for a successful academic career….
>
> There is little information about the amounts and types of benefits received by postdoctoral researchers, although anecdotal evidences suggests that there is wide variation among institutions…. Almost all of the 74 institutions [that responded to a 2011 survey] provide health insurance benefits and about two thirds offered some amount of paid time

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[19] *Science and Engineering Indicators 2012,* page 3-39.

> off [that is, vacation time]. Fewer than one third of the responding institutions provided retirement benefits….
>
> [T]he working group concluded that the postdoctoral experience should include structured career development, and incentives should be provided by NIH to move postdoctoral fellows to more permanent positions as soon as possible…. Finally, the working group also recognizes that postdoctoral fellows have spent years in graduate training, and should be compensated accordingly, including receiving a reasonable level of benefits.[20]

3.4 Inadequate Training for Non-Academic Careers

Some observers have also criticized doctoral programs for not doing enough to help interested students prepare for non-academic jobs. If relatively few students will have regular faculty positions (that is, tenured and tenure-track university jobs), then, these critics say, universities should do a better job of preparing them for alternative careers.

For example, recently two professors collected information from 4,109 U.S. doctoral students in the life sciences, chemistry, and physics, asking them about their career preferences and whether their PhD advisors and courses helped them prepare for possible non-academic positions. Here is what the two professors found and what they think are the implications of those findings:

> Our data show that a faculty research career is the career path most often considered "extremely attractive" and ranks among the most desirable careers for over 50% of life scientists and physicists. Given that the number of faculty positions is much smaller, these findings support the concern that the supply of science PhDs interested in faculty research positions significantly exceeds the number of available positions in these fields. At the same time, the majority of chemistry students as well as significant shares of students in the life sciences and in physics prefer

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[20] Biomedical Research Workforce Working Group, National Institutes of Health, *Report,* June 14, 2012, pages 36-37, http://acd.od.nih.gov/Biomedical_research_wgreport.pdf.

> careers outside of academia, regardless of job availability. Academic administrators and advisors should consider such heterogeneity in career preferences when designing graduate curricula, ensuring that students have opportunities to acquire the skills and knowledge required to perform in non-academic careers….
>
> Second, respondents across all three major fields feel that their advisors and departments strongly encourage academic research careers while being less encouraging of other career paths. Such strong encouragement of academic careers may be dysfunctional if it exacerbates labor market imbalances or creates stress for students who feel that their career aspirations do not live up to the expectations of their advisors….
>
> Third, our data suggest that students' interest in academic research declines over the course of PhD training, while other careers become relatively more attractive…. [A] declining interest in a faculty research career may imply a greater divergence between students' interests on the one hand, and the academic orientation of traditional PhD curricula as well as advisor expectations on the other.[21]

The NIH working group cited earlier also discussed the training issue. The report notes that the proportion of life sciences PhDs moving into tenured or tenure-track faculty jobs has fallen – from 34 percent in 1993 to 26 percent today. Then the report says the following:

> Despite these changes, graduate training continues to be aimed almost exclusively at preparing people for academic research positions. Therefore, the working group believes that graduate programs must accommodate a greater range of anticipated careers for students. Graduate programs should reflect that range, and offer opportunities to explore a variety of [career] options while in graduate school without adding to the length of training. Graduate programs also should openly communicate the career outcomes of their graduates to potential students.[22]

Do industry leaders believe that graduate education and post-doctoral fellowships in academia give students the skills they need to succeed in

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[21] Henry Saurermann and Michael Roach, "Science PhD Career Preferences: Levels, Changes, and Advisor Encouragement," *PLos One,* Volume 7, Issue 5, May 2012, http://www.plosone.org/article/info:doi/10.1371/journal.pone.0036307.

[22] Biomedical Research Workforce Working Group, page 8.

industry? We have only anecdotal evidence. But it seems that at least some industry executives believe that new PhDs may have good skills for conducting basic research but often lack skills in applied research, communications, team-building, finance, and entrepreneurship.

3.5 Chapter Conclusion

U.S. graduate education and U.S. post-doctoral fellowships remain among the best in the world. However, America is producing growing numbers of science and engineering doctorate recipients, and producing many more recipients than the number of available jobs on university faculties or in traditional industry research laboratories. The number of post-doctoral researchers is also increasing, possibly because fewer job opportunities are available when young people first get their doctorates but also because these positions are valuable apprenticeships.

Some critics argue that graduate programs and post-doctoral programs in the United States are doing less than they should to prepare students for non-academic careers. And in fact, they say, post-doctoral programs often do not even give young researchers the practical skills they need if they want to run successful academic research programs.

Some leaders in government and academia have begun to respond to these criticisms. The next chapter of this report discusses several existing and proposed initiatives to help S&E doctorate recipients prepare for the actual jobs they are likely to take.

4. ENHANCING DOCTORAL AND POST-DOCTORAL EXPERIENCES

4.1 Chapter Introduction

As illustrated in the previous chapters, doctoral and post-doctoral education in the United States faces a number of challenges. Among them are:

- A supply-driven system of producing doctoral degree holders that is more responsive to the needs of universities and faculty members for graduate research and teaching assistants than it is to the needs of potential employers for new hires with advanced education in science and engineering.
- A mismatch between the skills that employers say they want new doctorates to have mastered and the skills that doctoral students learn in graduate school.
- A sharp rise in the number of persons engaged in post-doctoral work in many fields of science and engineering.
- A post-doctoral system that has grown rapidly with little attention to quality standards, working conditions and preparation of its participants to assume increased responsibilities.

These and other challenges are being addressed by a wide variety of initiatives taken by funding agencies, foundations, universities, professional associations, and students themselves. This chapter discusses a number of these initiatives.

Some of the initiatives are intended to broaden the horizons of graduate students to help them better prepare for careers other than traditional academic positions. Others are intended to help make doctoral and post-doctoral students more employable by giving them a wider array of skills that are useful in the workplace. Still others are intended to improve the conditions of work for advanced students, especially for those in post-doctoral positions.

4.2 Initiatives to Enhance the Employability of Doctorate Recipients and Post-doctoral Researchers

4.2.1 Overview

Federal agencies, companies, professional associations and foundations have all taken initiative to enhance the employability of new PhDs and of post-doctoral students. These initiatives take several forms. For example, some are designed to enrich education at the doctoral level so that new PhDs will be better prepared to locate good permanent positions. Others are non-traditional post-doctoral programs that are designed to give new PhD graduates exposure to skills that will make them more employable in their original fields at the end of their post-doc. Still others provide training and experience in radically different fields such as business, entrepreneurship and public policy.

It is important to note that, despite the evidence that the United States has overproduced new PhDs in certain fields relative to the demand for such people in academia or in business and government, there has been remarkably little experimentation with initiatives that would redress this imbalance on the supply side. At the end of this section in initiatives, we discuss a few ideas that have been suggested for better management of the supply of new PhDs.

4.2.2 Enriching Doctoral Education

U.S. doctoral education in the sciences and engineering has historically been a highly-focused learning experience, quite unlike the diversified education offered in the U.S. at the undergraduate level. Doctoral students take most of their course work in the discipline of their major, and their research projects are usually one-person affairs of a fundamental nature. In years past, when America looked to Europe for scientific leadership and proficiency in foreign languages was important to success, doctoral students were required to demonstrate competence in one or even two languages other than their native language. German and French, and later, Russian, were most common. And, some doctoral programs required students to take courses in a second field, or "minor," closely allied with the major. So, a mechanical engineering student might take a minor in classical physics or a physics student might take a minor in applied mathematics. Other than foreign languages and minors, however, doctoral programs were deliberately narrow. Students were expected to "pick up" understanding of how to do research, how to publish, and how to teach by following the examples of their mentors. Many felt that there was so much to learn in the major that there was no space in the curriculum for "frills" that could be learned on the job.

As noted in Chapter 3, however, it has been increasingly recognized that the historical model of doctoral education does not provide adequate preparation for career success in the 21st century. The Council of Graduate Schools in cooperation with the Educational Testing Service recently issued a report on preparation of graduate students for academic positions that found that students, and faculty in many cases, are remarkably ill-informed about career paths and skills needed to succeed.[23] This is not a new subject for the Council. In 1993 it was a founding partner with the Association of American Colleges and Universities of the Preparing Future Faculty (PFF) program.[24] According to the PFF web site,

> The Preparing Future Faculty (PFF) program is a national movement to transform the way aspiring faculty members are prepared for their careers. PFF programs provide doctoral students, as well as some master's and post-doctoral students, with opportunities to observe and experience faculty responsibilities at a variety of academic institutions with varying missions, diverse student bodies, and different expectations for faculty.

PFF was eventually adopted and funded by NSF, the Pew Charitable Trusts, and the Atlantic Philanthropies and involved more than 45 academic institutions.

Enriching the traditional curriculum has been the goal of a number of specific initiatives. One of the earliest examples of federal funding to enrich and broaden doctoral education is the Engineering Research Centers (ERC) program of NSF, established in the mid-1980s. The ERCs are typically multi-disciplinary centers funded by NSF for at least six and as many as eleven years. The NSF funding is contingent on matching funds from industrial sponsors. The ERC program was intended to build stronger ties between industry and universities, but also to give doctoral students sustained exposure to industrial problems, researchers and culture. Evaluations of the ERC program have found that its graduates are highly desired by industry because of the additional skills and perspectives they have acquired from the program.

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[23] Council on Graduate Schools and the Educational Testing Service, Commission on Pathways Through Graduate School and Into Careers, April 2012. On line at: http://pathwaysreport.org/rsc/pdf/19089_PathwaysRept_Links.pdf

[24] http://www.preparing-faculty.org/

Another example, which takes a very different approach, is the Keck Graduate Institute's PhD Program in Applied Life Sciences. Their combined master's and doctoral program includes not only course work in their scientific specialties but also paid summer internships in industry, industry-sponsored team masters projects, conducting market research, and preparing business plans. They also examine the regulatory environment that is so important to life sciences research.

The University of California, San Francisco, in 2008 set up a Graduate Students Internships for Career Exploration Program (GSICE) focused on giving medical and other life sciences students information and experiences that will help them make better informed career decisions.[25] Graduate students do a series of workshops on career choices and can elect to do internships during their graduate studies or immediately thereafter.[26]

The National Institutes of Health has for a number of years promoted training for all student researchers it supports in "responsible conduct of research.[27]" The NIH has taken the position that training in such matters as scientific integrity, ethics, and misconduct is essential to preparing students for professional practice and requires grant recipients to undergo such training. This requirement has shifted such preparation from the domain of knowledge that is randomly and informally picked up from observing mentors to a structured educational experience that ensures mastery of the underlying concepts by all doctoral graduates supported by NIH.

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[25] Mascarelli, Amanda, "Stepping Stones," Nature, 490, 571-573, 25 October 2012.

[26] Ibid.

[27] http://grants.nih.gov/grants/guide/notice-files/NOT-OD-10-019.html

These and many other initiatives at the national and local levels in the United States were established to give pre-doctoral students better preparation for success in relatively traditional careers in academia and industry. For those students who participate, the idea is that they will be stronger competitors for good positions once they earn their doctorates.

Efforts such as these to broaden doctoral education found their most influential voice in a recent report of a working group of the Advisory Committee to the Director of NIH.[28] The working group recognized that doctoral training in the life sciences faces a number of problems and made several recommendations. Among them is that

> NIH should create a program to supplement training grants through competitive review to allow institutions to provide additional training and career development experiences to equip students for various career options….[29]

4.2.3 Broadening Post-doctoral Training and Education

Post-doctoral programs have seen a rich array of experiments and new approaches that are intended to improve the employability of persons who already have a doctoral degree. These experiments are more feasible than those at the doctoral level, in part, because the entire world of post-doctoral education and training is much less standardized than is the world of doctoral education. At times, this lack of standardization can be a problem for post-docs, but it also enables great flexibility.[30]

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[28] Biomedical Research Workforce Working Group, draft report, June 2012. On line at: http://acd.od.nih.gov/bmw_report.pdf

[29] Ibid.

[30] The National Post-Doctoral Association was founded in 2002 by a group of post-doctoral students, each of whom was a leader of post-doctoral students at his or her own institution. It was founded "…with the

Many of the experiments at the post-doctoral level are similar to those at the doctoral level, except that they find a somewhat more congenial environment because the post-doc has always been seen as an opportunity to both deepen and broaden one's professional capabilities.

The National Postdoctoral Association has prepared a Postdoctoral Core Competencies Toolkit that details six core competencies related to success in a career in any sector that a post-doc should have or seek to develop, including:

- Discipline specific conceptual knowledge
- Research skill development
- Communication skills
- Professionalism
- Leadership and management skills
- Responsible conduct of research.[31]

The Toolkit provides long lists of specific competencies under each of these categories and discusses ways in which they can be used by individuals for self-assessment or by institutions planning enrichment programs for post-docs.

The NIH Biomedical Research Workforce Working Group discussed above also considered the problems of post-docs and made recommendations to address them including enhanced training for post-docs.

NIH has responded to the challenge from its Working Group by publishing its intent to solicit applications for a new program to be called the NIH Director's Workforce Innovation Awards.[32] We quote extensively from the

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goal of fostering necessary improvements to the postdoctoral situation in the United States." http://www.nationalpostdoc.org/index.php/about-the-npa-2/our-founding

[31] http://www.nationalpostdoc.org/index.php/publications-5/competencies

[32] http://grants.nih.gov/grants/guide/notice-files/NOT-RM-13-005.html, dated December 21, 2012.

announcement of these intended awards because it responds to so many of the issues discussed above, as follows:

> These awards will be available to doctoral degree-granting institutions that propose bold and innovative programs to significantly enhance traditional research-oriented doctoral and post-doctoral training. This initiative is developed in response to advice provided by the Advisory Committee to the Director, NIH. The committee studied the current state of the biomedical research workforce, and NIH's support of training for this workforce (http://acd.od.nih.gov/Biomedical_research_wgreport.pdf). The novel programs supported by this initiative should be informed by the anticipated needs of the future biomedical research workforce as described in the above report.
>
> NIH is seeking innovative programs to broaden the training of graduate students and post-doctoral scientists desiring careers in all venues. This training might be in a variety of environments: industry, biotechnology, entrepreneurial enterprises, technology transfer, science policy, governmental regulatory agencies etc. Training may be accomplished by a variety of mechanisms: novel curricula, hands-on work/internships, lecture series, training in management and leadership, etc. The programs also will provide positive and attractive exit pathways early in pre-doctoral training for those individuals choosing careers that do not require the research doctorate. Partnerships with organizations that employ scientists engaged in diverse career paths are highly encouraged to ensure appropriate expertise is brought to bear on proposed coursework and/or that hands-on training experiences within these organizations may be possible.

It is anticipated that NIH will make these awards available to twenty-five institutions in the amount of $250,000 each. No awards have yet been made but a formal program announcement is expected soon.

Some universities have adopted the practice of requiring post-docs and their mentors to prepare an Individual Development Plan, a structured planning process that leads the post-doc to consider his or her career goals and opportunities as well as his or her professional skills along the lines of the

National Postdoctoral Associations Toolkit of skills discussed above. An example of how this process is put into practice is the guidance provided to post-docs by the University of Southern California's Office of Postdoctoral Affairs.[33]

One of the more interesting developments in post-doctoral education and training is the emergence of formal post-doctoral programs at industrial firms, including but not limited to those in the pharmaceutical industry.[34] As noted in the referenced articles, a few firms in a number of industries, such as Procter and Gamble, Exxon, and IBM, have long had informal post-doctoral programs. What is newer are the concerted efforts to host post-doctoral programs made by major pharmaceutical firms such as Merck, Eli Lilly, Hoffmann-La-Roche, and Novartis discussed in the *Nature* article just referenced. Novo Nordisk offers a formally organized "Industry Practice Postdoctoral Pharm.D. [doctor of pharmacy] Fellowships program in two variants, a one-year and a two-year program."[35] In all of these programs, the industrial post-docs are given temporary positions in the firm's R&D operations where they work under the guidance of a staff mentor on both research projects and an organized program of training in areas such as industrial practice, project management, finance, entrepreneurship, teamwork, presentations skills, planning, and communication.

Relative to the thousands of post-docs in academia, the industrial post-doctoral programs each engage only a handful of students. Nonetheless, they represent an interesting experiment in helping early career scientists make a smooth transition from the academic world to industry. They also give sponsoring firms the opportunity to get to know new scientists in depth and to

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[33] https://postdocs.usc.edu/mentoring/idp/

[34] "Postdocs Probe Industry," *Nature*, 478, published on-line 12 October 2011. Also see: Marasco, "Industrial Postdocs: Engaging Science," *Chemical and Engineering News*, September 29, 2003, pp. 57, 60, 62.

[35] http://www.novonordisk-us.com/images/pdf/nni_fellowship_bro_online41411_optimized.pdf

decide at leisure whether to offer them permanent employment, without needing to make a commitment to a new permanent hire that they might later regret.

4.2.4 Enabling Radical Shifts in Professional Careers

Perhaps the most interesting post-doctoral programs are those that are avowedly focused on helping new PhDs transition into positions that are quite different from those for which their graduate work prepared them.

There have always been a few new PhDs or post-docs who discover new interests and make their way into further education in fields such as law, clinical medicine, or teaching, but they do so at their own initiative. Programs discussed below have a career shift as one of their objectives.

One of the most interesting efforts that channels PhDs and post-docs into new lines of work is the array of congressional and executive branch fellowships programs sponsored and coordinated by the American Association for the Advancement of Science (AAAS).[36] Begun in the early 1970s with a handful of participants, today upwards of two hundred PhDs in math, science, engineering and related fields spend a year serving as "fellows" in policy-related positions on the staff of the U.S. Congress, in the Office of Science and Technology Policy, in the Department of State, in the Environmental Protection Agency, and in other government departments and agencies. Many of the former fellows have risen to positions of substantial responsibility, not only in government, but in industry, finance, the non-profit sector, and academic administration.

Another interesting development is the growth of the "Professional Science Master's" programs first championed in 1997 by the Alfred P. Sloan

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[36] http://fellowships.aaas.org/

Foundation and now coordinated by the Council on Graduate Schools.[37] The program can best speak to its own purposes, as follows:

> The Professional Science Master's (PSM) is an innovative, new graduate degree designed to allow students to pursue advanced training in science or mathematics, while simultaneously developing workplace skills highly valued by employers. PSM programs consist of two years of academic training in an emerging or interdisciplinary area, along with a professional component that may include internships and "cross-training" in workplace skills, such as business, communications, and regulatory affairs. All have been developed in concert with employers and are designed to dovetail into present and future professional career opportunities.[38]

The PSM programs have been popular, not only with students who do not wish to go on for a PhD but also for those who already hold a PhD and are looking for a way to transition into a career that typically is more involved with business and society and less with research.

4.2.5 Labor-market Initiatives

Nearly all of the activity in U.S. universities, industry, foundations, and government to address the mismatch of the supply of and demand for PhDs and post-docs has focused on the qualities and skills of the degree holders, rather than on their quantity. That is, it is tacitly assumed that the evident labor market problems that have driven the explosive growth in post-doctoral positions over the past few years can be dealt with by improving the people involved. Rarely has explicit attention been paid to the fact that there is currently an excess of people with advanced degrees in the sciences and some fields of engineering relative to the size of the job market for them.

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[37] http://www.sciencemasters.com/ScienceMastersHome/tabid/36/Default.aspx

[38] Ibid.

The Workforce Working Group report to the NIH Director was perhaps the most candid when it suggested that the imbalance in the biomedical field might be addressed in part by making it easier for academic institutions to carry out their NIH-funded research projects using full-time, non-faculty research staff scientists in place of some of their "trainees"(i.e., graduate students and post-docs).[39]

That said, few voices are heard urging a slowing or a reversal of the growth of graduate enrollment in the sciences or engineering or a reduction in the number of post-doctoral fellows. Yet, continuing to treat the problem as one of a mismatch of skills and needs, rather than as a problem of excess supply created by government R&D funding, especially in the life sciences, seems to perpetuate an ultimately unsustainable situation.

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[39] http://acd.od.nih.gov/bmw_report.pdf

5. CONCLUSIONS

Over the last ten to fifteen years, the conditions for doctoral recipients and "post-docs" in science and engineering have changed markedly in the U.S. This report focuses on these changing conditions, especially as they apply to post-doctoral appointments – defined herein as a limited-term research position, typically assumed immediately after obtaining a PhD.

The following conclusions emerge from the analysis:

1. While the number of PhD scientists and engineers trained in the U.S. has grown steadily since 2000, as have post-doctoral appointments, the reasons behind these trends are not fully understood.

2. There is a mismatch between the supply of new PhDs and the numbers of positions available in their traditional employment market, the professoriate. In addition, some industrial sectors are reducing the numbers of PhDs they hire. Therefore, a large number of PhDs must seek other types of positions.

3. Three types of motivations seem to lead new PhDs into post-docs:

    a. The "traditional" deepening and/or broadening of skills and knowledge
    b. The use of the post-doc as a "bridge" or buffer" while searching for a permanent position
    c. The flexibility and experience provided by post-doctoral appointments.

4. There is only limited debate in the U.S. about whether the supply of new PhDs is higher than needed or appropriate, either for the country or the PhDs themselves. In fact, there are many more calls for increasing the numbers of "STEM" graduates than for reducing them to bring them into better alignment with employment opportunities.

5. The post-doc experience in the U.S. is frequently criticized both for its working conditions and for its inattention to the longer-term career paths of its holders, particularly if they eventually work outside academia.

6. In the United States, government research agencies do not try to assess, much less regulate the overall number of doctorate degrees awarded in the country. So there is no formal, planned attempt to limit the number of PhDs to match the number of available jobs – although of course federal research funding and federal fellowships indirectly affect the number of U.S. graduate students, PhDs, and post-doctoral researchers.

7. Today, though, U.S. research universities train many more PhDs than universities or large companies will hire. Most federal officials and university leaders prefer to see this situation as a mismatch of skills and needs rather than a mismatch of the overall supply and demand for science and engineering PhDs. So, federal agencies, universities, and other organizations now have a large number of initiatives to help train PhD scientists and engineers for alternative careers. However, in reality most of these initiatives are small in scale and scope, and they do not appear to help large numbers of graduate students or doctorate recipients.

8. With few voices urging a slowing or reversal of graduate enrollment in science and engineering, there is likely to be a continuing excess supply of PhDs and post-docs relative to labor market demand.