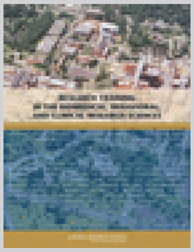

Research Training in the Biomedical, Behavioral, and Clinical Research Sciences

ISBN
978-0-309-15965-4

208 pages
8 1/2 x 11
PAPERBACK (2011)

Committee to Study the National Needs for Biomedical, Behavioral, and Clinical Research Personnel; National Research Council

RESEARCH TRAINING IN THE BIOMEDICAL, BEHAVIORAL, AND CLINICAL RESEARCH SCIENCES

Committee to Study the National Needs for Biomedical, Behavioral, and Clinical Research Personnel

Board on Higher Education and Workforce
Policy and Global Affairs

NATIONAL RESEARCH COUNCIL
OF THE NATIONAL ACADEMIES

THE NATIONAL ACADEMIES PRESS
Washington, D.C.
www.nap.edu

THE NATIONAL ACADEMIES PRESS 500 Fifth Street, N.W. Washington, DC 20001

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This project was supported by Contract/Grant No. DHHS-5294, Task Order #187 between the National Academy of Science and the National Institutes of Health, Department of Health and Human Services. Any opinions, findings, conclusions, or recommendations expressed in this publication are those of the Committee to Study the National Needs for Biomedical, Behavioral, and Clinical Research Personnel and do not necessarily reflect the views of the organizations or agencies that provided support for the project.

International Standard Book Number-13: 978-0-309-15965-4 (Book)
International Standard Book Number-10: 0-309-15965-2 (Book)
International Standard Book Number-13: 978-0-309-15966-1 (PDF)
International Standard Book Number-10: 0-309-15966-0 (PDF)
Library of Congress Control Number: 2011921184

Additional copies of this report are available from The National Academies Press, 500 Fifth Street, N.W., Lockbox 285, Washington, DC 20055; (800) 624-6242 or (202) 334-3313 (in the Washington metropolitan area); Internet, http://www.nap.edu.

Suggested citation: National Research Council. 2011. Research Training in the Biomedical, Behavioral, and Clinical Research Sciences. Washington, DC:The National Academies Press.

Printed in the United States of America.

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Preface

This analysis of the workforce needs in the biomedical, social and behavioral, and clinical sciences began in May 2008, when the storm clouds on the financial horizon were developing. We had our second meeting in late September 2008 in the midst of the financial meltdown. This has made the business of making projections into the future a very uncertain business indeed. The attempts to do just that were nonetheless carried out by the workforce committee, which met to review what data were available (not as much as one might wish) and to formulate recommendations to the National Institutes of Health (NIH) and the Congress as to what changes might best lead to continued vigor in what has been a great experiment in the training of biomedical scientists for over 35 years now. The ideas behind the recommendations were debated and analyzed by experts in the many areas toward which we were expected to direct our scrutiny. Eventually a broad consensus was attained, and that forms the basis of the recommendations in this document.

The basic biomedical sciences workforce itself numbers some 120,000 personnel with doctoral degrees mostly from U.S. institutions. These individuals are distributed primarily among academia (62,000), industry (29,000), and government or nonprofit organizations (12,000). Although it is somewhat of an oversimplification, the workforce can be considered as being composed of two groups, one consisting of the 57,000 workers who are advanced in their careers and are mainly involved in managing or directing research (61 percent of the 90,600 non-postdoctoral researchers), and the other consisting mainly of graduate students (25,000) and postdoctoral fellows (26,000). In some academic fields and some government laboratories the latter group provides much of the hands-on aspect of the research conducted. In other words the trainees themselves are an integral and key component of the workforce. In fact, after World War II the federal government made the deliberate decision to fund basic research through academic institutions in order to integrate research training with the active conduct of research.

By comparison, the research workforces in the behavioral and social sciences and the clinical sciences are much different. These research workforces are harder to quantify since many of those holding doctorate degrees turn to private practice after receiving their research degrees or else to other positions that do not rely on their research potential. With some qualification, the total number of U.S. doctorates in the behavioral and social sciences workforce is about 95,500, with over 47,100 in academic positions, about 32,800 in industry (including individuals who are self employed), 8,700 in government, and 6,900 in other employment sectors. There are only about 9,000 postdoctoral fellows included in these figures, and while they contribute to the research enterprise, they are usually not part of a large research group. The clinical sciences workforce is different still, since it is made up of doctoral fellows with either a Ph.D. in a clinical field or a specific professional degree. Many of these postdoctoral fellows will be recruited into faculty positions. In nursing, for example, a shortage in faculty in the near future will lead to pressure to increase the number of Ph.D.s who can contribute in this regard. Again, unlike the basic biomedical workforce, graduate students and postdoctoral fellows make up a small subset of the overall clinical research workforce.

The committee identified a number of important issues, and in this overview we mention the most pressing, upon which we dedicated a considerable amount of discussion time. These most pressing issues are: (1) the job situation for postdoctorates completing their training, (2) questions about the continued supply of international postdoctorates in an increasingly competitive world, (3) the need for equal, excellent training for all graduate students who receive NIH funding, regardless of whether it is from the National Research Services Award (NRSA) program or through R01 support, and (4) the need to increase the diversity of trainees.

THE JOB SITUATION

The biomedical workforce, then, is different from the other fields in that a major component (perhaps as much as 50 percent) is composed of individuals who are in training primarily within an academic research environment. This body of graduate students and postdoctoral fellows provides the dynamism, the creativity, and the sheer numbers that drive the biomedical research endeavor. As such, this group is of enormous value to the country's investments in obtaining knowledge about the fundamental nature of disease processes and in developing the means to correct malfunctions. It has to be understood that, to a significant degree, the value of the trainees supported by the NIH lies more with their current research output while they are trainees than with their future career development.

Indeed, the size of this component of the biomedical research workforce is greater than the number needed to staff the current and estimated future openings in the pool of positions for academic principal investigators. As a result, the number of trainees hired and trained is determined by the number of personnel needed to perform the work rather than the number needed to replenish retiring senior investigators, who are involved mainly in administering their laboratories. This situation has been exacerbated in recent years by financial stresses and the understandable reluctance of older but healthy faculty members to retire. As a consequence, the primary regulator of the size of the student and postdoctoral workforce is not determined by anticipated specific employment needs in the generally older group of research managers and directors. Instead, it is governed mostly by the amount of funds (mostly R01 grants) made available (primarily by the NIH and other federal agencies) for the conduct of biomedical research.

A direct corollary of this approach is that the workforce is constantly being replaced with new cadres of graduate students and postdoctorates. Although some trainees do, of course, move on to employment as "independent investigators" in academia or industry, this is definitely not the case for the majority of those completing their training—in contrast to the situation 30 years ago. Certainly many of the graduates have, out of necessity, been highly creative in looking for new career outcomes, and in a sense this has also supported science within this country. However, the fact remains that more recently this incredibly productive approach has generated a significant number of individuals who leave bench science after completion of their training. No one disputes that the system has been incredibly successful in pushing the boundaries of scientific discovery, but, at the same time, it has compelled both individuals and institutions to be creative in preparing for the wide range of so called "alternative careers" that many of the graduates of the training programs now prepare themselves for. In this regard it is important that institutions are honest with entering graduate students as to what they may expect and that students recognize that the best opportunities will come to those postdoctorates who have dedicated themselves to excellence.

The financial crisis not only has affected the process of the review of this committee, but also has clearly exacerbated a number of issues that had been developing in previous years. A key issue concerns the likelihood of obtaining a position in the academic research environment. The age of retirement in academia is increasing significantly (see specific data in chapter 3). Furthermore, the financial issues of the past two years have substantially affected faculty 401(k) plans, and it seems unavoidable but that the consequence will be a further decrease in retirement rate until the retirement funds have recovered some of the lost ground. A further result of the problems over the past two years is that universities in general have not expanded their research activities, and this has put further stress on the availability of new positions. The net effect is that the previously tight job situation for postdoctorates looking for teaching or research academic positions is likely getting worse.

Concern for the employment issues (some said the plight) of postdoctorates surfaced in the late 1990s as postdoctorates found that the traditional paths for career development had become less accessible. Some thought that perhaps this was because postdoctorates were being held in the postdoctoral position beyond the time in which the training was complete. These issues were debated by distinguished groups, and this led to the formation of the National Postdoctoral Association. One of the major goals of this organization was to impose a time limit on the postdoctoral period in the hope that this would lead to the timely identification of a career position. Indeed, many institutions promptly implemented policies forbidding the postdoctoral time period from being longer than (usually) 5 years. The outcome was predictable: This approach did nothing to create new jobs or positions, but instead it probably led to postdoctoral fellows being reclassified as research (non-tenure-track) faculty, a type of position that mostly lacks individual space, intellectual independence, or financial resources. This "faculty" position has been the most rapidly growing one in medical schools over the past decade, and it has served to accommodate, in a somewhat precarious position, significant numbers of Ph.D.s in mostly clinical departments, where they remain subject to the vagaries of NIH funding as well as to departmental strategic plans and the funding exigencies of their senior faculty advisors.

INTERNATIONAL POSTDOCTORATES

Another consequence of the difficult economic times should also be considered. As is documented in Chapter 2, more than 50 percent of the postdoctorate workforce is made up of individuals who obtained their Ph.D. from other countries. Indeed, one can make a strong argument that the influx of highly trained and creative foreigners has contributed greatly to U.S. science over the past 70 years. However, the difficulty of obtaining jobs after the postdoctorate period has discouraged domestic students from pursuing graduate and subsequent postdoctorate training. The shortfall required to support the R01 workforce has been made up with international scientist postdoctorates. The major source of such postdoctorates in recent decades has been China and India. However, in recent years China has been investing massively in its research base, and it is now second in the world in research and development, and at the same time the U.S. share of new doctorates has dipped below 50 percent for the first time. If the attractiveness of biomedical research conducted in these foreign postdoctorates' homelands were to exceed that of a stint in the United States, then the reservoir from which we have driven (at least in part) our R01 research for the past 30 years might well dry up. And because Ph.D. training is a lengthy process we would not at present be able to quickly replace this shortfall with homegrown Ph.D.s. If this process were to happen relatively suddenly (and given the economic uncertainties this is no longer a outlandish suggestion) the effect on biomedical research in this country could be profound.

EXPORTING TRAINING GRANT SUCCESSES TO NIH-SUPPORTED TRAINEES

The training grant mechanism has contributed to a number of significant improvements in overall graduate education over the past two decades. These include improvements in minority recruiting, more rigorous and extensive training in the responsible conduct of research and ethics, increased emphasis on career development, more attention to outcomes, and the requirement for incorporating more quantitative thinking in the biomedical curriculum. At schools with training grants these attributes unavoidably spill over somewhat into those graduate programs, which might lack a training grant. However, without the pressures coming from the training grants, schools could easily miss out on some of these benefits.

In practice the majority of students—including, of course, all non-citizen students—are not supported by training grants. These students are mostly supported by R01 grants. The committee felt that all students and postdoctorates who are supported by NIH monies, either directly or indirectly, should benefit from the best practices developed through the training grant mechanism. There are many ways this might be achieved, and the NIH should encourage universities and other institutions to develop these approaches in the ways they see as most applicable to the culture at their own institutions.

DIVERSITY

Training grants have been promoting diversity for 20 years. In some ways they have now succeeded, though much remains to be done. In particular, the gender difference has essentially disappeared for graduate students and, recently, even among postdoctorates. However, it is clear that women continue to be less represented among tenure-track faculty in research-intensive universities.[1] A series of studies have suggested that this, in part, reflects the fact that women in general do not see a tenure-track faculty position as attractive and family friendly, and improvement is unlikely until universities change basic policies related to family issues. At the same time we do see ever more women moving from the postdoctorate period into non-tenure (research) track positions (AAMC data book 2010).

The representation of ethnic and racial minorities in graduate programs has increased quite dramatically in biomedical research, almost certainly in response to pressure from the requirements of training grant applications. In fact, the representation of such minority groups in graduate-student and postdoctorate populations is approaching the same proportion that these groups have represent among B.S. recipients. However, the appointment of minority groups to biomedical science tenure-track faculty positions has so far not followed this trend, and, indeed, minority representation in medical school basic science faculties has been static for 30 years. As with women, racial and ethnic minorities seem disinclined (AAMC data) to look for (or stay in) tenure-track faculty positions. In the past there might have been a criticism of hiring practices, but increasingly we have to face the possibility that this is not the explanation for the current situation and that some other critical issue related to the satisfaction and stresses of a faculty career is now coming into play.

DATA COLLECTION

One issue that surfaced time and again was related to data collection. In its training grant and fellowship applications, the NIH collects a wondrous amount of information. If entered into an appropriate database, this information would provide the foundation for evaluating the effectiveness of the NRSA funding over time. Unfortunately, although the information probably exists (and is certainly collected), until recently it has been difficult to access, as it has existed mainly in the form of paper files and, more recently, as electronic "flat" files. The workforce committee is recommending that a training database be established that would allow mining for outcomes and comparison with training outside the NRSA mechanism (through R01 support).

Finally, the committee spent quite some time discussing the actual process of conducting this review. In essence, although one or two committee members were "holdovers" from the previous group, most of the members were new. It took at least two meetings to figure out exactly what was required and what the scope of the review was in order to understand the nature of the charge to the committee. Then we evaluated the impact of the previous workgroup, and

[1] See http://www.americanprogress.org/issues/2009/11/women_and_sciences.html.

how that affected our goals. Thus it became apparent that there was little continuity in the review mechanism, and, in essence, each newly constituted committee has to reinvent the wheel every time. This is inefficient. And so, guided by the retained members who reported that they experienced the same problem four years previously, we have proposed that a mechanism be developed at the NIH to evaluate the recommendations and their implementation as appropriate and to ensure that this ongoing process is forwarded to the new workforce committee at the very onset of the next review process.

ACKNOWLEDGMENT OF REVIEWERS

This report has been reviewed in draft form by individuals chosen for their diverse perspectives and technical expertise, in accordance with procedures approved by the National Academies' Report Review Committee. The purpose of this independent review is to provide candid and critical comments that will assist the institution in making its published report as sound as possible and to ensure that the report meets institutional standards for objectivity, evidence, and responsiveness to the study charge. The review comments and draft manuscript remain confidential to protect the integrity of the process.

We wish to thank the following individuals for their review of this report: Irwin Arias, National Institute of Child Health and Human Development; Wendy Baldwin, Population Council; Ralph Catalano, University of California, Berkeley; Charles Gilbert, Rockefeller University; R. Bryan Haynes, McMaster University; Hedvig Hricak, Memorial Sloan-Kettering Cancer Center; Marjorie Jeffcoat, University of Pennsylvania; John Norvell (retired), National Institute of General Medical Sciences; Joel Oppenheim, New York University; Jonathan Skinner, Dartmouth University; and Nancy Woods, University of Washington.

Although the reviewers listed above have provided many constructive comments and suggestions, they were not asked to endorse the conclusions or recommendations, nor did they see the final draft of the report before its release. The review of this report was overseen by Georgine Pion, Vanderbilt University, and Charles Phelps, University of Rochester. Appointed by the National Academies, they were responsible for making certain that an independent examination of this report was carried out in accordance with institutional procedures and that all review comments were carefully considered. Responsibility for the final content of this report rests entirely with the authoring committee and the institution.

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Summary

The importance of research for the improvement of health and health care has been recognized both nationally and internationally for many decades. In the United States the most visible sign of this recognition is the strong and enduring support for the National Institutes of Health (NIH). The creation of a research establishment that supports research ranging from very basic to applied has yielded incredible dividends in terms of improving the health care of the nation. Many of these improvements have a common theme: Very fundamental basic research provided an understanding of human physiology that ultimately resulted in improved health care. In many cases, the basic research occurred decades before its application and with no apparent application. Thus, the benefits of research to the health care of the nation are quite clear.

To continue to derive and extend these benefits, we require a highly trained workforce. This workforce must have an infusion of new people with new approaches on a steady basis if it is to be successful. An investment in the training of this workforce is an investment in the health of this country. The introduction of the National Research Services Award (NRSA) program in 1973 was a significant step in maintaining this workforce, and while it supports only a small fraction of the predoctoral and postdoctoral scientists in the biomedical, behavioral, and clinical sciences, it has set the standard for training, regardless of the sources of support.

The legislation establishing the NRSA program also called for periodic review by the National Research Council of the program and evaluation of the national needs for research personnel, and this report is the thirteenth in the resulting series. The task of assessing and predicting the status of research personnel is complicated by the need for accurate and complete data on the supply and demand of personnel and by the effects of external forces. Examples of the latter are downturns in the economy, the effect that national health care legislation will have on the clinical profession, and possible changes in the flow of international talent in the biomedical sciences with the development of world-class research institutions in foreign countries. The statement of task for the committee is:

> A committee will advise the National Institutes of Health (NIH) and the Agency for Healthcare and Quality Research (AHRQ) on issues regarding research personnel needs as they relate to the administration of the National Research Service Awards (NRSA) program. The committee will gather and analyze information on employment and education trends of research scientists in the broad fields of the biomedical, behavioral, and clinical sciences, and in the subfields of oral health, nursing, and health services research. The analysis will take into consideration the demographic changes in the United States, changes in disease pattern, and changes in scientific opportunity. The committee will deal broadly with the training needs and direction of the NRSA program as they relate to relevant federal research training policies, the impact of changes in the level of support for research and training, and the emergence of cross-disciplinary research areas. The analysis will include an estimate of the future supply of researchers from the current and future population of graduate students and postdoctorates, and the committee will make recommendations on the overall production rate of research personnel in the biomedical, behavioral, and clinical sciences for the period 2010 to 2015 as it relates to the NRSA program. Separate consideration will be given to training with respect to NIH dual-degree and career development programs, and NIH programs that are designed to address diversity in the research workforce.

Reflecting the broad fields identified in the statement of task, the committee divided the research enterprise into three major areas: basic biomedical, behavioral and social sciences, and clinical research. These areas are discussed in detail in individual chapters in this report. Additional chapters are devoted to dentistry, nursing, and health services research, even though these can be thought of as subfields of the major areas. An additional chapter addresses training issues that cut across the above fields. Recommendations are found in the individual chapters and are referenced here by number following the recommendation.

FUTURE WORKFORCE PROJECTIONS

For each of the three major areas considered—biomedical sciences, behavioral and social sciences, and clinical sciences—the committee commissioned contractors to develop workforce models using two different methods. One is a life-table model, similar to that used in the past two studies, and the other is a new approach that relied on a systems dynamics model. Each model includes estimates of the numbers of new Ph.D.s and M.D.s entering the workforce and of the size of the workforce through 2016. The results of this modeling should be taken as approximations, because the data available to analyze the past and current status of the workforce are incomplete, the career trajectories of new doctorates are not predictable, and most importantly, it is impossible to judge the effects of the current major stresses on the world and national economies, on the budget available for research, and on the state of the world in general with regard to war, disease, and immigration policies.

The models predict substantial growth in the biomedical and clinical sciences and little growth in the behavioral and social sciences. The role that foreign scientists will play in influencing the size of the job market in the biomedical and clinical sciences is significant, and changes in the level of participation among these foreign scientists could reduce the predicted growth. The life-table model estimates a larger biomedical workforce in 2016 than does the systems dynamic model for scenarios with the greatest projected workforce entrance. The differences in the workforce projections among the different scenarios are substantial, and it is difficult to predict which scenario will provide the best estimate, considering the status of the economy, the national debt, and research support. Unemployment among trained researchers should remain low; however, in 2006 there was an increase in the number of postdoctorates in all sectors, and this may reflect a weakening of the job market as the NIH budget, after its doubling, was essentially kept constant.

ECONOMIC REALITIES

When the study committee began its deliberations, the economy was showing the first signs of a downturn that would deepen to a recession and dramatically affect employment and economic development around the world. Spending over the past decade and the cost of the stimulus package have significantly increased the debt of the federal government, and reports such as that from the U.S. Deficit Commission predict massive reductions in U.S. spending. The extent of any future cuts in the NIH budget—and, in particular, the extent of cuts that affect training—is unknown. As the committee reviewed the state of research training, however, it became clear that recommendations that call for increases in the NIH training budget are important and should be made for the health of the current and future research workforce in the biomedical, behavioral, and clinical sciences.

Given the current and projected future economic environment, it is unlikely that the NIH budget will allow for the implementation of recommendations that require new external funds. A more realistic possibility is the reallocation of existing resources. It is not within the committee's charge, nor did we have the information to recommend how funds within the NIH might be reallocated. The NIH is in the best position to realign its agenda. Recognizing that reallocation of existing funds is nearly inevitable, however, we have identified the three most costly recommendations and placed them in priority order.

RECOMMENDATION ON THE NRSA POSITIONS

The primary task of recommending the number of NRSA positions for 2010-2015 was complicated by the inconclusive results from the two models for projecting the future workforce combined with the existence of major economic uncertainties. Based on the ongoing need to maintain a strong research workforce, the committee recommends that **the total number of NRSA positions in the biomedical and clinical sciences should remain at least at the fiscal year 2008 level and in the behavioral sciences should increase back to the 2004 level. Furthermore, future adjustments should be closely linked to the total extramural research funding in the biomedical, clinical, and behavioral sciences (3–1, 4–3, and 5–1).** In recommending this linkage, the committee realizes that in the case of a decline in extramural research, a decline in training would also be appropriate.

The year 2008 is the last year for which the most complete data are available and represents the highest level of support in recent years in the biomedical and clinical sciences. In contrast, 2008 support in the behavioral sciences declined from the 2004 level. Bringing the level of support in the behavioral and social sciences in 2008 up to the level in 2004 would require the addition of about 370 training slots at a cost of about $15 million. Considering the importance of research in this area, a return to the previous level is essential.

The highest quality of workforce is necessary for a successful research enterprise. The NRSA program is important in this regard. Even if it trains only a small fraction of all the students and postdoctoral fellows involved in research, these training programs set the standards for the entire research training establishment. In addition, they attract high-quality students into research and into fields of particular need. The record of success of NRSA award holders in obtaining research funding is impressive, and the results of the nation's training efforts are self-evident: The United States continues as a world leader in research.

PRIORITIES FOR OTHER RECOMMENDATIONS WITH LARGE COST IMPLICATIONS

In addition to the recommendation on the number of NRSA positions, there are several other recommendations in this report that will require additional resources. Most call for modest increases and could be accomplished by a shifting of resources within an institute or center. Three, however, would require significant additional funds. They are listed below in priority order. In prioritizing these actions, the committee considered both their cost and their merits, along with likely future constraints on the NIH budget.

(1) NIH should reinstitute its 2001 commitment to increase stipends at the predoctoral and postdoctoral levels for NRSA trainees. This should be done by budgeting regular, annual increases in postdoctoral stipends until the $45,000 level is reached for first-year appointments, and stipends should increase at the cost of living thereafter. Predoctoral stipends should also be increased at the same proportional rate as postdoctoral stipends and revert to cost-of-living increases once the comparison postdoctoral level reaches $45,000 (2–1).

When fully implemented, the estimated annual cost of this recommendation would be about $80 million, or 10 percent of the NRSA budget. If phased in over four years, the $20 million dollar annual increase would be about 2 percent of the NRSA training budget. This increase should not be accomplished by reducing the number of individuals supported by the NRSA program. Despite the cost, the committee thought this increase to be sufficiently important to give it the highest priority.

It has been almost 10 years since NIH endorsed the recommendation from the 2000 National Research Council (NRC) report and subsequently instituted a plan to increase the minimum postdoctoral stipend to $45,000 with proportional increases at the predoctoral level. But after a few years of implementation, there were no compensation increases, and in the past two years the increases were 1 percent. By returning to its targeted minimum, the NIH would allow NRSA stipends to be competitive and would retain the best trainees in the program. The quality of the workforce cannot be maintained without an appropriate level of support. The President also sees this as an issue, and the 2011 budget request for NIH included a 6 percent increase in stipend levels, although it was at the expense of a 1 percent decrease in the number of training slots.

(2) The size of the Medical Science Training Program (MSTP) should be expanded by at least 20 percent, and more if financially feasible (3–4).

Currently there are 911 MSTP slots at an average cost of $41,806 per slot. An increase by 20 percent to about 1,100 slots would increase the MSTP budget by about $7.6 million, or 1 percent of the NRSA budget. If phased in over time, the impact would be less.

The MST Program has proved remarkably successful in attracting outstanding physicians into research. Although the program is expensive, we believe that a modest expansion would serve the nation well. A recommendation to increase the size of the program was made in the previous NRSA study but was not implemented. The committee also recommends, strongly, that this increase in the size of the MST program be accomplished by increasing the total number of MST programs and thereby the number of students trained, and not by expanding the size of existing MST programs. Broadening the scope of MSTP training responds to the current national commitment to improve the effectiveness, efficiency, and accessibility of health resources, while controlling costs.

(3) NIH should consider an increase in the indirect cost rate on NRSA training grants and K awards from 8 percent to the negotiated rate currently applied to research grants. The increase in the rate could be phased in over time (2–2).

This would require a five- or six-fold increase in indirect costs, or $191 million for the NRSA program at its current size and $338 million for K awards. There was not unanimity within the committee on this recommendation because of concerns about costs and the reduction in program size that could result with a stagnant NIH budget. An increase of $529 million is significant, even in light of the reasoning to have NIH share the full cost of administrating these programs, but the committee wanted to record its support for the measure and its hope that it could be implemented at some point.

Many of the requirements and support activities centered in training grants—such as minority recruiting, education in the responsible conduct of research, and professional development—have improved the overall tenor of graduate education immensely over the past decade. However, these activities cannot be covered by the current 8 percent indirect cost allowance and therefore must rely on institutional funds. Similarly the K awards, which have served a tremendously important role in fostering the early career development of both basic and clinical researchers, utilize the same facilities as funded researchers and generate their own significant administrative costs, yet have the same 8 percent indirect cost allowance.

OTHER RECOMMENDATIONS

Training in Responsible Conduct of Research

NIH in 2009 issued a detailed policy outlining the agency's expectations for training in the responsible conduct of research (RCR), along with recommendations on how to establish specific curricula. The requirement of RCR training within the T32 mechanism has led to the development of curricula and educational practices that should benefit all students and postdoctorates being trained in biomedical, health sciences, and behavioral research. **Accordingly, all graduate students and postdoctoral fellows who are supported by the NIH on Research Program Grants (RPGs) should be required to incorporate certain additional "training grant-like" components into their regular academic training program. These should include RCR training, exposure to quantitative biology, and career guidance and advising (2–3).**

Diversity

The demographics of this country are changing, and underrepresented minorities (URMs) are approaching a majority of the citizenry. The NIH is committed to increasing the diversity of the health sciences workforce through many programs, such as the Minority Access to Research Careers and Minority Opportunities in Research programs in the National Institute of General Medical Sciences (NIGMS), and the number of URM students in biomedical graduate programs has increased from 2 percent in 1980 to 11 percent today. However, in 2009 minority representation was 2 percent for tenured and tenure-track medical school faculty in basic science—the same as in 1980—and was 4 percent for non-tenured or non-tenure track faculty. G**raduate student and postdoctoral training programs that educate and train students who are funded by RPGs should be subject to the same expectations for diversity of trainees that are expected of training grants. Such programs should be required to provide assurance on R01 grant applications that efforts are being made to increase diversity, though they will likely have to be at an institutional level (2–4).**

K24 Mentoring Awards

The K24 mentoring award has been successful in developing the careers of clinical scientists and should be expanded to the basic sciences. In addition, this mechanism could also be used to support diversity at the faculty level. **The NIH should** e**xpand the K24 mentoring award mechanism to include the basic sciences and adapt the K24 mechanism to provide the opportunity for established mid-career faculty to mentor early-stage investigators in the basic sciences, including recipients of the the new R00 awards (Phase 2 of the Pathways to Independence Award-K99/R00 Award). Additionally, the K24 award mechanisms for both basic and clinical mid-career faculty should be utilized to enhance institutional efforts to recruit and develop a diverse faculty. Specifically, the NIH should develop a new category of K24 awards targeted to enhance the success of early-stage basic and/or clinical investigators, or reserve a fraction of existing K24 awards for mid-career applicants whose mentees will include one or more URM faculty members (2–5).**

Data Management

Are NRSA awardees more successful and productive in their subsequent careers than others? Competitive initial and renewal applications for these programs contain an enormous amount of information, but no systemic approach has been developed to capture this information for rigorous, data-driven analysis. This problem will become all the more acute if trainees supported on R01 grants become a part of the overall database. The need for a modern data recording and management system is desperate, and such a system should be implemented without delay. T**he NIH should collect reliable data on all of the educational components that it supports in such a manner that this information can be stored in an easily accessible database format. Such data might consist of important components of the training grant tables, as well as retention and subsequent outcomes (2–6).**

In the same vein, applications for training grant support require many detailed data tables, some of which are largely irrelevant to the proposal award process. **The committee recommends that the data tables be reviewed and a determination made, in consultation with the awardee community, as to which are really essential for reviewing the proposal and which should be incorporated into the databases (2–7).**

Program Evaluation and Future Coordination

One aspect of training programs that has not been evaluated to date is how the value of the research training was perceived by the program director and the trainees themselves. This information should be collected by an anonymous survey, where the only identifier would be the particular institute or center at which the NIH trainee was supported. Specifically, **a training evaluation questionnaire should be created so that all participants in the full range of NIH-funded training vehicles can provide a confidential, unbiased evaluation of the program in which they were trained. The intent of this recommendation is not to provide additional information for the competitive renewal of a particular program, but rather to allow the NIH to evaluate the merit of all of its training approaches broadly (2–8).**

There should also be better communication between the NIH and the NRC during the periods when the NRSA program is not in review. Such coordination would enhance the information-gathering process and allow the committees at the start of the review to complete their work more rapidly and efficiently. Greater continuity would benefit subsequent NRC committees in crafting recommendations and in monitoring their implementation by the NIH. Accordingly, it is recommended that **the appropriate office at the NIH involved in analyzing these recommendations should issue an annual report to the Director's Advisory Committee on the status of review and implementation. After**

approval, such a report should be forwarded to the NRC to be made available to the subsequent review committees. In addition, the NIH may wish to invite external experts to provide added insight into the analysis. There are a number of ways that this could be done, but the exact mechanism is left up to the NIH (2–10).

Nontraditional Outcomes

Traditionally, a successful career in the biomedical sciences was defined as a research position in a university with grant support from NIH or other funding organizations. While many trainees still aspire to this career goal, many others use their biomedical training to provide other societal benefits—as researchers in the private nonprofit sector or in the pharmaceutical, biotechnology, and medical device industries; by inventing and developing new products; by teaching science in the secondary schools; and with careers in intellectual property law, in finance, and in government service. To recognize these career paths, **peer reviewers in evaluating training grant applications, especially competing renewals, should be instructed to broaden their conception of "successful" training outcomes to recognize nontraditional outcomes that meet important national priorities and needs in the biomedical, behavioral, and clinical sciences (3–2).**

Similarly, in light of chronic and escalating concerns about the uneven quality of precollege science education and its effect on students' career choices, **one highly needed and extremely valuable outcome is for biomedical and behavioral sciences trainees to teach middle and high school science. The NIH and the Department of Education should work to provide incentives that would attract trainees into these teaching careers and lead a national dialogue to accelerate the processes of teacher accreditation controlled by the individual states (3–3).**

M.D./Ph.D. Training Programs

In addition to having their funding increased by 20 percent **(3-4), MSTPs should be encouraged to include basic behavioral and social sciences training relevant to biomedical and health sciences research (3–5).** This is consistent with the recommendations below to increase training programs in basic behavioral and social sciences across NIH centers and institutes (**4–1, 4–2, 4–4**).

MSTPs should also be encouraged to intensify and document their efforts to identify and recruit qualified nontraditional, underrepresented groups (women and minorities). These efforts should be a factor in the evaluation of all requests for MSTP funding increases and should be conditions for receipt of any MSTP funding increases. Success depends on having a critical mass (rather than isolated examples) of underrepresented trainees in any given MSTP (3–6).

Furthermore, the F30 awards have proven to be an effective way for students in M.D./Ph.D. programs to gain NIH support for their activities. They also provide a means of support for students at institutions that do not have an MSTP. Consequently, **all institutes should be encouraged to make F30 fellowships accessible to qualified M.D./Ph.D. students (3–7)**.

Behavioral and Social Sciences

The behavioral and social sciences receive considerably less training support than the other two major fields, but their role in the nation's health has become increasingly important. The lack of support may in part be due to the lack of an NIH institute that focuses exclusively on *basic* behavioral and social sciences research. Much of the current funding is oriented toward the research areas of the categorical institutes, and this should continue since it links behavioral and social sciences research to the missions of the institutes. However, **training programs in basic behavioral and social sciences that cut across disease categories and age cohorts should be housed at NIGMS, which would be consistent with the NIGMS congressional mandate. Given its disciplinary expertise, the Office of Behavioral and Social Sciences Research (OBSSR) should cooperate in this effort. NIGMS will need funds and appropriate staff dedicated to this new effort (4–1).**

In addition, **training programs in basic and traditional behavioral and social sciences that bear specifically on particular diseases and specific age cohorts should be housed in all the relevant institutes and centers. Given both its disciplinary expertise and its role in connecting institutes and centers (ICs), OBSSR should cooperate in this effort (4–2).** An earlier recommendation calls for expanding the MSTP to the behavioral and social sciences. In parallel, **the F30 program should also be extended to clinical behavioral scientists in M.D./Ph.D. programs (4–4).**

Clinical Sciences

The earlier recommendation for the MSTP applies with equal force to the clinical sciences, since part of the training occurs in this area. However, the hope that M.D./Ph.D. programs would provide the transitional and clinical research workforce has not been completely fulfilled. On the other hand, medical students and residents might be attracted to research in these areas if they are exposed to the principles of clinical research and given the training to carry out such research effectively. **The NIH, in consultation with academic medical leadership, should identify better training mechanisms for attracting medical students into translational and clinical research and should fund pilot programs designed to implement promising new approaches to accomplishing that objective (5–2).** While the areas of oral health and nursing are considered subfields of the clinical sciences, and while health services research is at least partially a subfield, these areas were considered separately in this study.

Dentistry

While dentistry is primarily practice-oriented, there is another career path that brings strong science to the problems of oral, dental, and craniofacial health. There is a need for a critical mass of investigators with a long-term commitment to research in the oral health sciences. Consistent with the 2009 National Institute of Dental and Craniofacial Research (NIDCR) strategic plan, the committee recommends several actions to increase the biomedical research workforce in the oral health sciences. First, **efforts should be made to achieve closer integration between schools of dentistry and the broader biomedical and health sciences research, practice, and education communities with the goal of generating new and vibrant research pathways and partnerships for students and faculty (6–1).**

Second, financial support of dental students and postdoctorates with an interest in research is critical. **NIDCR should establish research fellowships, including K awards, and individual research awards to provide greater opportunities for independent NIH research support for dentists, as well as programs to fund non-dentists in Ph.D. programs in subject areas relevant to oral health and also programs for internationally trained non-U.S. citizen dentists seeking Ph.D. and postdoctoral fellowships. To accomplish this may well require that NIDCR rethink its current priorities and may require additional funding. Partnerships between NIDCR and other components of the academic health system need to be developed and maintained based on recognition of the value added by the oral health sciences. The NIH-sponsored Clinical and Translational Science Awards and Practice-Based Research Networks should explicitly identify a collaborative role for oral health research (6–2).**

Third, it is essential that some form of debt relief be available to dental students who commit to pursue research careers. Most students graduate with debt well over $100,000 and not unreasonably view dental practice as the only way to pay that debt. The committee recommends **the development of programs that offer supplements for full or partial coverage of tuition or that offer loan forgiveness, or both, for the dental school component of combined D.D.S./D.M.D./Ph.D. programs. This would allow most of the burden of the D.D.S./D.M.D. tuition to be covered for students who commit to long-term careers in dental research. Enhanced stipends for graduate students should be provided if fiscally feasible without causing students to lose eligibility for low-interest student loans. In conjoined D.D.S./D.M.D./Ph.D. programs, when the clinical degree is awarded prior to the Ph.D., the NIH should permit postdoctoral stipend levels to apply during the post-D.D.S. phase (as opposed to the lower, predoctoral stipend levels). The feasibility of adaptations of the existing Medical Science Training Program (M.D./Ph.D.) model to dental education—including full funding for eight or so years—should be explored (6–3).**

Nursing

The nursing profession shares the same shortage of research personnel as dentistry, but for different reasons. Because of the structure of their profession and their education process, nurses begin doctoral study at a much later time in life and take longer to complete the degree than in other fields with more NRSA support. In response to the graying of the profession, **the T32 programs in nursing should emphasize a more rapid progression into research careers. Criteria for application should include predoctoral trainees who are within eight years of high school graduation, streamlining the requirement for a nursing master's degree in passing to the Ph.D. and providing support for postdoctoral trainees who are within two years of completion of the Ph.D. (7–1).**

To increase research capacity for the existing workforce, the National Institute of Nursing Research (**NINR) should (1) increase the number of mid- and senior-career awards to enhance the number of nurse scientists capable of sustaining programs of research, and (2) increase the length of support for K awards to five years to be consistent with other institutes and centers (7–3).** The NINR budget is less than half that of any other institutes that provide NRSA support and, because of that, has difficulty balancing training and research support. In consideration of the size of the NINR budget and the acute need for nursing faculty, **NIH should request additional support from Congress to allow NINR to more closely meet this acute need (7–4).**

As described elsewhere, the MSTP has proven to be beneficial in attracting and sustaining a research workforce. In this regard, **NINR should develop and pilot test a MSTP-like program to support clinical training at the Master of Science in Nursing (MSN) or Doctor of Nursing Practice (DNP) level for those nursing students wishing to be clinician scientists (7–5).**

Health Services Research

Considering the critical need for health services research at a time when the nation's health-care system is undergoing extraordinary changes, the NRSA support for such training at NIH is modest, less than half a percent at the predoctoral level and less than half of that at the postdoctoral level. **Health services research training should be expanded and strengthened within each NIH institute and center (8–1).** Also, the 1 percent of the NRSA budget that is now set aside is not sufficient for the training supported by the

AHRQ; **AHRQ training programs should be expanded, commensurate with the growth in total spending on health services research, including comparative effectiveness research (8–2).**

CONCLUSION

In general, over the past 40 years the NRSA program has been of enormous benefit in training the workforce responsible for the dramatic advances in the understanding of disease and has provided insights that have led to more effective and targeted therapies. The NRSA program has been an important component of the biomedical research enterprise in the United States—the standard that other nations measure against. To sustain this preeminence, NIH training mechanisms must be nimble in responding to changes in U.S. immigration policy, changes in global employment opportunities for international graduate students and postdoctorates, growth in U.S. minority populations, profound changes in the health-care system, severe financial problems in U.S. higher education systems, chronic inadequacy of science education in K-12, and other conditions that may arise. Strengthening the NRSA and related training programs will help them meet these challenges.

1

Context and Issues

STUDY CONTEXT AND HISTORICAL DEVELOPMENTS

Advances in biomedical, clinical, and behavioral research have significantly contributed to increased human life span and well-being over the past century, and the support and guidance of the National Institutes of Health (NIH) has had a significant role in enabling this research. Among the major benefits of this research have been vaccines for polio, measles, mumps, *Streptococcal pneumonia*, *Hemophilus meningitis*, and a host of other infectious diseases; insulin treatment for diabetes and sophisticated instruments for monitoring glucose levels in the blood; medications to control blood pressure and serum cholesterol; medical and surgical procedures for the treatment of heart disease, including cardiac valve and whole organ transplants; antiretroviral drugs for the treatment of AIDS; and increasingly successful treatments for cancer. The successful completion of the Human Genome Project has led to a plethora of new insights and experimental strategies for understanding major, chronic human diseases at the most fundamental levels and has led to continuously growing numbers of diagnostic tests based on genome, proteome, and metabolome arrays as well as to new types of powerful and targeted treatments. These advances are already transforming our understanding of human physiology and pathophysiology and redefining with far greater specificity and precision our understanding of, and approaches to, complex human diseases. Not only are these advances transforming the practice of medicine, but also they have enabled new, quantitative whole-organism approaches to the study of health and disease by providing the scientific and technological foundation for the burgeoning new discipline of systems biology.

The behavioral and social sciences in recent years have benefited from a tremendous leap in the sophistication of methods and tools, leading to a realistic expectation that useful and effective answers to fundamental questions central to disease prevention and health promotion will result from investing in research training in these areas. At the level of human behavior, the behavioral and social sciences produce knowledge about health issues such as drug and alcohol abuse, obesity, violent behavior, smoking, maintenance of drug treatment regimens, stress management, ability to cope with illness, and health decision-making. At the level of society, the economics of maintaining health and delivering health care can significantly benefit from the research that is carried out in this area.

As these sciences have been maturing, our society has come to realize the absolute necessity of the research findings they produce for the understanding and the treatment and prevention of its health problems. To capitalize on these often-transformational changes requires a highly trained work force that is capable of contributing in increasingly multidisciplinary teams that span scientific domains from biology, chemistry, and physics to engineering, informatics and mathematics. Continuing to invest in the training of this workforce is to invest in the health and well-being of this country.

RESEARCH TRAINING AT THE NATIONAL INSTITUTES OF HEALTH

The history of clinical and research training at the NIH dates back to the naming of the NIH in 1930, when Congress also authorized the first research fellowships in the biological and medical sciences. The ensuing decades have witnessed dramatic growth not only in the NIH budget but also in the number of institutes, the disciplines encompassed, and the mechanisms for funding. From 1975 to 2008 the National Research Service Award (NRSA) program has provided traineeship and fellowship support at the predoctoral level for about 40,000 graduate students in the biomedical, behavioral and social, and clinical sciences. At the postdoctoral level, during this period about 31,000 trainees and fellows were supported across the same broad fields.

BOX 1-1
Research Training at the National Institutes of Health

The origins of research training at NIH date to 1930, when the Ransdell Act changed the name of the Hygienic Laboratory to the National Institute of Health (a single institute at that time) and authorized the establishment of fellowships for research into basic biological and medical problems. While the harsh economic realities of the Great Depression imposed constraints, this legislation marked a new commitment to public funding of medical research and training. The National Cancer Act of 1937, which established the National Cancer Institute (NCI) within the Public Health Service (PHS), funded the first training programs targeting a specific area. This legislation supported training facilities and the award of fellowships to outstanding individuals for studies related to the causes and treatment of cancer. In 1938, 17 individuals received fellowships in cancer-related research fields, such as biochemistry, physiology, and genetics.

NCI became part of NIH with the passage of the Public Health Services Act of 1944—the legislative basis for NIH's wartime and postwar expansion of research and training programs and, more generally, for a major federal commitment to support biomedical research. This expansion was supported by legislative actions that converted existing divisions within NIH to institutes and centers and the establishment of new institutes or centers, each with field-specific training and research missions. In particular, the first of these laws—the National Heart Act of 1947—established the National Heart Institute and changed the name of the National Institute of Health to the National Institutes of Health.

Throughout the 1940s, 1950s, and 1960s there was substantial growth in the NIH budget, with annual increases averaging 40 percent from 1957 to 1963 (with dollar increases ranging from $98 million to $930 million). This funding raised the number of grants to academic institutions and enabled greater federal assistance in both the construction of research facilities and the establishment of fellowship and training programs for research personnel; it even allowed for limited investment in the support of research in foreign countries. The growth in research and training support slowed in the late 1960s, to about 6 percent annually, with a consequent decline in the number of research grants, both foreign and domestic, and a curtailment of facilities construction.

Support in the 1970s reflected public and congressional interest in specific diseases. Legislation provided increased funding for such research areas as cancer and pulmonary and vascular disorders, and the eleventh institute on the NIH campus, the National Institute on Aging (NIA), was established in 1974. The NIA also brought a new perspective to NIH in that it was authorized to support not only biological research but also social and behavioral research. While funding for research in targeted areas was welcomed at NIH, this also meant that research in less visible areas tended to decline. Institutes such as the National Institute for General Medical Sciences and the National Institute of Allergy and Infectious Diseases saw annual average reductions of about 10 percent.

By the early 1970s, training support was authorized through the different institutes and centers by 11 separate pieces of legislation. However, in its fiscal year 1974 budget recommendations, the administration proposed the phasing out of research training and fellowship programs over a five-year period by making no new awards and honoring only existing commitments. The reasons it cited for this proposal were that the need for such programs and the manpower trained by them had never been adequately justified, people trained in these programs earned incomes later in life that made it reasonable to ask them to bear the cost of their training, large numbers of those trained did not enter biomedical research or continue their training, alternative federal programs of support for this training were available, and the programs were not equitable because support was not available equally to all students.

The administration's proposal met with virtually universal opposition by members of the nation's biomedical research community. As a result, the administration revised its position and proposed a new, but smaller, fellowship program at the postdoctoral level. This proposal also met with objections, and in 1974 Congress enacted the National Research Act (P.L. 93-348), which amended the Public Health Services Act by repealing existing research training and fellowship authorities and consolidating them into the National Research Service Award (NRSA) program. The legislation authorized support for individual and institutional training grants at the predoctoral and postdoctoral levels, with the stipulation that an individual could be supported for no more than 3 years. Moreover, to safeguard against some of the cited abuses of the former programs, it restricted training support on the basis of subject-area shortages and imposed service obligations and payback requirements.

In the years since the National Research Act was signed, the law governing the NRSA program has been modified several times in order to include new areas of research training and to establish funding levels for selected disciplines. The first change came in 1976, when Congress extended the program to encompass research training in nursing. Then, in 1978, Congress expanded the NRSA program to cover training in health services research. In 1985 the program was enlarged once again to include training in primary care research.

Specific funding targets for training in health services and primary care research were established with the Health Research Extension Act of 1985, when Congress required that 0.5 percent of NRSA funds be allocated to each of the two fields. The same law directed that funds for training in health services research be administered by the Agency for Health Care Policy and Research and its successor, the Agency for Healthcare Research and Quality. Research training in primary care originally came under the purview of NIH but in 1988 was delegated to the Health Resources and Services Administration by Congress after concerns were raised that NIH was interpreting the meaning of "primary care" too broadly. Funding levels for training in health services and primary care research were increased to 1 percent of the NRSA budget with the passage of the NIH Revitalization Act of 1993, and these two fields remain the only ones for which specific funding levels have been established by law.

SOURCE: NRC. 2005. *Advancing the Nation's Health Needs: NIH Research Training Programs.* Washington, DC: The National Academies Press, pp. 5-7.

Career Development Programs

While the education and training of graduate students and postdoctoral fellows prepares individuals to do research, the NIH recognized the need for programs that would help such individuals go on to establish strong and productive research careers. In the 1980s they initiated programs (the K awards) to facilitate the transition from trainee to research scientist and to give established scientists the opportunity to pursue new research directions. These programs had two goals: (1) to provide Ph.D. scientists with the advanced research training and additional experiences needed to become independent investigators, and (2) to provide holders of clinical degrees with the research training needed to conduct patient-oriented research.

Dual Degree Training

The Medical Scientist Training Program (MSTP) was established by the National Institute of General Medical Sciences (NIGMS) in 1964 to fund research training leading to the M.D./Ph.D. degree in order to better bridge the gap between basic science and clinical research.. Graduates complete the dual degree in about 8 years. Composing only about 2.5 percent of medical school graduates, M.D./Ph.D.s annually receive about 33 percent of the NIH grants made to physician-scientists—attesting to their impressive level of research productivity. Indeed, by 2004 the number of first-time M.D./Ph.D. applicants for NIH R01 grants approximately equaled the number of M.D. first-time applicants even though the total populations of M.D.s and M.D./Ph.D.s are vastly different. In 2009, 10.5 percent of tenured or tenure-track faculty held dual degrees, and they made up 11.1 percent of the clinical department faculty and 8.7 percent in basic sciences department faculty.

The dual-degree program started in 1964 with three M.D./Ph.D. programs—at the Albert Einstein College of Medicine, Northwestern University, and New York University—with 66 trainees; by 2009 the program had grown to include more than 2,000 M.D./Ph.D. trainees at more than 75 institutions nationwide, supported by a complex mix of federal plus diverse institutional and extra-institutional funding sources. MSTP graduates receive training in a diverse set of fields, including not only the biological sciences but also the chemical and physical sciences, social and behavioral sciences, economics, epidemiology, public health, computer science, bioengineering, biostatistics, and bioethics.

Although the fact that the program is expensive has repeatedly led to concerns about whether it is justified in terms of the overall outcome, several reports suggest that the MSTP has delivered on its promise to create a strong workforce of physician scientists. In 1998 NIGMS published a matched sample study that compared individuals who completed a MSTP program with those who had an M.D., Ph.D., or M.D. /Ph.D. from a non-MSTP program and found that MSTP recipients were more likely both to publish and to apply for and receive grants from the NIH.[1] Graduates from a non-MSTP dual-degree program were also found to be highly productive.

Most recently, a report by Brass et. al. has provided strong evidence for the success of this approach in supplying a dedicated and well trained cadre of clinician biomedical scientists.[2] This report examined the graduates of 24 M.D./Ph.D. programs including 4 that were not receiving NIH MSTP support. Twenty of the programs were among the 42 receiving MSTP support. Their finding that 82 percent of the program graduates are doing research and have funding is consistent with that of the NIH study of MSTP graduates. An important observation was that program graduates pursue a broad range of research areas and that many are conducting translational and patient-oriented research as well as basic research. Already such individuals are making major contributions both in terms of new discoveries and also in infusing research strength into major clinical departments in medical schools across the country. By any criteria this program can now be judged a success. In Chapter 3 we recommend an expansion of the program and encourage that it be diversified to a degree into non-bench-oriented disciplines.

Minority Programs at the NIH

NIH has been active in the recruitment of underrepresented minorities into careers in research for nearly 40 years, working through a constellation of support mechanisms targeted at specific populations under the Minority Access to Research Careers (MARC) program and the Minority Biological Research Support (MBRS) program.

Both the MARC and the MBRS programs are housed in NIGMS, which encourages cooperation with the other parts of the institute and regularly promotes MARC and the MBRS program activities through conferences and other events. In addition, there are special initiatives that promote training and career development for minorities, such as the Bridges to the Doctorate Program, which provides support to institutions to help students make the transition from master's to Ph.D. programs. Minority graduate students working toward the Ph.D. or M.D./Ph.D. degree are also supported through the MARC program by F31 fellowship awards. The full range of minority programs for graduate students and postdoctorates housed in NIGMS and other institutes is described in detail in Chapters 4 and 5 of the 2003 National Research Council (NRC) report[3] *Assessment of NIH Minority Research and Training Programs, Phase 3*.

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[1] National Institute of General Medical Sciences, 1998. Available at http://publications.nigms.nih.gov/reports/mstpstudy/.

[2] Brass, L. F., M. H. Aabas, L. D. Burnley, D. M. Engman, C. A. Wiley, and O. S. Andersen. 2010. Are MD-PhD Programs Meeting Their Goals? An Analysis of Career Choices Made by Graduates of 24 MD-PhD Programs. *Academic Medicine* 85(4):692-701.

[3] NRC. 2005. *Assessment of NIH Minority Research and Training Programs, Phase 3.* Washington, DC: The National Academies Press.

BOX 1-2
History of Minority Programs at the NIH

In 1972, at about the same time that the NRSA program was established, the Minority Schools Biomedical Support program—under the administration of the NIH Division of Research Resources—began awarding grants to faculty and students at minority institutions. That same year research awards were made to minority faculty under the Minority Access to Research Careers (MARC) Visiting Scientist and Faculty Fellowship program, and in 1974 MARC was officially established within NIGMS as a formal program to stimulate undergraduates' interest in biomedical research and to assist minority institutions in developing strong undergraduate curricula in the biomedical sciences. In 1977 the MARC Honors Undergraduate Research Training (HURT) program was established, and in 1981 the MARC Predoctoral Fellowship program was created to provide further incentive for graduates of the HURT program to obtain research training in the nation's best graduate programs.

These programs continue today with some modifications, such as the replacement of the MARC HURT program with the MARC Undergraduate Student Training in Academic Research program, which is designed to help meet the need for continual improvement in institutional offerings. Other additions have included the Post-Baccalaureate Research Education Program Award, MARC Faculty Predoctoral Fellowships, MARC Faculty Senior Fellowships, MARC Visiting Scientist Fellowships, and MARC Ancillary Training Activities.

As the MARC programs have been growing, the Minority Schools Biomedical Support program also has been evolving. When eligibility for the program was expanded in 1973, it was renamed the Minority Biological Support program; its name was changed again in 1982 to the Minority Biological Research Support (MBRS) program in order to reflect its research scope. This MBRS program was transferred to NIGMS from the Division of Research Resources in 1988, and the NIGMS established the Minority Opportunities in Research (MORE) program branch to serve as the focal point for efforts across NIH to increase the number and capabilities of minority individuals engaged in biomedical research and teaching. In 1996 the MORE Faculty Development and Initiative for Minority Student Development awards were established, and in 1998 the Institutional Research and Academic Career Development Award was announced to encourage postdoctoral candidates' progress toward research and teaching careers in academia.

SOURCE: NRC. 2005. *Advancing the Nation's Health Needs: NIH Research Training Programs*. Washington, DC: The National Academies Press, p. 7.

NATIONAL RESEARCH SERVICE AWARD PROGRAM

In its almost 40-year history, the National Research Service Award (NRSA) program has provided more than 160,000 training slots in the biomedical, behavioral, and clinical sciences to students and young investigators. This has been accomplished through a combination of individual fellowship awards and institutional training grants. Over the 10-year period from 1998 to 2007, trainees were to be found in some 258 universities, research institutes, and teaching hospitals. As the NIH and the Public Health Service (PHS) have grown over the past quarter of a century, the NRSA program has evolved to include new fields in the basic biomedical sciences, such as genome research and neuroscience, and has expanded to support training in such clinical sciences as communication disorders, health services, primary care, oral health, and nursing.

Institutional training grants, which fund the education of about 83 percent of NRSA participants, are widely regarded as one of the best avenues for learning the theories and techniques of biomedical and behavioral research.[4,5] These programs are overseen by awardee institutions rather than by individual research mentors, and this allows for the implementation of trans-institutional standards for trainee stipends and benefits, mandated instructional programs in such foundational areas as the responsible conduct of research (RCR), the ethical conduct of human and animal subjects research, and sundry career development and counseling programs addressing such topics as grant writing and reviewing, publication practices, mentorship, laboratory management, and preparation of resumes.

Institutional training grants assure institutional ownership of, and responsibility for, the quality of trainees and their training programs as well as making available professional and career development services that may not otherwise be accessible to trainees on individual fellowships. In other words, in order to gain support for a training grant application, each institution has to review and strengthen all of its approaches to graduate education, a process from which all students benefit, not just those specifically supported by the training grant.

Individual fellowships, which support almost 18 percent of NRSA recipients at the predoctoral level and 35 percent at the postdoctoral level, are also awarded on a competitive basis and provide what is often a first step toward professional independence. Fellows develop their own proposals and, once an

[4] NRC. 1995. *Reshaping the Graduate Education of Scientists and Engineers.* Washington, DC: National Academy Press.

[5] NRC. 1998. *Trends in the Early Careers of Life Scientists.* Washington, DC: National Academy Press.

award has been made, are generally accorded a great deal of autonomy in pursuing their educational and research goals.

In the years since the NRSA program was established, funding for research training has grown overall much more slowly than the NIH budget. In 1975, when the NRSA program began, it supported 3,752 graduate students and postdoctoral fellows, and this grew to 11,565 slots by 1980. Thirty-two years after this, when the NIH budget had grown by more than 1300 percent (in nominal dollars), the NRSA program supported only 13,790 slots per year. The level of support has been approximately stable since 1995. It is important to note that these numbers refer to available "slots" on the grants, and since a given student is often appointed for more than one year, this measure of level of support overestimates the actual number of students supported by this mechanism, possibly by as much as two-fold. The NRSA provides but a small part of NIH's total support for graduate education—about 22 percent—while roughly two-thirds of the nation's graduate student support is in the form of Research Assistantships funded directly by NIH research grants.

The relative numbers of trainees at the predoctoral and postdoctoral levels have varied over the life of the program. More training was initially provided at the postdoctoral level, but by 2008, 55 percent of the trainees were predoctoral. The training mechanisms (i.e., trainee vs. fellow) have also changed. Although the growth in predoctoral training has predominantly been at the individual fellowship level, in absolute terms the trainees still far outnumber fellows. In contrast, the decline in postdoctoral training has been all at the fellowship level (see Table 1-1).

These numbers do not reflect the actual number of predoctoral and postdoctoral trainees and fellows since an individual may receive support for up to 3 years. In recent years the average median time for a trainee has been 2 years, which implies that the actual number of graduate students who have received predoctoral support is less than the total in the table by a factor of about two. The average period for fellows is slightly longer at 2.2 years. In summary, this means that about half of the 6,641 trainees in 2008 and a little over half of the 1,537 fellows in 2008 should be counted as also

TABLE 1-1 NRSA Trainees and Fellows, by Broad Field, 1975-2008

FY	1975	1980	1985	1990	1995	2000	2005	2006	2007	2008
Basic Biomedical Sciences										
Predoctoral Trainees (T32)	1,009	4,184	4,026	4,701	5,095	4,628	4,845	4,516	4,937	5,390
Predoctoral Fellowship (F30, F31)	27	21	80	123	411	400	862	962	1,074	1,154
Postdoctoral Trainees (T32)	474	2,200	2,128	2,232	2,191	2,310	2,598	2,463	2,386	2,475
Postdoctoral Fellowship (F32)	1,106	1,982	1,583	1,483	1,679	1,598	1,365	1,374	1,291	1,284
Total	2,616	8,387	7,817	8,539	9,376	8,936	9,670	9,315	9,688	10,303
Behavioral and Social Sciences										
Predoctoral Trainees (T32)	208	655	501	619	505	451	506	522	421	416
Predoctoral Fellowship (F30, F31)	125	74	41	58	101	207	214	183	154	147
Postdoctoral Trainees (T32)	32	368	392	398	411	465	460	401	350	301
Postdoctoral Fellowship (F32)	146	131	86	78	112	114	104	77	50	50
Total	511	1,228	1,020	1,153	1,129	1,237	1,284	1,183	975	914
Clinical Sciences (Excluding Health Services)										
Predoctoral Trainees (T32)	65	284	379	385	830	558	633	602	711	807
Predoctoral Fellowship (F30, F31)	3	2	8	153	108	123	190	209	222	228
Postdoctoral Trainees (T32)	346	1,408	1,714	1,287	1,553	1,467	1,893	1,930	1,872	1,968
Postdoctoral Fellowship (F32)	211	250	180	99	75	93	140	131	137	143
Total	625	1,944	2,281	1,924	2,566	2,241	2,856	2,872	2,942	3,146
Health Services Research Predoctoral										
NIH Predoctoral Trainees	0	3	10	11	6	0	20	27	28	28
NIH Predoctoral Fellows	0	0	1	1	4	8	14	7	8	8
AHRQ Predoctoral Trainees	0	0	8	22	19	3	71	67	76	71
AHRQ Predoctoral Fellows	0	0	0	0	0	0	1	2	1	2
Total	0	3	19	34	29	11	106	103	113	107
Health Services Research Postdoctoral										
NIH Postdoctoral Trainees	0	3	5	31	16	0	31	39	29	40
NIH Postdoctoral Fellows	0	0	1	2	1	1	4	3	3	5
AHRQ Postdoctoral Trainees	0	0	5	5	1	3	40	35	37	40
AHRQ Postdoctoral Fellows	0	0	0	3	0	0	2	2	3	2
Total	0	3	11	41	18	4	77	79	72	85
Total All Fields	3,752	11,565	11,148	11,691	13,118	12,429	13,993	13,552	13,790	14,555

supported in a previous year, which indicates that the actual number of trainees is about 3,700 individuals per year. This is consistent with NIH data on the number of Ph.D.s with some form of NRSA support, which, allowing for attrition, stands at about 3,000 Ph.D.s.

The relative distribution of trainee support between the biomedical sciences (70 percent) and all the other areas supported by the NRSA mechanism has changed little over the years. However, the number of NRSA-supported trainees in the social and behavioral sciences has declined recently. Until 2000 the percentage of trainee slots in this area was almost constant at 10 percent, but by 2007 it had fallen to 7.1 percent. In contrast, during this interval the number of supported trainee slots in clinical training increased from 18 percent to 21.3 percent.

Evaluation of the NRSA Program

A number of attempts have been made to quantify the value of NRSA training. In 1984, NIH conducted an extensive evaluation of the program, with a follow-up evaluation in 1998.

These evaluations showed that NRSA trainees and fellows graduated 3 months sooner than those without NRSA support at the same institutions and 7 months sooner than their counterparts at institutions without any NRSA grants. In addition, nearly 58 percent of the NRSA trainees and fellows had received their doctorate by the age of 30, as compared with 38.9 percent and 32.3 percent for the non-supported doctorates from NRSA and non-NRSA institutions, respectively. One factor that may play a role in the difference is that if students are not NRSA supported, they may have significant teaching assistantship responsibilities, which may contribute to a longer time to degree.

Following graduation, NRSA predoctoral trainees and fellows were more likely to move quickly into research positions. In fields where postdoctoral study was common, 93 percent of the trainees and fellows reported having definite postdoctoral commitments, compared to 80 percent of graduates in the same fields at non-NRSA institutions. It is difficult to report career path progression accurately, since people move in and out of positions and postdoctoral appointments tend not to be for fixed time periods, but NRSA trainees and fellows appeared to be more likely to move into faculty or research positions. About 37 percent of the NRSA recipients held faculty positions 7 to 8 years past the doctorate, compared to 16 percent from non-NRSA institutions. Also, 87 percent of previous NRSA trainees and fellows, compared to 72 percent from non-NRSA institutions, were in research-related positions in academia, industry, or other research settings.

If one examines research grants and publications as measures of research productivity, one finds that the NRSA trainees and fellows were more likely to have grants and more publications. For example, among the 1981-1988 Ph.D.s who had applied to NIH by 1994 for research grant support, the success rate for NRSA recipients was 67 percent, compared with 47 percent for non-NRSA institution graduates. With regard to publications, NRSA predoctoral trainees and fellows in the 1981-1982 cohort had a median number

BOX 1-3
NIH Evaluations of the NRSA Program

A 1984 evaluation of formal NIH-sponsored research training (which included programs existing before the establishment of the NRSA) found that a larger percentage of participants in NIH training programs completed their doctoral programs and went on to NIH-supported postdoctoral training than among their counterpart trainees. Furthermore, those supported by the NIH during their predoctoral studies were more likely to apply for and receive NIH research grants, authored more articles, and were cited more often by their peers.

At the postdoctoral level, both those appointed to institutional training grants and recipients of individual fellowship awards were more likely to pursue research careers than their colleagues without formal NIH research training, and the former were more successful by such measures of achievement as obtaining research funds, publication, and citations by their peers. These differences were true for M.D.s with postdoctoral research training as well as for Ph.D.s.

A follow-up to the 1984 evaluation of the NRSA Predoctoral Program was conducted in 1998, and many of the findings from the earlier study were found to still hold true. The 1998 study examined the characteristics of NRSA-supported doctorates between FY 1981 and 1992 against their Ph.D. counterparts at institutions with NRSA training grants who did not receive this type of support and at another group at institutions without NRSA grants.[a] The study found that 80 percent of the NRSA trainees or fellows received their Ph.D. from 50 institutions that ranked in the top quarter of all biomedical sciences programs, and nearly 60 percent received their degree from the top 25 institutions. The completion rate for students supported by the NRSA program was an estimated 76 percent and was comparable to that of other merit-based, national fellowship programs and of students in high-quality doctoral programs.

[a] National Institute of General Medical Sciences, 1998. Available at http://publications.nigms.nih.gov/reports/mstpstudy/.

of publications twice that of doctorates from institutions without NRSA grants, 8.5 publications as compared to 4. Non-NRSA-supported Ph.D.s at NRSA institutions also had fewer publications by almost as large a margin, 5 publications as compared with 8.5.

Such studies do not, of course, indicate whether the success of former NRSA trainees and fellows reflects the training they received, the selection process, or a combination of factors. In addition, as alluded to above, these data have to be viewed with caution because a non-NRSA student in other funded positions such as an assistantship may have to spend additional time in activities not directly related to his or her research. Nonetheless, these findings do suggest that there are significant strengths and achievements within the NRSA program at the predoctoral level.

In assessing the needs for training support in the biomedical, behavioral, and clinical sciences, it is important to understand the role of NRSA awards. Although, as indicated above, NRSA awards support only a small fraction of the total number of trainees, the role of these awards in the training process is extremely important for the following reasons: First, they serve to attract highly qualified people into biomedical research. As discussed above, a good example of this is the Medical Scientist Training Program (M.D./Ph.D.), which has a well-established track record for launching physicians into productive—and often outstanding—research careers. Second, they have served over the years to direct training into specific research areas, which have often been emerging areas for which other mechanisms may not be available, such as molecular medicine, biophysics, and bioinformatics, and, as such, they have stimulated cross-disciplinary research. Third, they establish innovative training standards not only for NRSA awardees, but also for all trainees, regardless of their mechanisms of support. This last point is of great importance, and, indeed, over the past decade this may have been one of NRSA program's most important contributions.

A report published in 2006 by ORC Macro for the NIH examined the career achievements of NRSA postdoctoral trainees and fellows from 1975 to 2004. The results of this study were inconclusive. By some measures the trainees had an advantage, and by other measures they did not. Most tellingly, the study concluded that after 12 years the postdoctorates who received NRSA support were largely indistinguishable from those who did not. Unfortunately the study is flawed: The postdoctoral pool is radically different from the predoctoral pool in that more than 50 percent of the postdoctorates are internationals and thus unable to become NRSA trainees because of the citizenship restrictions. Presumably, the international pool contains a significant number of equally talented and creative individuals who are well equipped to compete with the U.S.-trained postdoctorates, thus rendering any relative performance conclusions moot.

NATIONAL RESEARCH COUNCIL ROLE IN ASSESSING PERSONNEL NEEDS

The Study's Origins

Since 1975, the NRC has issued regular reports on the supply of biomedical and behavioral researchers in the United States and the likely demand for new investigators. This con-

BOX 1-4
National Research Service Award Act of 1974 (P.L. 93-348)

Sec. 472. (a) (3) Effective July 1, 1975, National Research Service Awards may be made for research or research training in only those subject areas for which, as determined under section 473, there is a need for personnel.

Sec. 473. (a) The Secretary shall, in accordance with subsection (b), arrange for the conduct of a continuing study to—
(a) establish (A) the Nation's overall need for biomedical and behavioral research personnel, (B) the subject areas in which such personnel are needed and the number of such personnel needed in each such area, and (C) the kinds and extent of training which should be provided such personnel;
(b) assess (A) current training programs available for the training of biomedical and behavioral research personnel which are conducted under this Act at or through institutes under the National Institutes of Health and the Alcohol, Drug Abuse, and Mental Health Administration, and (B) other current training programs available for the training of such personnel;
(c) identify the kinds of research positions available to and held by individuals completing such programs;
(d) determine, to the extent feasible, whether the programs referred to in clause (B) or paragraph (2) would be adequate to meet the needs established under paragraph (1) if the programs referred to in clause (A) of paragraph (2) were terminated; and
(e) determine what modifications in the programs referred to in paragraph (2) are required to meet the needs established under paragraph (1).

(c) A Report on the results of the study required under subsection (a) shall be submitted by the Secretary to the Committee on Energy and Commerce of the House of Representatives and the Committee on Labor and Human Resources of the Senate at least once every four years.

tinuing series of reports was initiated by the U.S. Congress with the passage of the National Research Service Award Act of 1974,[6] which consolidated the variety of research training activities then sponsored by the National Institutes of Health and the Alcohol, Drug Abuse, and Mental Health Administration into a single, inclusive program: the National Research Service Awards.

In the same legislation, Congress decreed that National Research Service Awards be made only in areas for which "there is a need for personnel" and directed that the National Academy of Sciences be asked to provide periodic guidance on the fields in which researchers were likely to be needed and the numbers that should be trained (see Box 1-1). The present study is the twelfth completed by the NRC, the operating arm of the National Academy of Sciences, the Institute of Medicine, and the National Academy of Engineering.

Past Reports

To date there have been 12 assessments of the "national need" for research personnel in the biomedical and behavioral sciences conducted by the NRC, and while the purpose of these assessments was to provide NIH and the Congress with information that could be used to make budget decisions, the manner in which the assessments should be conducted or the scope of the investigation has been left to the discretion of the NRC. Those who conducted the first assessment in 1974 chose to limit its study to the demand for faculty, as shaped by federal support for university-based research and enrollments in higher education. It interpreted the faculty research areas broadly to include the basic biomedical sciences, the behavioral sciences, the clinical sciences, and health services research. In their first full-length report, issued the following year, committee members concluded that Ph.D. production in the biomedical and behavioral sciences was more than adequate to meet existing demand.

In studies conducted from 1977 to 2002, subsequent committees incorporated employment trends in industry, government, teaching hospitals, and similar settings in their assessments of the demand for biomedical research personnel. In 1985 and 1989, the committees recommended additional research training in the basic biomedical sciences, due in part to increased demand from the biotechnology industry. The 1994 committee advised that training in the biomedical sciences be maintained at existing levels but called for an increase in research training in the behavioral sciences.

The 1994 report also redefined the scope of its investigation by highlighting a number of issues that were of particular concern to the administrators of the NRSA program. These included the growth of the Ph.D. population in the biomedical sciences, the decline in the number of physician researchers, the recognition that the behavioral sciences should play a more important role in health care, the decline in the relative share of graduate students funded by training grants, and the lack of promising research career options for young scientists, among other concerns. These and other issues related to the state of the nation's research workforce have to this day been the focus of considerable attention and discussion and the subject of numerous national meetings, public policy studies, and congressional hearings.

Some of this activity was prompted by the 1994 "national needs" report itself and the subsequent response to it by the NIH, the Agency for Health Care Policy and Research (AHCPR), and the Health Resources and Services Administration.[7] Of the eight major recommendations put forth by the 1994 committee, the agencies focused on two: increasing the stipends for trainees and fellows, and evaluating the NRSA program. Although they did not require any new steps, the suggestions put forth in the 1994 report for maintaining training levels in the basic biomedical sciences and for increasing the numbers of underrepresented minorities were also adopted. At the same time, however, recommendations for increasing the number of NRSA training grants and fellowships in the behavioral and clinical sciences, oral health, nursing, and health services research were not acted upon, prompting a congressional inquiry in the fiscal year 1997 appropriations for the NIH. In explaining their actions to Congress, the NIH and the other agencies indicated that they had focused on the highest priority recommendations and were likely to continue to direct additional research training monies to stipends until NRSA stipend levels were comparable to other sources of research training support.

In the meantime, other reports on clinical research and training were being issued. In its 1994 report *Careers in Clinical Research: Obstacles and Opportunities,*[8] the Institute of Medicine (IOM) recommended (a) further evaluating clinical research training programs, (b) redirecting funds to the most effective forms of clinical research training, (c) emphasizing training programs that provide an opportunity to earn an advanced degree in the evaluative sciences, (d) increasing the number of M.D. /Ph.D. and D.D.S./Ph.D. programs that train investigators with expertise in patient-oriented research, and (e) expanding initiatives that reduce educational debt, either through tuition subsidies, as in the case of M.D. /Ph.D. programs, or loan forgiveness.

In 1997 an NIH panel produced a report on the status of clinical research in the United States, including the recruitment and training of future clinical researchers.[9] The panel recommended: (a) initiating clinical research training programs

[6] National Research Service Award Act of 1974, Public Law 93-348. 93rd Congress, June 28, 1974.

[7] NIH. 1997. Implementing the Recommendations in the 1994 Report from the National Academy of Sciences: Meeting the Nation's Needs for Biomedical and Behavioral Scientists. Unpublished report to Congress. Washington, DC: NIH.

[8] IOM. 1994. *Careers in Clinical Research: Obstacles and Opportunities.* Washington, DC: National Academy Press.

[9] NIH. 1997. *Director's Panel on Clinical Research. Report to the Advisory Committee to the NIH Director.* Washington, DC: NIH.

aimed at medical students, such as M.D./Ph.D. programs for clinical research, (b) ensuring that postdoctoral training grants include formal training in clinical research, (c) providing new support mechanisms for young and mid-term clinical investigators, and (d) taking steps to reduce the educational debt of clinical investigators. Some of these recommendations had already been put in place at NIH before the panel report was completed. These included: (1) a program to bring medical and dental students to NIH's Maryland campus for a one to two years of clinical research training; (2) new NIGMS guidelines for its M.D./Ph.D. program to encourage research training in fields such as computer sciences, social and behavioral sciences, economics, epidemiology, public health, bioengineering, biostatistics, and bioethics; and (3) three new career development awards for young and mid-career investigators focused on careers in clinical research. This current report will again stress the value of additional training in informatics, social and behavioral sciences, epidemiology and biostatistics, and bioethics.

In a related area, another Institute of Medicine committee published the results of a study on the training and supply of health services researchers. In its 1995 report, *Health Services Research: Workforce and Educational Issues*, the IOM committee endorsed the number of training positions in health services research that had been recommended in the 1994 "national needs" study. The committee also encouraged the AHCPR to focus its training funds on areas in which researchers were reported to be in short supply, such as outcomes measurement, biostatistics, epidemiology, health economics, and health policy, and to set aside a number of institutional training grants for innovative research training programs. In response, the Agency for Healthcare Research and Quality made "innovation awards" to 10 institutions in 1998 to support the design and implementation of new models of health services research training.

Just as clinical research training has been the subject of multiple studies since the 1994 NRC report, so too has doctoral training in the basic biomedical sciences; some of these studies have also encompassed the behavioral sciences. In a 1995 study commissioned by the National Science Foundation, the NRC's Committee on Science, Engineering, and Public Policy reviewed graduate education across the biological, physical, and social sciences and engineering. The report, *Reshaping the Graduate Education of Scientists and Engineers*, urged universities to provide a broader range of academic options and better career guidance for their students and called for federal agencies to encourage this trend through training grants. Partly in response, new NIGMS training grant guidelines encouraged graduate programs to provide opportunities for trainees to take internships in industry and gain experience in teaching as well as to provide them with information on the career outcomes of graduates and with seminars on employment opportunities and career counseling.

Shortly after *Reshaping the Graduate Education of Scientists and Engineers* was published, William Massy and Charles Goldman published a paper using mathematical modeling to demonstrate that U.S. universities were overproducing Ph.D.s in fields such as engineering, mathematics, and the biological sciences, thus creating a group of Ph.D.s that was chronically underemployed. They concluded that increases in research funding would be likely to worsen job prospects for Ph.D.s and urged academic departments to bring the production of Ph.D.s into balance with the demands of the labor market—not just the demand for research and teaching assistants.

In 1996 the Federation of American Societies for Experimental Biology convened a conference to discuss these topics, which concluded with participants opposing any national regulation of the size of graduate programs. Instead, the participants called for data on employment trends to be made available to students and for universities to "self-regulate" the size of their graduate programs. Institutions were urged to refrain from admitting graduate students in order to meet needs for teaching or research assistants. Information about institutions that have aggressively reduced the size of their biomedical graduate programs is lacking.

Subsequently, an NRC committee examining the career paths of young investigators issued a report in the fall of 1998 that also called for restraining the rate of growth in the number of graduate students in the life sciences. In *Trends in the Early Careers of Life Scientists*, the NRC committee noted that the number of Ph.D.s awarded annually might already be too high and called for prospective students to be better informed about research careers. The committee urged the government to consider restricting the numbers of graduate students supported by research grants and to emphasize research training via training grants and fellowships, acknowledging at the same time that the number of Ph.D.s produced is ultimately determined at individual and campus levels.

Although universities control the influx of graduate students into their programs, experience shows that they (unsurprisingly) tend to include their specific workforce needs in their calculations, and the data clearly indicate that they have not collectively restricted the growth of the graduate student pool. The fact of the matter is that the bulk of the creative work and discovery in the biomedical sciences is driven by R01 grants to individual faculty members. These faculty members are under immense pressure to be productive, and a workforce composed of trainees is vastly more effective than one composed of technical assistants. The trainee workforce is also much less expensive to the individual grant than senior research personnel such as instructors or research faculty.

It has to be recognized that this system has been enormously successful over many years; it also has to be acknowledged that if R01 support increases, then the number of trainees will ineluctably increase in lockstep, as happened during the recent doubling of the NIH budget. And if there are insufficient U.S. national trainees, then faculties will aggressively look to international Ph.D.s to fill the gap. No amount of well-intentioned urging of institutions to self-correct will change this equation. The important question to be asked is, If this is such a successful model in terms of scientific progress and return to the taxpayers' investment, then what responsibility do we have to these young men and women as they complete their contributions to research during their training period? This will be addressed in the recommendations below.

The 2000 assessment of the need for research personnel, which was begun in 1997, concentrated on the three broad fields of biomedical, behavioral, and clinical research, with dental, nursing, and health services research included in the third category. A major change from earlier reports was the movement away from detailed recommendations on the number of individuals who should be trained under the NRSA program and the use instead of a demographic life-table model, proposed in the 1994 report, to estimate the size of the workforce each year up to 2005. The life-table model was adopted because previous models of supply and demand had proved unreliable for valid forecasts. The life-table-based analysis considered such factors as the average age of current investigators in the biomedical and behavioral sciences, the number of Ph.D.s expected to join the work-force in the years ahead, and the likely effect of retirements and deaths. The committee supplemented this analysis by reviewing such indicators of short-term demand as trends in faculty and industry hiring and perceptions of the job market by recent Ph.D.s. The model was implemented for the bio-medical and behavioral sciences and showed that the supply of doctorates, even if at a low level, would be much greater than the need for researchers during the projection period.

This finding prompted the committee to recommend that degree production be maintained at current levels in all three broad fields. It did, however, make recommendations for increases in clinical research training related to patient care and in interdisciplinary research in the biomedical and behavioral fields. Many of the committee's recommendations concerned the administration of the NRSA program; the NIH, in response to the report, established new guidelines for stipends at the predoctoral and postdoctoral levels, supported the recommendation on early completion of doctoral and postdoctoral education and training, and supported limitations on the period of NRSA support at the predoctoral and postdoctoral levels.

The study immediately preceding this one was begun in late 2002, and the study report was published in 2005. That study built on the 2000 assessment and used the same life-table analysis to make projections from 2005 to 2011 in each of the main fields. Individual chapters in the report were devoted to oral health, nursing, and health services research, but no projections of the workforce were made in these areas since there were insufficient data. Because the numbers of individuals working in these areas are less than in the three major fields, a life-table model was considered impractical. In terms of workforce projections, the study committee concluded that training in the biomedical, clinical, and behavioral and social sciences should remain at least at the 2003 level, and training after 2003 should be commensurate with the rise in the total NIH extramural research funding in the three fields.

There were several reasons for the committee's recommendation concerning the level of NRSA support and for not changing the mechanisms for support. The committee members examined the workforce from the perspective of its size, composition, and age distribution and concluded that it had been fairly stable over recent years. In addition, a life-table analysis of the workforce in each of the three fields showed no signs of over- or under-employment during the period from 2005 to 2011. Degree production, specifically in the biomedical sciences, had leveled off, and the size of the postdoctoral pool was declining. All of these factors led the committee to believe that no change in the level of NRSA support was necessary. It did recommend an expansion of the MSTP by 20 percent and the greater involvement of clinical, health services, and behavioral and social sciences in the program.

Other recommendations were made concerning the structure of the NRSA program—in particular, to provide postdoctoral fellows with the normal employee benefits of the institution and to use NRSA awards to target emerging and interdisciplinary areas of research. The committee made a strong recommendation to restructure the career development grants (K awards) to have fewer mechanisms and to implement them consistently across the NIH. The recommendation also called for more flexibility in the management of K grants to allow for transition awards from senior postdoctoral status to independent research positions and for awards to allow individuals to maintain research careers during periods when personal demands prevent full employment status.

The recommendations were generally not acted on by NIH. This may in part be due to a set of recommendations that came from another NRC committee concerning the long duration of postdoctoral training in the biomedical sciences and the time it takes to become an independent researcher. This issue was of prime importance at the NIH, and in response to the recommendations from this report the NIH introduced the K99/R00 award, aimed exclusively at Ph.D.s, to provide 5 years of support during the transition from postdoctoral to faculty status. The aim of this program was to maintain and increase a strong cohort of new, well-trained, NIH-supported independent investigators capable of competing for NIH support.

THE CURRENT STUDY

The current study began in 2008 with the selection of an expert committee to guide the study. The first meeting was in the late spring of that year and was followed by six more meetings, with the last taking place in early 2010. The committee was charged, as were the past few, with the task of examining the current workforce and projecting the need for additional personnel in the biomedical, behavioral and social, and clinical sciences as they pertain to the research mission of the NIH. Individual chapters of this study report are devoted to these fields, and special attention was given to the clinical fields of oral health, nursing, and health services research, with the inclusion of separate chapters, as required in the Statement of Task.

In assessing the characteristics of the past and current workforce, datasets from the National Science Foundation and the Association of American Medical Colleges were used. An additional dataset that became available near the end of the study came from the National Research Council Study of Research Doctorate Programs. The value of these datasets depended on whether the study fields were included in their taxonomy or data were collected on degree types. In particular, the clinical sciences posed a problem, since data are not readily available on researchers with medical degrees, and it is difficult to distinguish between basic and clinical research in medical school departments.

Projections for the size of the future workforce are provided in Appendices D and E using a life-table model and a systems dynamics model, respectively. The projections were based on different estimates of researchers entering the workforce from doctoral programs and through U.S. immigration and emigration. The task of projecting the workforce was particularly difficult because of the state of the current economy and the unknown future demand for researchers.

RECENT DEVELOPMENTS

When the study committee first met, the economy was showing the first signs of a downturn that would deepen to a recession and eventually dramatically affect employment and economic development around the world. As the committee reviewed the state of research training in subsequent meetings, it became clear that a projection of the future research workforce in the biomedical, behavioral, and clinical sciences would be difficult to develop from available data and would furthermore be risky, given the uncertain duration and severity of the recession. The workforce was contracting with a decline in industrial employment, especially in the pharmaceutical area, and academic institutions had slowed their expansion of faculty and research facilities in response to the reduced values of endowments and state appropriations as well as the overall economic uncertainty. At the same time, faculty members were delaying retirement, and this in turn was reducing the hiring of junior faculty members. These and other conditions might call for a reduction in research training, even though enhancements to training programs would be of great benefit.

Given the current economic realities, the committee recognized that the NIH budget would not allow for the implementation of recommendations that would require new funds. The only possibility was the reallocation of existing resources, and NIH was in the best position to realign their agenda. The committee debated how it could nevertheless fulfill its charge and assist NIH in its decision making, and it concluded that in order to maintain the high standards of the programs and continue to attract the best students into research careers, it would go forward with its recommendations to improve training programs but would prioritize the most important ones and identify the costs.

The committee was unanimous in its recommendations and prioritization except for the one recommendation that called for an increase in the indirect cost rates for NRSA awards (see below).

RECOMMENDATION ON NRSA POSITIONS

The primary task of this committee is to recommend the number of NRSA positions for 2010-2015. Based on the need to maintain a strong research workforce, we recommend that the total number of NRSA positions in the biomedical and clinical sciences should remain at least at the fiscal year 2008 level and that in the behavioral sciences they should increase back to the 2004 level. This increase will require the addition of about 370 training slots at a cost of about $15 million. The committee also recommends that future adjustments in the number of NRSA positions be closely linked to the total extramural research funding in the biomedical, clinical, and behavioral sciences. In recommending this linkage, the committee realizes that a decline in extramural research would imply that there should also be a decline in training.

PRIORITIES FOR OTHER RECOMMENDATIONS WITH LARGE COSTS IMPLICATIONS

In addition to the recommendation on the number of NRSA positions, there are several other recommendations in this report that require additional resources. Most call for modest increases and could be accomplished by a shifting of resources within an institute or center. Three, however, would require significant additional funds. They are listed below in order of priority. In prioritizing these actions, the committee considered both their costs and their merits as well as likely future constraints on the NIH budget.

First, NIH should reinstitute its 2001 commitment to increase stipends at the predoctoral and postdoctoral levels for NRSA trainees. This should be done by budgeting regular, annual increases in postdoctoral stipends until the $45,000 level is reached for first-year appointments, and stipends should increase with the cost of living thereafter. Predoctoral stipends should also be increased at the same proportional rate as postdoctoral stipends and revert to cost-of-living increases once the comparison postdoctoral level reaches $45,000. The estimated annual cost when fully implemented would be about $80 million, or 10 percent of the NRSA budget. If phased in over four years, the $20 million dollar annual increase would be about 2 percent of the NRSA training budget. This should not be implemented by reducing the number of individuals supported by the NRSA program.

Second, the size of the MSTP should be expanded by at least 20 percent—and more, if financially feasible—with an emphasis on clinical, behavioral, and social sciences in the expansion. This program has been highly successful in producing researchers in basic biomedical, transitional, and clinical research.[10] Again, recommendations to increase MSTP training were made in previous NRSA reports, and an increase was endorsed by NIH following the 2000 NRSA report. Currently there are 911 MSTP slots at an average cost of $41,806 per slot. An increase by 20 percent to about 1,100 slots would increase the MSTP budget by about $7.6 million, or 1 percent of the NRSA budget. Phasing it in over 4 years would not have a significant impact on the budget.

Third, NIH should consider an increase in the indirect cost rate on NRSA training grants and K awards from 8 percent to the negotiated rate currently applied to research grants. The increase in the rate could be phased in over time. This would require a five- or six-fold increase in indirect costs, or $191 million for the NRSA program at its current size, assuming that stipends amount to about half of the awards, and $338 million for K awards. There was not unanimity within the committee on this recommendation because of concerns about costs and the reduction in program size that could result with a stagnant NIH budget. An increase of $529 million is significant, even in light of the reasoning that NIH should share the full cost of administrating these programs, but the committee wanted to record its support for the measure and its hope that it could be implemented at some point.

The committee had the option of putting forth recommendations without prioritization, but it believed that guidance in these difficult economic times would add to the weight and credibility of the recommendations.

[10] The National Institute of General Medical Sciences. 1998. Available at http://publications.nigms.hix.gov/reports/mstpstudy/,

2

Crosscutting Issues

This chapter addresses some training issues that cut across disciplines and that pertain generally to the National Research Service Award (NRSA) and other training mechanisms. The committee considered a number of these issues and identified the following as ones that require attention:

- financial support of the trainees,
- cost recovery by educational institutions,
- participation by underrepresented minorities,
- responsible conduct of research,
- National Institutes of Health (NIH) data systems
- the emerging role of biomedical informatics,
- workforce data requirements, and
- international workforce.

FINANCIAL SUPPORT OF THE NRSA PROGRAM

The National Research Council (NRC) in the report, *Addressing the Nation's Changing Needs for Biomedical and Behavioral Scientists* (2000), recommended "that stipends and other forms of compensation for those in training should be based on education and should be regularly adjusted to reflect changes in the cost of living." In 2001 the NIH concurred with this recommendation and set a target of $45,000 per year for new postdoctoral scholars, with the expressed intention to raise the then-current stipends by 10 to 12 percent per year until this target was reached. Additionally, the NIH pledged to budget for annual cost-of-living increases to keep pace with inflation and to prevent the loss of buying power seen as stipends had remained largely flat over the previous decade. However, stipend levels at both the predoctoral and postdoctoral levels have not kept pace with the NIH targets. There were increases in 2000, 2002, and 2003 at all levels that conformed to the goals set by NIH in 2001, but in 2004 the increase was less than half the recommended level, and from 2006 to2008 there were no increases (see Table 2-1). Of course, from fiscal year 1999 to 2003 the NIH budget was doubling, but from fiscal year 2004 to 2008, the budget was essentially unchanged, and, in fact, during this interval it lost nearly 13 percent of its purchasing power. In fiscal year 2009, there was a small increase of about 1 percent in the NIH appropriation, and a similarly modest increase was enacted for fiscal year 2010. These modest increases, well below the levels of biomedical research inflation (as measured by the Biomedical Research and Development Price Index in the respective years), were independent of the nearly $10 billion of American Recovery and Reinvestment Act (ARRA) funding that was awarded in fiscal year 2009 for NIH research. The ARRA initiative was driven by the goal of creating or saving jobs, and the funding for NIH was explicitly a one-time infusion of "stimulus" funds that were to be entirely obligated within 2 years for primarily short-term research projects. None of the ARRA funds were to be used to address structural problems in research training programs. The President's NIH budget request for 2011 contains a 6 percent increase for NRSA trainee stipends, but at the cost of a 1 percent decrease in the number of training slots.

In addition to supporting the originally targeted stipend increases, the 2005 NRC report also recommended that NIH develop a mechanism for support such that postdoctoral fellows receive the employee benefits of the institution in which they are located. It is clear that all postdoctoral fellows should be supported in terms of receiving appropriate benefits at each institution. However, the fact that there are two categories of postdoctorates—NRSA trainees and postdoctoral employees—is a consequence of a federal decision to pay trainees a stipend (as opposed to a salary). As such, following the requirements of the Internal Revenue Service imposes different tax liabilities on the two groups of postdoctorates. Trainee postdoctorates cannot be categorized as employees, they do not pay Federal Insurance Contribution Act (FICA), and they cannot receive benefits in the same fashion as employees. However, this should not mean that they cannot receive parallel support systems.

To demand then that all postdoctorates be treated identically becomes the training equivalent of trying to put a square

TABLE 2-1 NRSA Stipends

Years	2001	Percent	2002	Percent	2003	Percent	2004	Percent
Predoctorate	$ 16,500	10	$ 18,156	10	$ 19,968	10	$ 20,772	4
Postdoctorate Level 0	$ 28,260	5	$ 31,092	10	$ 34,200	10	$ 35,568	4
Postdoctorate Level 1	$ 29,832	5	$ 32,820	10	$ 36,108	10	$ 37,476	4
Postdoctorate Level 2	$ 35,196	5	$ 38,712	10	$ 40,920	6	$ 41,796	2
Postdoctorate Level 3	$ 36,996	5	$ 40,692	10	$ 42,648	5	$ 43,428	2
Postdoctorate Level 4	$ 38,772	5	$ 42,648	10	$ 44,364	4	$ 45,048	2
Postdoctorate Level 5	$ 40,560	5	$ 44,616	10	$ 46,404	4	$ 46,992	1
Postdoctorate Level 6	$ 42,348	5	$ 46,584	10	$ 48,444	4	$ 48,852	1
Postdoctorate Level 7	$ 44,412	5	$ 48,852	10	$ 50,808	4	$ 51,036	0
Years	2006	Percent	2007	Percent	2008	Percent	2009	Percent
Predoctorate	$ 20,772	0	$ 20,772	0	$ 20,772	0	$ 20,976	1
Postdoctorate Level 0	$ 36,996	4	$ 36,996	0	$ 36,996	0	$ 37,368	1
Postdoctorate Level 1	$ 38,976	4	$ 38,976	0	$ 38,976	0	$ 39,360	1
Postdoctorate Level 2	$ 41,796	0	$ 41,796	0	$ 41,796	0	$ 42,204	1
Postdoctorate Level 3	$ 43,428	0	$ 43,428	0	$ 43,428	0	$ 43,860	1
Postdoctorate Level 4	$ 45,048	0	$ 45,048	0	$ 45,048	0	$ 45,504	1
Postdoctorate Level 5	$ 46,992	0	$ 46,992	0	$ 46,992	0	$ 47,460	1
Postdoctorate Level 6	$ 48,852	0	$ 48,852	0	$ 48,852	0	$ 49,344	1
Postdoctorate Level 7	$ 51,036	0	$ 51,036	0	$ 51,036	0	$ 51,552	1

SOURCE: NIH Stipend Levels, http://grants.nih.gov/nrsa.htm.

peg into a round hole. The simplest solution is to create a square hole, which offers all the advantages of a round one. With increasing awareness of this contradictory issue, many institutions have devised creative solutions aimed at maintaining parity between the two groups of postdoctorates. Thus, although trainee postdoctorates cannot usually be included on employee health coverage, highly competitive insurance can in fact be purchased, usually more cheaply than the employee plan and offering better coverage because the postdoctorates tend to be younger than the general employee population. It is true that postdoctorate trainees cannot get university retirement benefits, but the cash value lost is in fact less than the gain in income from not paying FICA. Not being on the human resources list of employees may cause frustration with issues such as parking and child care. However, payment of a very nominal sum to the trainee as salary solves this problem without jeopardizing his or her status as primarily a stipend-receiving trainee.

Recommendation 2–1: NIH should reinstitute its 2001 commitment to increase stipends at the predoctoral and postdoctoral levels for NRSA trainees. This should be done by budgeting regular, annual increases in postdoctoral stipends until the $45,000 level is reached for first-year appointments, and stipends should increase at the cost of living thereafter. Predoctoral stipends should also be increased at the same proportional rate as postdoctoral stipends and should revert to cost-of-living increases once the comparison postdoctoral level reaches $45,000.

The estimated annual cost when fully implemented would be about $80 million, or 10 percent of the NRSA budget. If phased in over 4 years, the $20 million dollar annual increase would be about 2 percent of the NRSA training budget. This should not be implemented by reducing the number of individuals supported by the NRSA program. The committee notes that the Obama administration has recently proposed a 6 percent increase in stipends for 2011 over the 2010 level. This is a positive step on the way to the recommended stipend levels.

INDIRECT COST RATES

It is debatable whether training grants lead to a superior or better trained individual in the long run. The rather limited amount of data and related evaluations are certainly consistent with this conclusion, although the degree of significance is not high. Of course, institutions tend to put their best students on training grants, and the outcomes likely should be better. However, to a degree this is immaterial. The key role of NRSA training lies in the fact that the applications are scrupulously peer reviewed. This, in turn, drives institutions to review their approaches to graduate education on a regular basis and encourages them to establish best practices that can then be honed through the peer-review system. As a result, in the competition to recruit graduate students, even non-NRSA schools will feel the pressure to create an excellent training environment. In this sense, over the past decade or so the training grants have served as major drivers of innovation in graduate education, and this may be their greatest contribution to the biomedical research training environment.

Thus, the many requirements and expectations for support activities centered on training grants, such as minority recruiting, education in the responsible conduct of research (RCR), and professional development, have improved the overall tenor of graduate education immensely over the past decade. These expectations have come at a considerable price, however, and this price has largely been covered by institutional funds. The current 8 percent indirect cost allowance (which is not applied to tuition and fees, health insurance, and expenditures for equipment) is insufficient to cover the university's costs. Similarly, the K awards, which have served a tremendously important role is fostering the early career development of both basic and clinical biomedical researchers, use the same facilities as funded researchers and generate their own significant administrative costs, yet they have the same 8 percent indirect cost allowance, which as best one can determine is arbitrary and is based on no carefully argued rationale.

The indirect cost rate has varied over time. Prior to 1958, the rate for training grants was set at 8 percent by the Department of Health, Education and Welfare, and the rate has remained at this level to this day. The rate on non-training grants was increased to 15 percent in 1958 and to 20 percent in 1963. In 1966 the ceiling on indirect costs was removed, but in 1991 OMB Circular A-21 imposed a cap of 26 percent on the recovery of administrative costs from research grants, and the cap has remained unchanged in spite of compelling documentation by the Council on Governmental Relations that these costs in all the top research universities sampled were significantly greater than could be recovered under the 26 percent cap. As a result, many of the improvements in graduate education and early career development, such as special skills courses, increased focus on interdisciplinary studies, increased diversity, RCR training, and career advising and outcomes research, have all come through resources provided by the institutions applying for NRSA support.

The committee finds that the institutional commitment of resources for training grants and K awards is no different from that for research grants. Graduate and postdoctoral trainees require the same facilities in the laboratory as their counterparts in the same laboratory who are supported on a research grant that carries the institution's negotiated rate. Likewise, individuals on K awards act in a capacity similar to that of a researcher on an R01 or other research project grant. The committee was not unanimous with regard to the NRSA part of the following recommendation because of concerns about costs and the reduction in program size that could result from a stagnant NIH budget, but it did endorse the increase for the K awards.

Recommendation 2–2: NIH should consider an increase in the indirect cost rate on NRSA training grants and K awards from 8 percent to the negotiated rate currently applied to research grants. The increase in the rate could be phased in over time, for example, by increasing the rate by 8 percent each year until the negotiated rate is reached.

Implementing this recommendation would require a five- or six-fold increase in indirect costs, or $191 million for the NRSA program at its current size and $338 million for K awards. An increase of $529 million is significant, even in light of the reasoning to have NIH share the full cost of administrating these programs, but the committee wanted to record its support for the measure and its hope that it could be implemented at some point.

RESPONSIBLE CONDUCT OF RESEARCH

NIH's NRSA grants require awardee institutions to establish specific curricula in the responsible conduct of research. Indeed, in late 2009 NIH issued a detailed policy statement outlining its expectations along with recommendations on how to approach these expectations (NIH policy statement NOT-OD-10-019). It is worth noting that National Science Foundation (NSF) has issued similar requirements for all personnel participating in NSF-funded research, including undergraduate students.

The requirement of RCR training within the T32 mechanism has led to the development of curricula and educational practices for NRSA that would benefit all students and postdoctorates being trained in biomedical and health sciences research and should be required in all graduate and postdoctoral education programs supported by the NIH. Since with relatively few exceptions the majority of this training takes place in laboratories supported by NIH research program grant (RPG) mechanisms, this leads to the expectation that all students supported by the NIH (i.e., including those students supported by R01 grants during their education) should be required to benefit from such training.

Recommendation 2–3: All graduate students and postdoctoral fellows who are supported by the NIH on RPGs should be required to incorporate certain additional "training-grant-like" components into their regular academic training program. These should include RCR training, exposure to quantitative biology, and career guidance and advising.

NIH DIVERSITY INITIATIVES WITHIN THE NRSA PROGRAM

Minorities[1] now account for 50 percent or more of the population in several states, and at some time within

[1] Minorities are defined as Blacks, Hispanics of Puerto Rican , Cuban, or Mexican extraction, American Indians, and Pacific Islanders. Does not include Asian.

the foreseeable future the demographics of the country will have changed to the point where current minority groups will be approaching a majority of the citizenry. The NIH is committed to increasing the diversity of the biomedical workforce. There is no doubt that over the past 15 years NIH-supported training programs have driven major changes in trainee diversity. Leadership from the Minority Opportunities in Research (MORE) division of the National Institute of General Medical Sciences should be acknowledged in this regard. As a result, the number of minority students in biomedical graduate programs has increased from 2 percent in 1980 to 11 percent today (and, relative to U.S. nationals, the percentage is actually a little higher since the denominator for this calculation includes international graduate students). We should bear in mind that the current participation level is not far from the 14 percent of underrepresented minorities students among all students receiving a B.S. degree in biological sciences. Comparable results are seen in the U.S. citizen component of postdoctoral programs in the biomedical sciences. Sadly, however, the minority representation of 2 percent on tenure-track medical school faculties has not changed significantly since 1980. Unfortunately, there are essentially no data on what careers prove to be attractive to minority graduates after they leave postdoctoral training and why on average they choose careers other than academic research.

The following recommendations pertain to strengthening diversity within the educational system supported directly or indirectly by NIH grants.

Recommendation 2–4: Graduate student and postdoctoral training programs that educate and train students who are funded by RPGs[2] should be subject to expectations for diversity of U.S.-native trainees similar to those expected of training grants. Such programs should be required to provide assurance on R01 grant applications that efforts are being made.

The K24 mentoring award has been successful in developing the careers of clinical scientists. The committee views this program as highly valuable and would like to see this approach applied to the basic sciences; in addition, a mechanism may be developed to this end that also serves to support diversity at the faculty level. The impact of this type of mid-career career development award would enable faculty members to incorporate mentoring of other junior and early-stage investigators in order to enable their success in leading and managing a research team. The basic science faculty member, particularly in today's system where faculty members need to generate protected time much like clinicians, would also serve to acknowledge and reward best mentoring practices that can support the success of a diverse array of new investigators including K01 , R00, and first-time R01 recipients. Broadening the K24 program to include basic biomedical studies is both feasible and readily achievable.

[2] Research Project Grant (RPG).

Recommendation 2–5: The K24 mentoring award mechanism should be expanded to include the basic sciences. Use of the K24 award to enhance efforts to recruit diverse faculty should be a component of the award criteria.

NIH DATA SYSTEMS

Any discussion of the merits of NRSA training, both at the level of T32 and of F31/32 awards, invariably includes the question: Are the individuals educated in this fashion more successful and productive in their future careers? Although the competitive initial and renewal applications for these programs contain an enormous amount of information, no systemic approach has been developed to capture this information for rigorous scrutiny, and, as a result, no critical, data-driven analysis can be applied to the wealth of information that institutions have provided for more than 30 years. This problem will become all the more acute if trainees supported on R01 grants become a part of the overall database. The availability of such data would be enormously helpful to the NIH in the development of sound future policy. Accordingly, a modern data recording and management system is needed desperately and should be implemented without delay.

Newly instituted data collection procedures at the NIH will provide data on graduate students and postdoctorates with NIH support, as long as the data are input into a database or a tabular file and not simply recorded as unformatted electronic files. These data will be useful in estimating the numbers and research areas of individuals in training, but the lack of data on the career outcomes of NRSA- and R01-funded trainees makes it difficult to produce an informed comparative assessment of the research training programs. Moreover, this lack of information hinders the development of those training mechanisms and strategies that will best ensure a talented and productive research workforce.

Recommendation 2–6: To assist future assessments of the research training more effectively, the NIH should collect reliable data on all of the educational components that it supports in such a manner that this information can be stored in an easily accessible database format. Such data might include important components of the training grant tables as well as retention and subsequent outcomes.

Recommendation 2–7: The applications for training grant support require many detailed data tables. Some of these are very important and essential for the review; some are merely compendia of largely irrelevant data that could equally well be summarized briefly. The committee recommends that the data tables be reviewed and a determination made, in consultation with the awardee

community, as to which are really essential for reviewing the proposal and which should be incorporated into the databases described in Recommendation 2–6.

In addition, one aspect of the outcomes of training programs that has not been evaluated to date is how the value of the research training is perceived by the program director and by the trainees themselves. In no sense should collecting such data be a popularity contest or, worse, a complaint session against individual training-grant principal investigators. Rather we believe that broad anonymous surveys, in which the only identifier would be the fact of having been an NIH supported trainee, can be quite valuable. The NIH institute or office funding the training might be identified, but the institution offering the training would be confidential.

Recommendation 2–8: We recommend that a training evaluation questionnaire be created so that all participants in the full range of NIH-funded training vehicles can provide a confidential, unbiased evaluation of the program in which they were trained. The intent of this recommendation is not to provide additional information for the competitive renewal of a particular program, but rather to allow the NIH to evaluate the merit of all of its training approaches broadly.

INTERDISCIPLINARY FIELDS AND THE EMERGENCE OF NEW KINDS OF TRAINING PROGRAMS

With the evolution of team science and the increasing dependence of research on interdisciplinary activities, new breeds of scientists have emerged in recent decades. Initiation of new kinds of formal training programs has occurred as a natural consequence, but these programs are too often neglected when NIH-funded NRSA training is considered and measured. Perhaps the most obvious examples can be found in the quantitative and computing sciences—areas that are now heavily represented in the research portfolios of the categorical institutes but that generally, other than a modest effort at National Institute of General Medical Sciences and at the National Library of Medicine (NLM), are not extensively supported by them as areas for focused research training. For example, the increasing interest in, and importance of, biomedical informatics—as reflected in the mandated biomedical informatics core resources for all clinical and translational science awards—has created a need for trained scientists in this field.

The principal extramural funding source for research and training in biomedical informatics has been the NLM, which is both a significant research institute at the NIH and the largest and most innovative medical library in existence. Its role as an NIH institute is often overlooked because its name conjures up images of a library facility, but its intramural and extramural research have played key roles in advancing the infrastructure for modern biological science as well as electronic health records, decision-support systems, and online access to the biomedical literature.

NLM programs all deal with information and knowledge management used to support biomedical research and clinical care along with the development and promotion of standards that allow the integration of biomedical and clinical data from diverse resources. Its training programs in biomedical informatics, which have supported graduate degree programs and postdoctoral fellowships since the early 1970s, are responsible for producing a generation of leaders who now head academic programs in health science institutions, perform today's cutting-edge informatics research, fill major leadership roles in the government's commitment to healthcare information technology, and staff or lead the companies that produce, sell, and implement today's burgeoning clinical information systems.

The NLM training grants (see Table 2-2) are administered as T15 programs, but although they are not formally designated as NRSA programs, they do follow NRSA guidelines for funding and training requirements and are in this sense indistinguishable from the other programs emphasized in this report. Because NLM's programs are not formally designated as NRSA programs, they are not monitored or measured in the same way that NRSA programs are, and the existence of its training programs is often overlooked. This has constrained the programs' growth despite the burgeoning national demand for trained research scientists in the field of biomedical informatics (which spans bioinformatics, clinical informatics, and public health informatics).

It is shortsighted for HHS to fund current implementations of health information technology (as the Office of the National Coordinator for Health Information Technology has done with ARRA stimulus funds) without a concomitant investment in the basic research and graduate training needed to develop the concepts and innovations that will

TABLE 2-2 Number of Full-time Pre- and Postdoctoral Research Training Slots Awarded

FY	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009[a]
Postdoctoral	60	84	105	103	130	109	110	99	82	94
Predoctoral	38	56	97	118	169	162	160	179	186	189

[a]The training slots for 2009 include those awarded with ARRA and other supplemental funds.
SOURCE: NIH National Library of Medicine, 2009.

drive progress in the future. Computer science in general has been a major stimulant to the U.S. economy and has had a remarkable influence on our quality of life, but the biomedical world cannot rely on the general engineering community to develop the solutions that health care and medical research require. The biomedical informatics community can fill that pipeline, as it has in the past, but this requires a program of funding and training that will produce both the ideas and the scientists that are needed to restore the momentum that we need in these important disciplines. The NLM is the only agency that has consistently supported such education, and it needs the resources to continue its important programs. There may be other similar interdisciplinary programs at NIH that have been overlooked because they do not use the NRSA or T32 mechanism. All such programs need to be considered explicitly in the guidelines and recommendations offered in this report.

Recommendation 2–9: The unique graduate training programs of the NLM, plus its postdoctoral fellowships in biomedical informatics, should receive gradually increasing support with incremental dollars over 5 years to produce a 50 percent increase in the number of funded training programs and a doubling of the number of funded training positions.

COORDINATION WITH NIH

When a new workforce committee is constituted, it spends a considerable amount of time reviewing the previous recommendations and the response by the NIH. This is often quite difficult to do in a satisfying manner since the exact implementation can be piecemeal, and, indeed, sometimes there may be very sound reasons for non-implementation. It is not easy for the new committee to triangulate how things have evolved in the four years since the previous recommendations were first presented. This committee was helped by a small number of individuals who had sat on the previous committee and were able to offer a valuable extended perspective. Clearly, better communication between the NRC review committees and the NIH could speed up the overall review process. The committee debated this issue for some time and eventually decided to make a recommendation that the NIH establish a review group that would analyze and collate the NIH responses to the committee recommendations and report its findings to the director's advisory committee. In this way the director of the NIH would be apprised of the relevant issues, and the appropriate components of the minutes could be used to inform the next NRC review committee four years from now.

Recommendation 2–10: The committee believes that subsequent workforce committees would greatly benefit from continuity in terms of crafting recommendations and following and monitoring the implementation of those recommendations by the NIH. Accordingly, it is recommended that the appropriate office at the NIH involved in analyzing these recommendations should issue an annual report to the director's advisory committee on the status of review and implementation. In addition, the NIH may wish to invite external experts to provide added insight into the analysis. There are a number of ways that this could be done, but the exact mechanism is left up to the NIH.

INTERNATIONAL CONTRIBUTION TO THE BIOMEDICAL WORKFORCE

Chapter 3 documents the contributions of foreign-educated scientists, particularly at the postdoctoral level, to the U.S. biomedical research workforce. Indeed, in the biomedical postdoctorate pool more than 60 percent of the fellows are foreign trained. In addition, typically 60 to 65 percent of these individuals indicate that they hope to stay in the United States after they have completed their fellowship. Without this component of the workforce, U.S.-educated Ph.D.s, at the current level of production, would not be able to provide the amount of human capital needed to meet the demands for research in this area. Over the past two decades the number of foreign-trained individuals in the postdoctoral workforce has steadily increased. However, we are now faced with a highly uncertain future in this regard. This is a direct consequence of two powerful forces, the effects of which are impossible to determine at present. On the one hand, the enormous growth of the Chinese and other Asian economies—and their explicit intentions to invest in the biomedical and life sciences and become "research powerhouses"—has already begun to attract their nationals to return and conduct research at their home institutions, a phenomenon that seems likely only to increase over the next decade. On the other hand, the pressing economic situation in the United States, especially the uncertainty of job availability in the future, may lead to a decreasing attractiveness of U.S. biomedical research careers to Ph.D.s from these foreign countries.

Although there is a great deal of uncertainty about how these phenomena will affect the contributions of international scientists to the U.S. biomedical research enterprise, our leaders at the NIH and in the Congress should be aware of this committee's concerns. It is probably not yet time to suggest that U.S. production of biomedical Ph.D.s should be increased, but clearly this issue needs to be carefully and continuously monitored.

3

Basic Biomedical Sciences

INTRODUCTION

The goal of basic biomedical research is to provide comprehensive and detailed understanding of the mechanisms that underlie the development and normal function of humans and other living organisms and thereby gain insights into the pathological and pathophysiological mechanisms that cause disease. A detailed understanding of these mechanisms and pathways is essential for identifying potential targets for rational therapeutic interventions, and for disease prevention. The scope of basic biomedical research is, therefore, broad, ranging from the study of single atoms and molecules to the complex functions and behaviors of the whole organism.

Although distinct from clinical research, which is covered in Chapter 5, it is basic biomedical research is nonetheless an important component of clinical success. In particular, it provides the detailed understanding of disease processes that undergird the development of new diagnostic procedures, therapeutic interventions, and preventative strategies that can be tested in clinical studies. In turn, the encounters of astute clinicians with patients can stimulate clinical investigations that may suggest novel mechanisms of disease that can be further examined in basic studies that may involve model organisms. Observations that drive new understandings of human diseases and the development of new strategies for their prevention, diagnosis, and treatment, flow bidirectionally from patient to laboratory and back, often passing en route through various stages of experimentation and validation in lower and higher animal species. There can be no doubt that the frequency and intensity of interactions between basic and clinical scientists will continue to increase. However, the basic and clinical workforces are for the most part distinct and linked by a third genus of biomedical scientists dubbed "translational" researchers, who have been trained to be knowledgeable in both the basic and clinical biomedical sciences, as well as proficient in patient care.

With respect to behavioral research, covered in a later chapter, there is a similar continuum within the neurosciences from basic neurochemistry and molecular neurobiology through cognitive neuroscience to biological psychology and behavior. The overlaps among these areas will inevitably increase as genetic and environmental influences that affect the formation and function of the nervous system are better understood.

It is fair to say that the landscape of biomedical research has been revolutionized in the past 20 years by major advances in technology and in our understanding of fundamental aspects of cell and organ function as well as by the impact of this work on human health. Genomic biology is now a fundamental aspect of research strategies and is in the process of leading to the realization of "personalized medicine." Concomitantly, quantitative biology has become an essential component of biomedical graduate education, and it is essential to know how to handle the prodigious influx of massive amounts of data generated by the new technologies. There have been astounding advances in our discovery and understanding of the roles of different populations of RNA molecules, such as RNAi, in cellular regulation and as research tools, and soon, as biologic interventions in disease. Cancer is being more effectively treated than ever before, the decreased incidence of cardiac mortality has been a major success story, and recently the first AIDS vaccine that may hold significant promise has been tested for the first time.

In order to apply scientific discoveries to the improvement of human health, a sufficiently large and diverse workforce trained in basic biomedical research is essential. That workforce must be able to conduct research in a wide variety of settings, including academic institutions, government laboratories, and a broad range of companies in pharmaceutics, biotechnology, bioengineering, and others.

BIOMEDICAL RESEACH WORKFORCE

For the descriptive material and the data presented in this report, researchers in the basic biomedical sciences are defined as individuals holding a Ph.D. in a field that deals with the biological mechanisms that are ultimately related to human health. These fields are listed in Appendix C. In this report we have attempted to focus on these specific areas, but on occasion, the available data may refer to biological sciences in general because sometimes no grouping of specific biomedical disciplines is available, and in these cases we have emphasized this point in the discussion. The workforce discussion below includes individuals who may also hold other degrees, such as an M.D. through an M.D./Ph.D. program or other dual-degree programs, but it does not include individuals with an M.D. degree alone. This is a shortcoming of the analysis, because a significant number of M.D.s have conducted and continue to carry out basic research in the fields listed in Appendix C, and some have won Nobel Prizes for their contributions. However, pertinent demographic information on these degree holders is limited. The American Medical Association maintains a national database that tracks the careers of all practicing physicians, but there is no database that specifically tracks the academic careers of graduates from medical schools, except for the data collected by the Association of American Medical Colleges (AAMC) and published annually in its Directory of Medical School Faculty. However, this database does not identify research areas. The analysis of the clinical research workforce in Chapter 5 will address these biomedical researchers to the extent that they can be identified. It should also be acknowledged that the committee's analysis does not include individuals with doctorates in other professions, such as nursing, dentistry, and public health, if they do not hold a Ph.D. in addition to their professional degree. There are important workforce issues in the first two of the three fields just cited, and they will be addressed in separate chapters in this report.

EDUCATIONAL PROGRESSION

Most researchers working in the United States in the biomedical sciences obtained their doctorate degrees from U.S. research universities, but a substantial number come from foreign institutions, either directly into a graduate research program, or more frequently via a postdoctoral position in the United States.[1]

For many in the biomedical sciences, interest in the field begins at an early age, in high school or even grade school. In this regard, over the past 20 years, the percentage of high school graduates who took a biology course has remained about the same at around 90 percent. This level is less than 99 percent of high school graduates who have taken mathematics course but greater than the percentage of any other type of science; only 60 percent of high school graduates have taken a chemistry course, for example.[2] The characteristics of the students planning a postsecondary education can be examined by the percentage taking the biology AP examination. The number has increased from about 32,000 in 1985 to 150,000 in 2008 and is second to mathematics at 280,000.[3] The interest in biology continues into college with 6.8 percent of the 2006 freshman science and engineering population declaring a major in biology. This is the second highest field preference in science and engineering (S&E), exceeded only by computer science. Overall, from 1980 to 2008 the fraction of the freshman college population who are biology majors increased from 4.9 to 9.3 percent. The number of bachelor's degrees awarded in the biological sciences was fairly constant in the 1970s and 1980s at about 40 thousand, and increased to 60,000 in the mid-1990s. Since that time it has steadily increased to nearly 78,000 in 2008. These data are for all areas in the biological sciences and are presented to show the trend in the field in pre-graduate education.

The number of students entering graduate school possibly in order to prepare for advanced degrees (M.S. and Ph.D.) in the biological sciences was about 9,400 in the early 1990s and increased to a little less than 12,400 in 2008. Obviously, some of these first-year students are only pursuing a master's degree, but the 32 percent increase in number of students does show the substantial overall growth of interest in the field. If we focus on students that enter into doctoral-granting biomedical sciences department, the entering student population was 8,800 in the early 1990s and has increased to 11,800 by 2008. The total full-time graduate enrollment in the biomedical sciences was fairly steady in the 1990s until the doubling of the NIH budget. The doubling began in 1998, and after a two-year lag, the number of biomedical graduate students increased steadily by a total of 22 percent over the period 2001-2006 (see Figure 3-1).

Such an increase should yield a proportionate increase in the number of Ph.D.s awarded from 2005 and succeeding years, an increase that has now been detected (see Figure 3-2). It should also be noted that about three-quarters of the Ph.D. graduates in biomedical programs also received their bachelor's degree in the same field.[4] In addition, since 1998 there have been more female than male graduate students enrolled in biomedical programs such that in 2008 females represented 56 percent of the graduate students. As a result of the increased participation of women in graduate school, the gender distribution of Ph.D.s in the biomedical sciences was almost equal in 2008 at 3,584 males and 3,511 females. The data on student enrollment do not accurately reflect the doctoral population and are presented to show the growth in the field over time. A more accurate assessment of total enrollment in Ph.D. programs comes from the research-doctorate study for one year, the fall of 2005, on Ph.D. enrollment (see Table 3-1).

[1] National Center for Educational Statistic, Digest of Educational Statistic, 2008.

[2] National Center for Educational Statistic, Digest of Educational Statistic, 2008.

[3] National Science Foundation, 2010. *Science and Engineering Indicators,* Washington, DC: NSF.

[4] Unpublished tabulation from the Survey of Earned Doctorates, 2001.

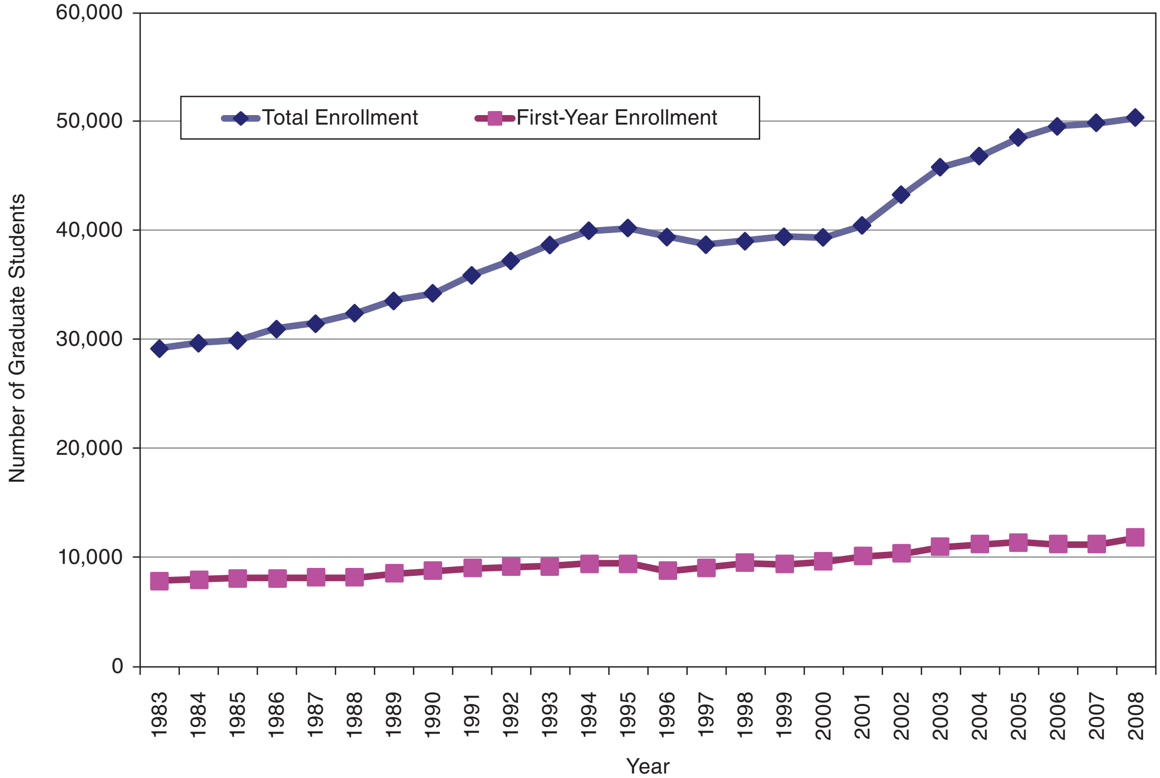

FIGURE 3-1 Full-time graduate enrollment in the biomedical sciences 1983-2008.
SOURCE: NSF. 2008. *Survey of Graduate Students and Postdoctorates in Science and Engineering, 2008*. Washington, DC: NSF.

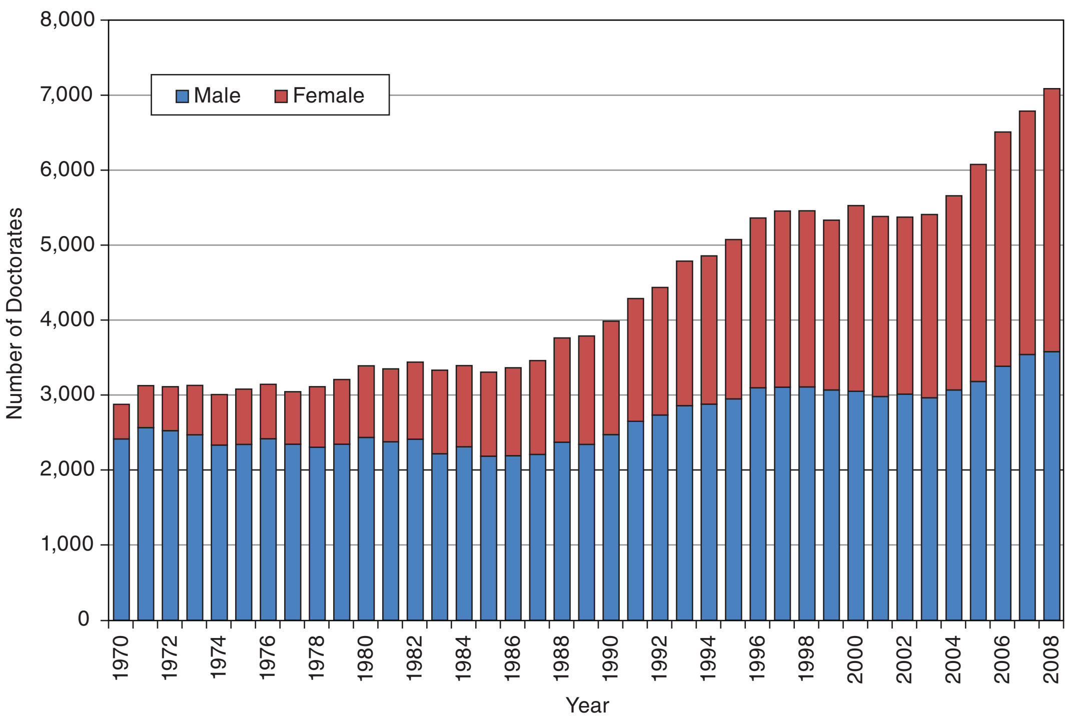

FIGURE 3-2 Biomedical Ph.D.s by year of degree and gender, 1970-2008.
SOURCE: NSF. 2008. *Survey of Earned Doctorates*. Available at http://www.nsf.gov/statistics/srvydoctorates/.

These data are reported by the institutions and represent almost all doctoral programs. In 2005, the reported total of Ph.D. students in the biomedical sciences was 41,115 or about 7,500 fewer students than the NSF data, which most likely reflects the inclusion of masters students. These data again show more female than male students, but only by a few hundred. Data from the research-doctorate study for the period from 2002 to 2006 on first-year enrollment mirrors the growth of the NSF data (see Table 3-2) and is generally about 1,500 less, accounting for master's students. Projecting the research-doctorate data, using the change in the NSF data, shows an increase in 2008 to about 10,000 first-year enrollees in Ph.D. programs.

Data on citizenship and race/ethnicity of doctoral students in the biomedical sciences are also available from the research-doctorate study. The percentage of doctoral students on temporary visas is about 30 percent, although the percentage of doctorates conferred on such students is somewhat less (see Table 3-3 and Figure 3-3), likely reflecting a continuing increase in the number of international students admitted into graduate programs and the attendant delay of five years before graduation.

Similarily, the percentage of underrepresented minority doctoral students in biomedical graduate programs is 11 percent from the research-doctorate data, but in the same year these student make up 8 percent of graduates, again likely reflecting an expanding pipeline (see Table 3-4 and Figure 3-3). It is unclear why these percentages are greater, but these students might take longer to get their degree.

THE NUMBER AND DEMOGRAPHICS OF BIOMEDICAL SCIENCES PH.D. RECIPIENTS

The increase in funding and enrollments led to increases in doctoral degrees. The numbers of Ph.D.s in the biomedical sciences awarded by U.S. institutions have increased from roughly 3,000 during the 1970s to 6,895 in 2007. The increase presumably reflects increases in the Gross National Product (GNP) as well as increases in the NIH budget over this time period, although over the past decade the percentage increases in the NIH budget have substantially exceeded those of Ph.D. output (see Figure 3-2).

Most of the surge occurred in the early to mid-1990s and, more recently, from 2003 to 2007. The latter increase can

TABLE 3-1 Number of Ph.D. Students Enrolled in the Biomedical Sciences, Fall 2005

Field	Male	Female
Biochemistry, Biophysics, and Structural Biology	3515	3021
Biomedical Engineering and Bioengineering	2842	1589
Cell and Developmental Biology	2602	2989
Genetics and Genomics	1230	1495
Immunology and Infectious Disease	1155	1429
Integrated Biomedical Sciences	3285	3664
Microbiology	1200	1592
Neuroscience and Neurobiology	2007	2019
Pharmacology, Toxicology, and Environmental Health	1755	1989
Physiology	784	953
Total	20375	20740

SOURCE: NRC. 2010. *A Data-Based Assessment of Research-Doctorate Programs*. Washington, DC: The National Academies Press.

TABLE 3-2 First-Year Enrollment in Biomedical Ph.D. Programs

Field	2001-02	2002-03	2003-04	2004-05	2005-06
Biochemistry, Biophysics, and Structural Biology	1334	1385	1556	1445	1437
Biomedical Engineering and Bioengineering	716	784	921	938	924
Cell and Developmental Biology	1365	1464	1558	1556	1610
Genetics and Genomics	594	582	654	674	619
Immunology and Infectious Disease	712	728	774	803	812
Integrated Biomedical Sciences	1288	1367	1398	1497	1519
Microbiology	669	672	731	728	688
Neuroscience and Neurobiology	761	891	957	886	913
Pharmacology, Toxicology, and Environmental Health	812	825	844	886	822
Physiology	397	417	481	456	445
Total	8648	9115	9874	9869	9789

SOURCE: NRC. 2010. *A Data-Based Assessment of Research-Doctorate Programs*. Washington, DC: The National Academies Press.

TABLE 3-3 Citizenship of Doctoral Students in the Biomedical Sciences, Fall 2006

	Percentage		
Field	Citizens	Permanent Residents	Temporary Residents
Biochemistry, Biophysics, and Structural Biology	61	3	36
Biomedical Engineering and Bioengineering	61	4	35
Cell and Developmental Biology	65	4	30
Genetics and Genomics	68	3	30
Immunology and Infectious Disease	70	4	26
Integrated Biomedical Sciences	69	3	28
Microbiology	73	3	24
Neuroscience and Neurobiology	75	3	22
Pharmacology, Toxicology, and Environmental Health	59	4	37
Physiology	64	3	33
Total	66	3	31

SOURCE: NRC. 2010. *A Data-Based Assessment of Research-Doctorate Programs*. Washington, DC: The National Academies Press.

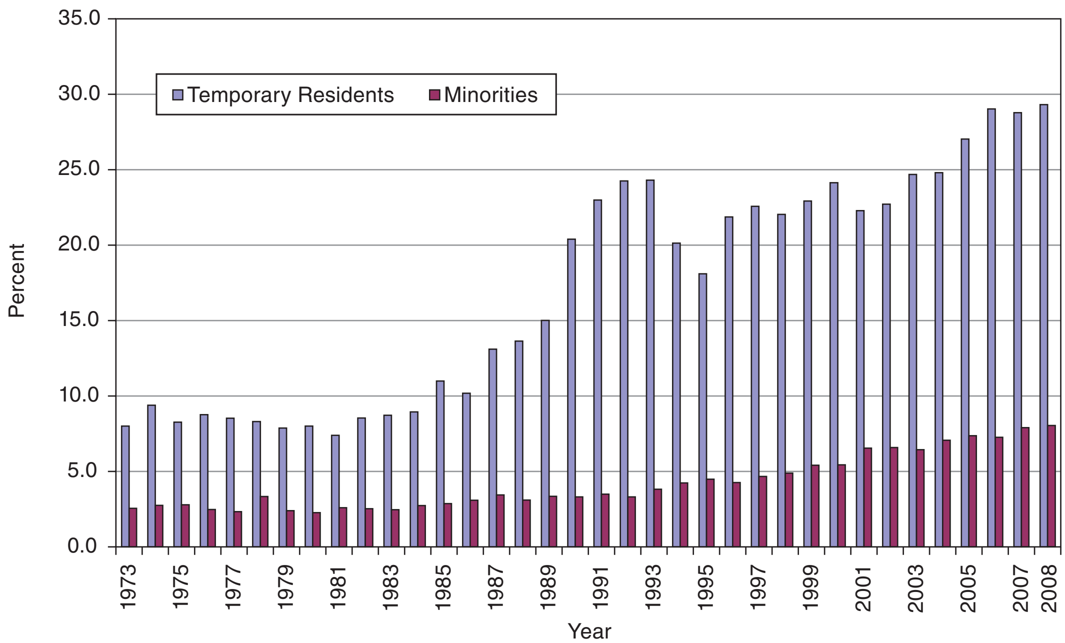

FIGURE 3-3 Biomedical Ph.D.s by citizenship and race/ethnicity, 1973-2008.
SOURCE: NSF. 2008. *Survey of Earned Doctorates.* Available at http://www.nsf.gov/statistics/srvydoctorates/.

TABLE 3-4 Race/Ethnicity by Percent of Doctoral Students in the Biomedical Sciences, Fall 2005

Field	White	Black	Hispanic	Asian	American Indian	Minority[a]
Biochemistry, Biophysics, and Structural Biology	77	3	5	14	1	9
Biomedical Engineering and Bioengineering	69	5	4	21	0	10
Cell and Developmental Biology	75	4	7	14	1	11
Genetics and Genomics	78	5	5	11	1	11
Immunology and Infectious Disease	76	6	6	12	1	12
Integrated Biomedical Sciences	79	5	5	10	1	11
Microbiology	78	6	7	9	0	14
Neuroscience and Neurobiology	76	4	7	12	1	12
Pharmacology, Toxicology, and Environmental Health	72	7	6	14	1	14
Physiology	77	7	5	11	1	12
Total	76	5	6	13	1	11

[a]Minority refers to Underrepresented Minorities that include Blacks, Hispanics, and American Indians
SOURCE: NRC. 2010. *A Data-Based Assessment of Research-Doctorate Programs*, Washington, DC: The National Academies Press.

be linked to the elevated research expenditures during the doubling of the NIH budget. Interestingly, a substantially larger fraction of the increase in the number of doctorates has come from increased participation by women.

In a dramatic demographic shift, the fraction of Ph.D.s awarded to temporary residents has increased from about 10 percent in 1970 to more than 30 percent in 2007 (Figure 3-3).This fraction is still lower than that in many fields in the physical sciences and engineering, but this differential is closing. In analyzing the participation by foreign-born students, we note that the dramatic spike in Ph.D.s awarded to international students in 1991-1993, presumably a reflection of increased entry into U.S. schools post-Tiananmen Square. Since the peak in 1993, the proportion was steady until 2003, when students admitted in the early years of the NIH doubling began to graduate. In the most recent three years the percentage has been almost constant, and maybe an indication of a decrease in Ph.D.s to foreign students in the future.

The number of minorities earning a Ph.D. degree in biomedical research has doubled since the early 1990s. Minority citizen and permanent resident Ph.D. awardees in 2008 stood at 8.0 percent of all biomedical research graduates in the United States; if one corrects for the number of non-U.S. citizens in the graduating class this amounts to 12.6 percent of graduating U.S. citizens and permanent residents. The fraction of minorities in the biomedical sciences has increased more than is seen in other biological areas. Recent studies show that this increase has occurred substantially at institutions receiving NIH training grant support, almost certainly a reflection of the mandate the NIH has placed on these institutions to aggressively recruit a diverse student group.

EMPLOYMENT IMMEDIATELY AFTER RECEIVING THE PH.D. DEGREE

The percentage of newly minted doctoral recipients with definite plans to do postdoctorate training relatively soon after receiving their degree increased sharply during the 1970s from about 50 percent to 80 percent in the mid-1980s and remained at that level until the mid 1990s with only periodic decreases since then (see Figure 3-4). Over the same time period, the fraction of new Ph.D.s who go directly into regular employment decreased steadily until about 1997, but subsequently appears to have stabilized.

As the number of minorities gaining a Ph.D. has increased, it is useful to ask about their plans upon graduation. Figure 3-5 shows that minority and majority outcomes were quite different over the period from 1973 to 1993 when minority Ph.D.s were much less inclined to take a postdoctorate position and more inclined to go directly into industry. However, since 1993, although there is a great deal of scatter in the data points, it is clear that the career progression of minority graduates now closely reflects that of majority graduates. The number of unemployed Ph.D.s at this stage of their careers is very small.

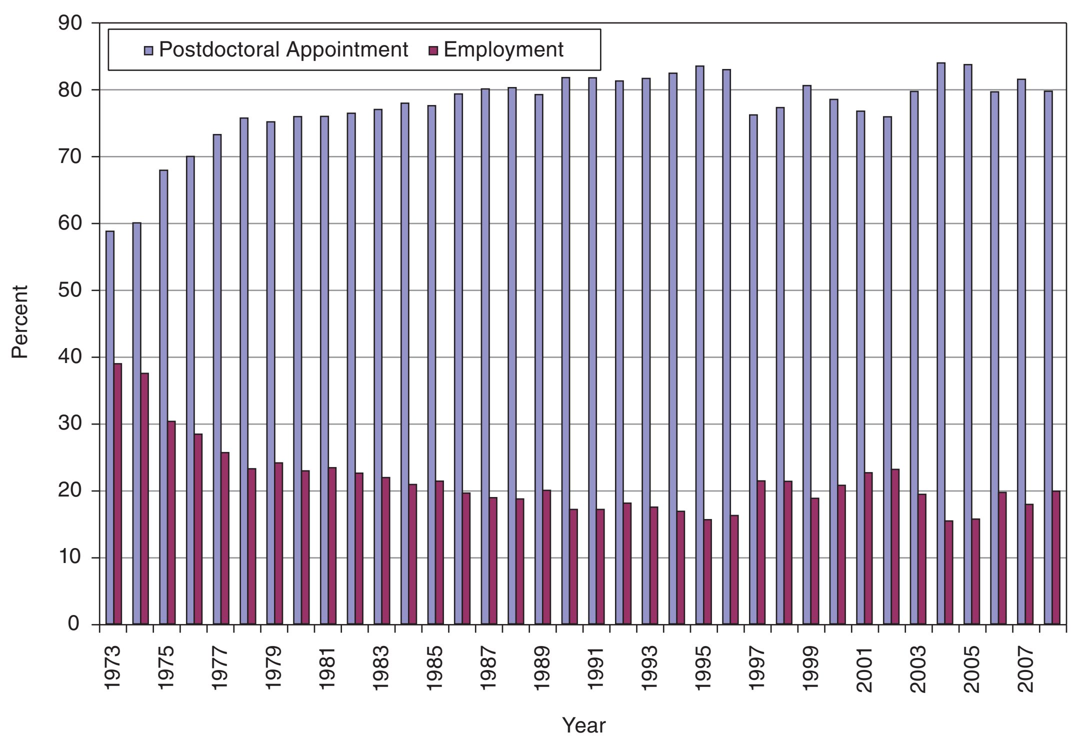

FIGURE 3-4 Postdoctoral plans at time of doctorate.
SOURCE: NSF. 2008. *Survey of Earned Doctorates.* Available at http://www.nsf.gov/statistics/srvydoctorates/.

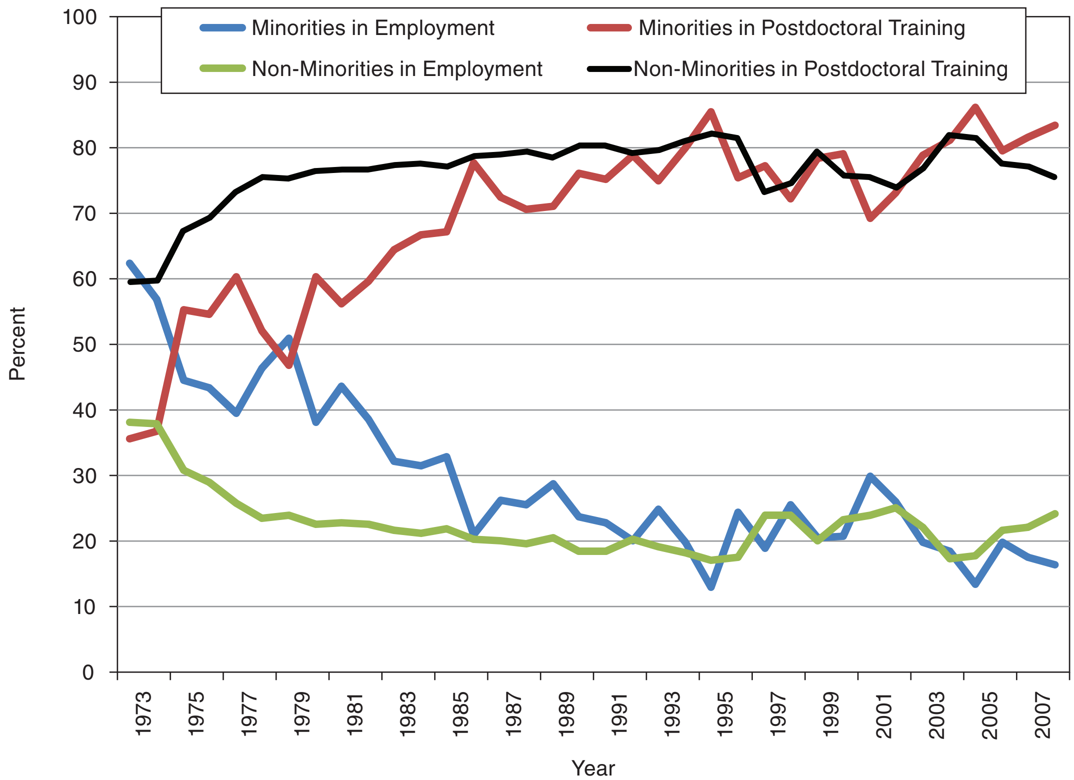

FIGURE 3-5 Postdoctoral plans of minorities and non-minorities in the biomedical sciences.
SOURCE: NSF. 2008. *Survey of Earned Doctorates.* Available at http://www.nsf.gov/statistics/srvydoctorates/.

The time to doctorate and age at time of receiving the degree have been cited as critical issues in terms of career progression of biomedical researchers and the increased length of training prior to reaching R01 research status.[5] Data from NSF suggest that graduate students are spending longer periods of time in their programs, with the median registered time in a graduate degree program increasing from 6 years in 1970 to 7 years in 2002, although there was a modest shortening of the time to 6.58 years in 2008. These times to completion are not significantly different from those in other S&E fields. However, these data run counter to the experience of essentially everyone in the biomedical research field. This may be because these data reflect the time from entering a graduate program to receiving the doctoral degree, and because some graduate students work for a period while in graduate school (a phenomenon that has increased over the past 15 years) then this way of measuring time to degree is increasingly imprecise. A new and very valuable resource has come from the Assessment of Research Doctorate Programs, which collected data on the median time to degree from individual programs. Table 3-5 shows that the program reported time ranges from 4.9 to 5.7 years across the biomedical sciences and on average is 5.5 years, or about 1.5 years shorter than the data collected by NSF.

POSTDOCTORAL FELLOWS

With the growth of research funding driving a major expansion of the biomedical research enterprise, and with the remarkable advances that have taken place in the biomedical

TABLE 3-5 Average Time to Degree

Field	Years
Biochemistry, Biophysics, and Structural Biology	5.61
Biomedical Engineering and Bioengineering	4.92
Integrated Biomedical Sciences	5.61
Cell and Developmental Biology	5.65
Genetics and Genomics	5.74
Immunology and Infectious Disease	5.31
Microbiology	5.56
Neuroscience and Neurobiology	5.67
Pharmacology, Toxicology, and Environmental Health	5.23
Physiology	5.17
Average time to degree	5.52

SOURCE: NRC. 2010. A Data-Based Assessment of Research-Doctorate Programs. Washington, DC: The National Academies Press.

[5] Goldman, E., and E. Marshall. 2002. "NIH grantees: Where have all the young ones gone?" *Science* 298(5591):40-41.

sciences in recent years, the postdoctoral appointment has now become a *sine qua non* for most subsequent career positions. From the 1980s to the late 1990s the number of postdoctoral appointments increased by about 60 percent for Ph.D. scientists at U.S. institutions (see Figure 3-6).

The rapid increase in the total U.S.-trained postdoctoral pool from 1993 to 1999 was probably the result of a number of factors. One was the increase in women graduates; another was the growth of international students attending U.S. schools.

Data on the length of the postdoctoral period show a steady increase in the 1990s, but this generated an outcry from postdoctoral organizations and, subsequently, several national university organizations. In response, the American Association of Universities issued a white paper in 2000 endorsing a limit of no more than 5 years for postdoctoral appointments. With some slight modifications to fit academic medicine, the Association of American Medical Colleges (AAMC) endorsed a companion white paper addressed to medical schools and teaching hospitals. Since then, many institutions instituted limits to the postdoctorate training period. These responses evidently yielded results, judging from data for the most recent period showing that the average postdoctoral training period has been significantly reduced. Whether term limits aided postdoctorates' ability to find new permanent positions is debatable. Indeed, a perusal of the AAMC faculty database over this period indicates that the number of tenure-track faculty positions did not increase over the past decade (and in fact they have declined), but a 40 percent increase was seen in the number of non-tenure-track (research-track) faculty as well as "other faculty," presumably senior research staff positions (see also Figure 3-7).

It is interesting to note that an increasing fraction of these non-tenure faculty positions are held by females. Twenty years ago the half-life in these non-tenure-track faculty positions was 7-8 years, but over the last decade this has dropped to 4-5 years, suggesting a more transient activity. Further, non-tenure-track positions may afford principal investigator privileges but they often lack oversight, and whether this is a viable next step on the employment ladder or whether those holding such appointments are merely "Postdoctorates by another name" remains to be seen. Finally, it should be mentioned that the AAMC databases do not give any information on citizenship of these individuals.

Data from the research-doctorate study show there are almost 24,000 postdoctoral appointments in biomedical programs (see Table 3-6). This is larger than the number reported on the NSF survey for academic postdoctorates by about 20 percent, and it may be a more accurate figure, since the NSF data are drawn from a sample of institutions. It should also be noted that females represented about 41 percent of the postdoctoral population, but they have represented more than 45 percent of the U.S.-trained doctorates since 2000. Also note that the percentage of minorities in postdoctoral positions is a little over 7 percent, which is consistent with the fact that minorities accounted for 6 to 7 percent minority U.S. doctorate degrees over the period from 2000 to 2006.

THE PARTICIPATION OF INTERNATIONAL POSTDOCTORATES IN BIOMEDICAL RESEARCH

U.S. citizens in postdoctoral positions in the biomedical sciences constitute only part of the postdoctoral training sector. There are also large numbers of doctoral recipients

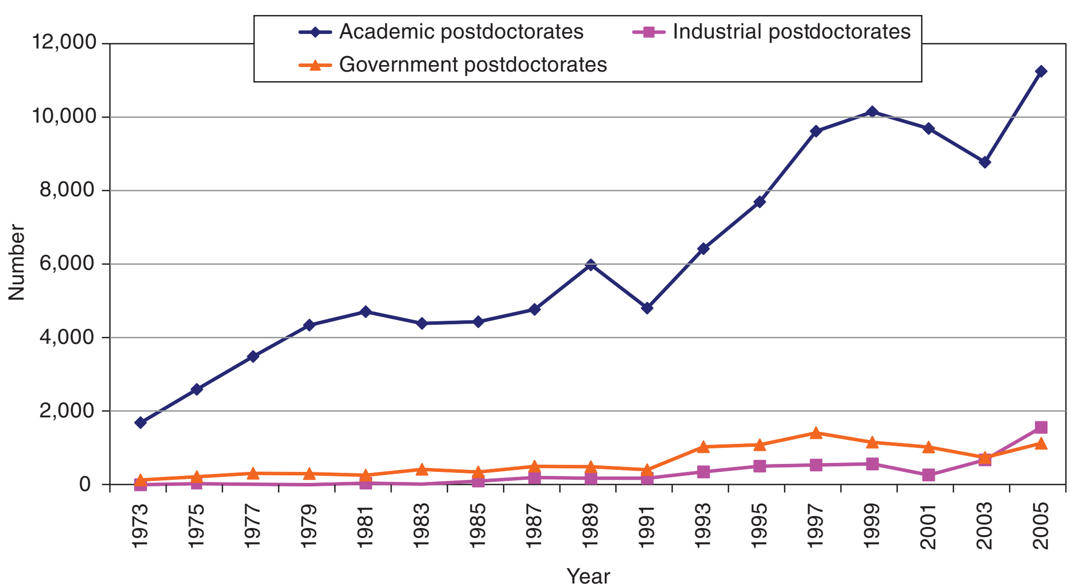

FIGURE 3-6 Postdoctoral appointments in the biomedical sciences.
SOURCE: NSF. *Survey of Doctorate Recipients, 1973-2006*. Washington, DC: NSF.

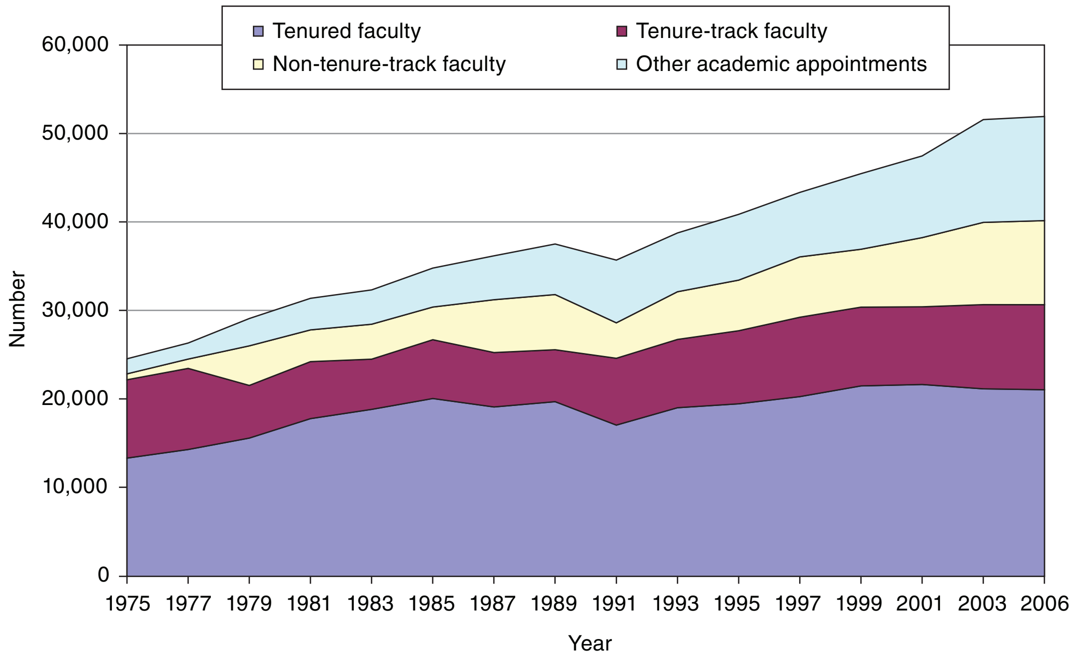

FIGURE 3-7 Academic positions of doctorates in the biomedical sciences, 1975-2006.
SOURCE: NSF. *Survey of Doctorate Recipients, 1973-2006*. Washington, DC: NSF.

TABLE 3-6 Postdoctoral Appointments in the Biomedical Sciences in Fall 2006

Field	Number of Applications	Male	Female	Minorities (%)
Biochemistry, Biophysics, and Structural Biology	3,625	2,087	1,242	5.1
Biomedical Engineering and Bioengineering	944	675	280	5.6
Cell and Developmental Biology	3,586	1,991	1,537	9.1
Genetics and Genomics	1,664	956	705	7.5
Immunology and Infectious Disease	1,688	875	746	9.1
Integrated Biomedical Sciences	5,349	2,493	1,790	6.7
Microbiology	1,413	739	624	7.2
Neuroscience and Neurobiology	2,620	1,515	1,049	8.5
Pharmacology, Toxicology, and Environmental Health	2,045	1,169	817	7.5
Physiology	793	464	330	7.5
Total	23,727	12,964	9,120	7.3

SOURCE: NRC. 2010. *A Data-Based Assessment of Research-Doctorate Programs.* Washington, DC: The National Academies Press.

with degrees from foreign institutions who are being trained in U.S. educational institutions and other employment sectors. Data are available on the number of postdoctoral appointments in academic institutions,[6] but there is no comparable source for data from the industrial, governmental, and non-profit sectors. However, the NIH supports about 4,000 intramural postdoctorates, and just over 60 percent of them are temporary residents from countries around the world, with the largest numbers coming from the People's Republic of China, India, Korea, Japan, and Europe. Almost all of them have foreign doctorates. Data from the NSF Survey of Graduate Students and Postdoctorates show that the number of temporary resident postdoctorates in academic institutions steadily increased through the 1980s and 1990s; by 2008 the number was almost 12,000 in the biomedical sciences. Currently temporary residents hold almost three-fifths of the postdoctoral positions in academic centers (see Figure 3-8).

There has been little change in the number of U.S. citizen and permanent resident postdoctorates in academic institutions since the early 1990s, though there was a 20 percent increase in temporary resident postdoctorates between 1998 and 2003 coinciding with the NIH doubling. The leveling off in the number of foreign postdoctorates from 2003 to 2006 is most likely related to the plateau in NIH funding rather than to

[6] NSF. 2004. *Survey of Graduate Students and Postdoctorates in Science and Engineering; 2002*. Washington, DC: NSF.

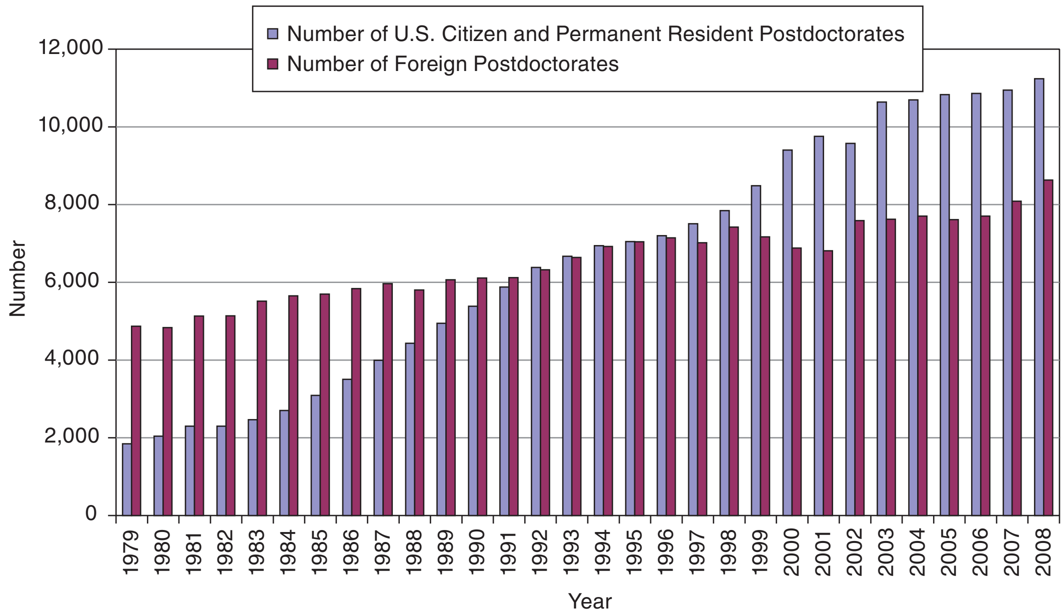

FIGURE 3-8 Postdoctorates in academic institutions.
SOURCE: NSF. *Survey of Graduate Students and Postdoctorates in Science and Engineering, 2008*. Washington, DC: NSF.

post-9/11 security issues. Almost certainly, the recent ARRA stimulus funding will generate a demand for additional postdoctorates, and since most of the U.S. graduates already enter this pool, the additional needs will be satisfied by an increase in international postdoctorates. It seems unlikely that the U.S.-trained postdoctorate pool would have been sufficient to produce the workforce for a response to the ARRA funding. Clearly, some of these international postdoctorates are well trained. However, a significant (and unknown) number have been trained as M.D.s, and their laboratory skills are hard to gauge; they may well receive much "on-the-job" training. Nonetheless, the international postdoctorate pool is highly elastic and responds quite rapidly to funding exigencies and opportunities driven by the NIH appropriation. Data indicate that 65 percent of these postdoctorates will probably stay in the United States and will thus contribute to the biomedical workforce over an extended period. However, exactly where these individuals will be employed has not been carefully measured. Nor has it been clearly defined how these international postdoctorates will handle the post-stimulus funding employment situation.

The Research-Doctorate Study collected data on programs with foreign postdoctorates and the country of origin for those postdoctorates. For the 983 biomedical programs in the study, 839 reported foreign postdoctorates in the program. For 430 of these programs, more foreign postdoctorates came from the Peoples Republic of China than any other country. India and Japan were the most populous for many fewer programs (see Table 3-7).

CAREER PROGRESSION

Traditionally, the career progression for biomedical scientists after graduate school and a postdoctoral appointment was to next take a position in an academic institution or in an industrial environment. However, individuals with a Ph.D. in the biomedical sciences now have a range of career opportunities, from academia and industry to science administration, policy, writing, and law, to name but a few of the options.

Until 1985, the first position to which Ph.D.s would aspire was generally in a university on the tenure track. However, after 1985 the bulk of the growth in academia has been in non-tenure-track appointments, with many in this latter category on "soft funding." Figure 3-9 shows that the average annual growth in the academic population was about 5 percent from the 1970s to 1991, except for a slowdown in the late 1980s and early 1990s due to economic conditions. Since 1995, however, growth has slowed significantly, and what growth there is has been in the area of non-tenure-track faculty and other academic positions. From 1999 to 2003, the number of positions in these areas grew about 20 percent (roughly 4 percent each year). Note that these data are from the NSF Survey of Earned Doctorates, and as such they apply to all biomedical science postdoctorates including those in clinical departments, but they do not include foreign non-tenure-track faculty, who have contributed additionally to the growth of this category of employment.

This growth is almost certainly due to the efforts of institutions to accommodate term limits for postdoctorates, as discussed above, and it is likely that these are individuals

TABLE 3-7 Number of Programs with Foreign Postdoctorates and the Three Most Popular Countries of Origin in Fall 2006

		Countries of Origin		
Field	Programs with Foreign Postdoctorates	China	India	Japan
Biochemistry, Biophysics, and Structural Biology	139	73	14	3
Biomedical Engineering and Bioengineering	59	32	8	2
Cell and Developmental Biology	113	56	8	5
Genetics and Genomics	54	31	5	2
Immunology and Infectious Disease	66	37	7	
Integrated Biomedical Sciences	106	44	13	5
Microbiology	67	34	6	3
Neuroscience and Neurobiology	72	40	4	3
Pharmacology, Toxicology, and Environmental Health	107	58	15	3
Physiology	56	25	4	3
Total	839	430	84	29

SOURCE: NRC. 2010. *A Data-Based Assessment of Research-Doctorate Programs.* Washington, DC: The National Academies Press.

TABLE 3-8 Tenure Status of Basic Science Medical School Faculty, 2002, 2005, and 2009

Degree	M.D.	M.D./Ph.D.	Other	Ph.D.	Unknown	Total
2002						
Tenured	821	642	17	7401	33	8914
Tenure Track	329	261	22	2419	23	3054
Non-Tenure Track	847	375	241	3269	162	4894
Tenure Not Available	151	39	21	423	9	643
Total	2148	1317	301	13512	227	17505
2005						
Tenured	764	679	18	7346	46	8853
Tenure Track	330	319	23	2619	31	3322
Non-Tenure Track	879	425	259	3857	108	5528
Tenure Not Available	194	52	22	503	16	787
Total	2167	1475	322	14325	201	18490
2009						
Tenured	600	684	16	6895	49	8244
Tenure Track	377	320	28	2844	71	3640
Non-Tenure Track	829	389	238	3561	122	5139
Tenure Not Available	250	66	43	640	48	1047
Total	2056	1459	325	13940	290	18070

SOURCE: AAMC. 2010. *Association of American Medical Colleges Faculty Roster, 2009.* Available at https://www.aamc.org/data/facultyroster/.

whose appointment titles changed from postdoctoral trainee to research associate, research scientist, instructor, or some similar title but who continued to do the same kind of work.

The almost flat growth over the three-year period from 2003 to 2006 in all position categories is almost certainly a consequence of the flat NIH budget after the doubling years. While data on the current faculty are not available, one expects that the ratio of tenure track to non-tenure-track academic positions may well look very different in 2009 and beyond due to the severe economic downturn and the financial problems besetting many institutions. It is worth mentioning that the number of basic sciences tenured and tenure-track faculty at medical schools increased from 2002 to 2005 and has actually declined in number since 2005 (see Table 3-8). The faculty size in 2009 stands at the 2002 level, and during this period the number of non-tenure-track faculty has increased by 12 percent. The stasis in overall tenure-track faculty numbers, coupled with the dramatic decrease in the number of faculty taking retirement, means that new, tenure-track assistant professor positions are increasingly scarce.

The decreased retirement rate and the longer time to independent research status are seen in the changes in the age distribution of tenured faculty from 1993 to 2006 (see Figures 3-9 and 3-10).

These figures provide dramatic evidence that the academic workforce is aging. By 2006 about 25 percent of the tenured academic faculty were over the age of 60, and about half were 55 or older. At the same time, the proportion of younger tenured faculty has necessarily declined over time, which is, of course, ultimately reflected in the increased average age at award of first R01 grant. Given the current

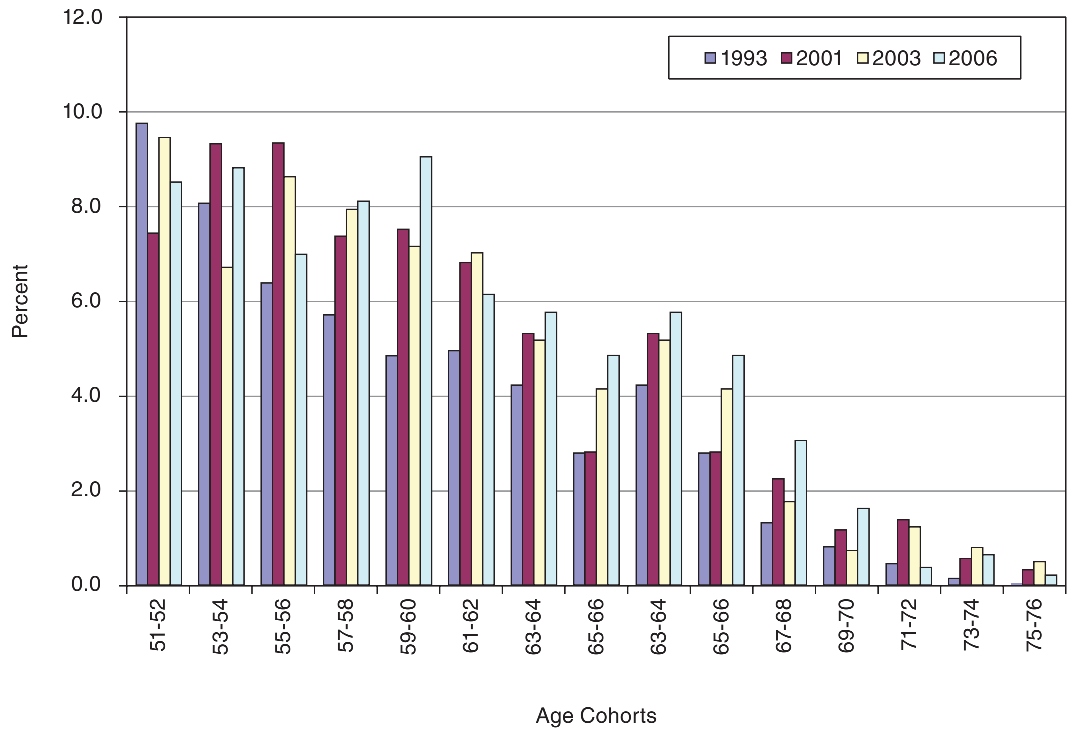

FIGURE 3-9 Age distribution of tenured faculty 1993, 2001, 2003, 2006.
SOURCE: NSF. *Survey of Doctorate Recipients, 1973-2006*. Washington, DC: NSF.

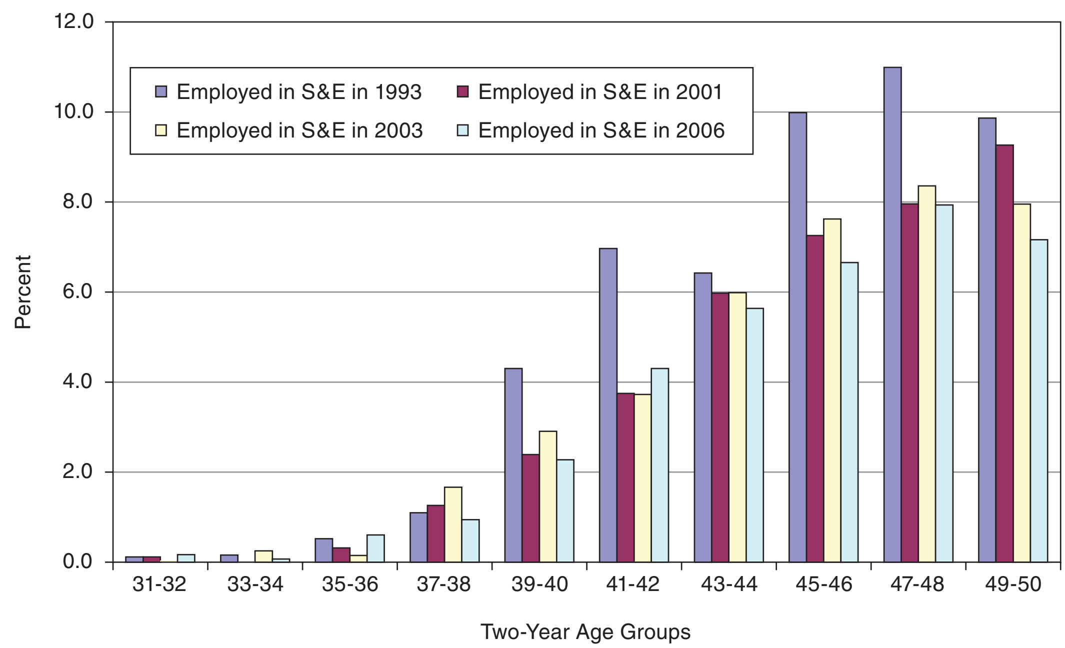

FIGURE 3-10 Percentage of tenured faculty in the biomedical sciences by 2-year cohort: Early career.
SOURCE: NSF. *Survey of Doctorate Recipients, 1973-2006.* Washington, DC: NSF.

economic downturn and its financial effect on retirement plans, it is highly likely that faculty members will delay retirement plans.

Thus in summary, the constraints of the biomedical academic workforce being rather young during the 1970s and 1980s, the prohibition of mandatory retirement in 1993, and the current (and understandable) reluctance of faculty to take voluntary retirement have combined to produce a progressively marked aging of faculties and a dearth of openings for new faculty researchers. It has been said about the tenure system that "where there's death, there's hope," and presumably, opportunities for new faculty hires will dramatically improve over the next decade as aging imposes its mortal laws. During the past five years we have seen a dramatic increase in the number of new medical schools. Depending upon how much they emphasize basic biomedical research, this situation may also provide additional employment opportunities.

While a majority of the biomedical sciences workforce is employed in academic institutions, a little more than 40 percent is employed in other sectors (see Figures 3-11 and 3-12). The number of scientists working in industry, the largest of these other sectors, had been growing at a steady rate of close to 7 percent over the past 20 years, at least until 2008. There was a lull in employment in the early 1990s, possibly as a result of the economy or unfulfilled expectations of biotechnology, but growth since the mid-1990s has been strong. In contrast, government and non-profit sector employment has been fairly stable, though with a low growth respectively, over recent years. The most recent date for which we have information is 2006. How the current fiscal crisis and recession, with its profound impact on employment, will affect industrial employment of the biomedical workforce remains to be seen.

The demographics of the workforce are also changing. Women are becoming a greater part of the biomedical workforce. In the early 1970s they represented only 13 percent across all employment sectors, and by 2006 their participation had grown to 35 percent (see Figure 3-13).

In 2006, the percentage of females with faculty rank in academic institutions—31 percent—was slightly lower than the percentage of females in the over biomedical workforce. It might be argued that because the numbers of female faculty are starting from a low base in the early 1970s, it is not surprising that it has taken women time to obtain parity in this area. However, looking at the data from the perspective of the number of Ph.D.s per year and the year of Ph.D. among female faculty, a different outcome between males and females has persisted for some time (see Figure 3-14). In fact, since 1990 the number of Ph.D.s awarded to females has increased by over 20 percent, to the point women earned half of all Ph.D.s in 2008, but the representation in faculty ranks has stayed constant at close to 30 percent. While it will take time before women are represented in proportion to the degrees awarded, it is disconcerting to realize that their Ph.D. representation is not reflected in the percentage of non-tenure-tenure track faculty in medical schools. From 2002 to 2009 the percentage of tenure-track females has increased from only 30 percent to 33 percent (see Table 3-9), and in

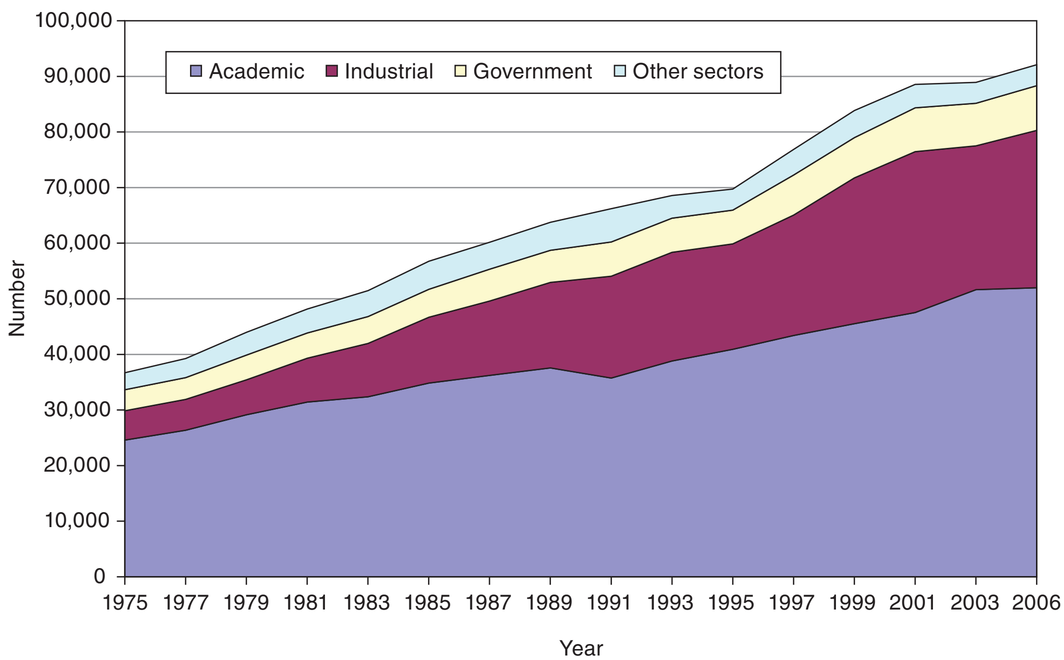

FIGURE 3-11 Biomedical employment by sector.
SOURCE: NSF. *Survey of Doctorate Recipients, 1973-2006*. Washington, DC: NSF.

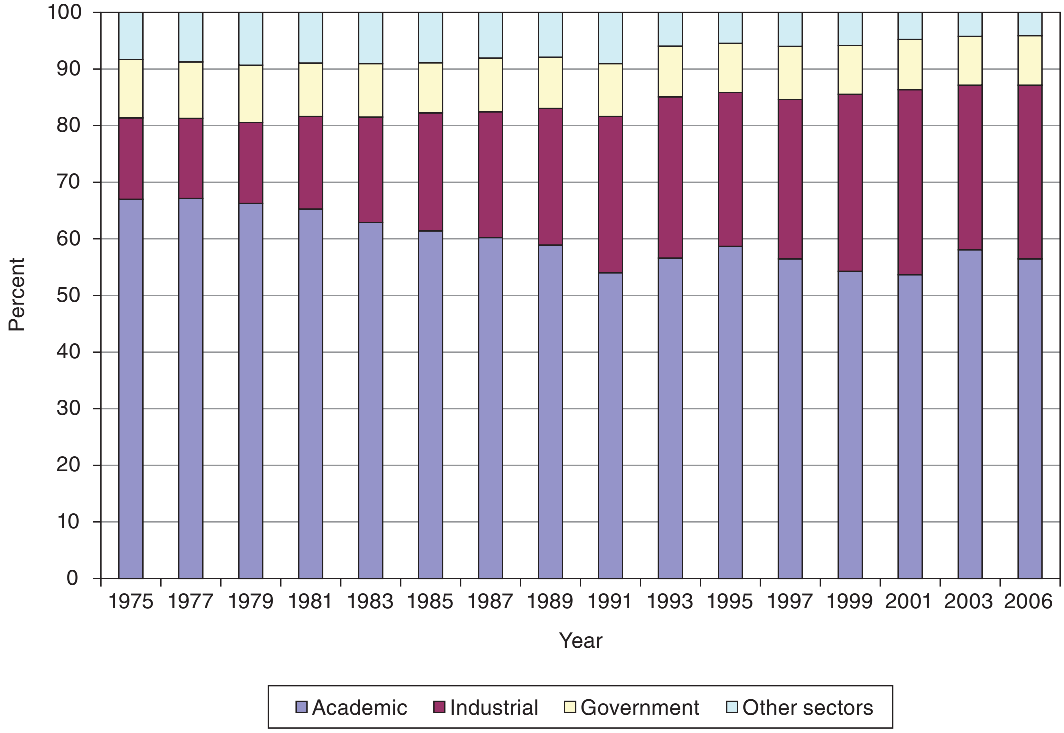

FIGURE 3-12 Percentage employment by sector.
SOURCE: NSF. *Survey of Doctorate Recipients, 1973-2006.* Washington, DC: NSF.

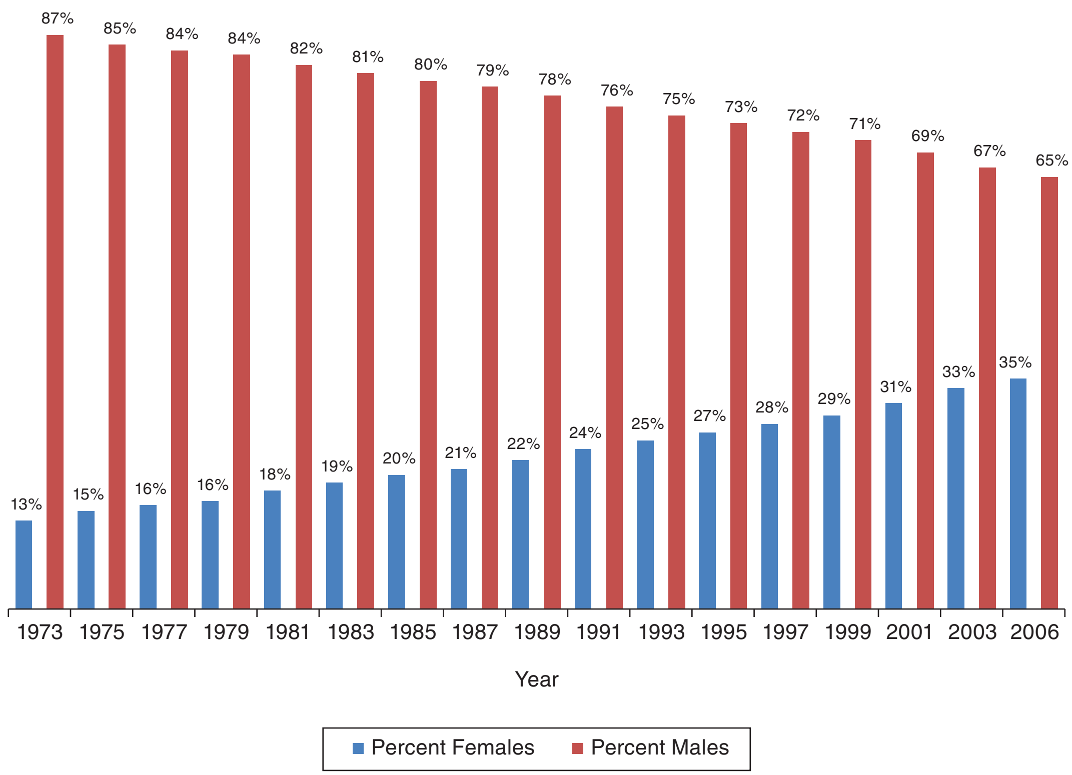

FIGURE 3-13 U.S. biomedical Ph.D.s employed in S&E fields by gender.
SOURCE: NSF. *Survey of Doctorate Recipients, 1973-2006*. Washington, DC: NSF.

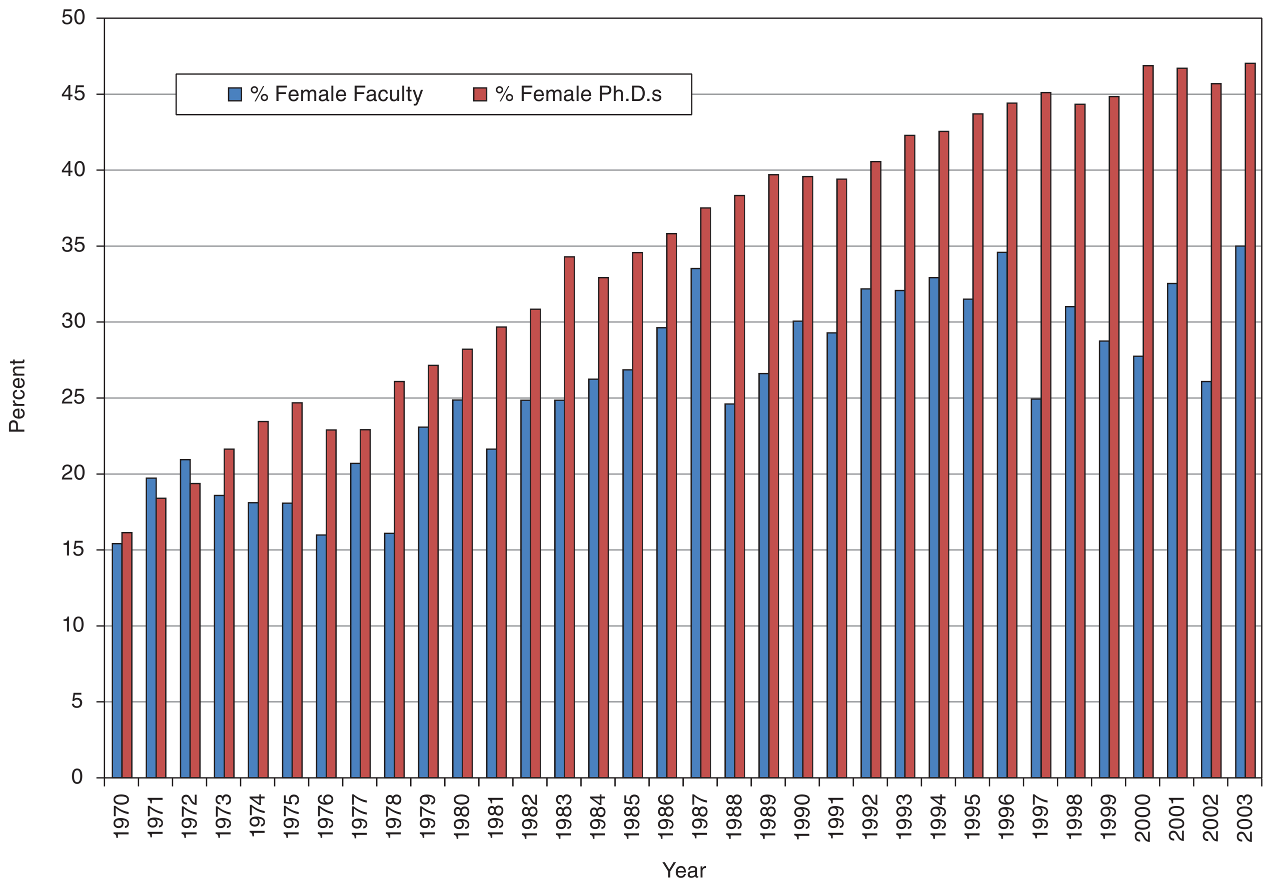

FIGURE 3-14 Percentage of female faculty in 2006 in the biomedical sciences by year of Ph.D. compared with the number of female Ph.D.s in the same year.
SOURCE: NRC. 2010. *A Data-Based Assessment of Research-Doctorate Programs.* Washington, DC: The National Academies Press.

TABLE 3-9 Distribution of Medical School Faculty by Track and Gender, 2002, 2005, and 2009

	Percent					
	2002		2005		2009	
	Females	Males	Females	Males	Females	Males
Tenured	18	82	20	80	21	79
Tenure Track	30	70	32	68	33	67
Non-Tenure Track	36	64	37	63	40	60
Total	26	74	28	72	30	70

SOURCE: AAMC, 2010. *Association of American Medical Colleges Faculty Roster, 2009.* Available at https://www.aamc.org/data/facultyroster/.

2009, 40 percent of women Ph.D.s were in non-tenure-track positions.

The data from the AAMC Roster are similar to the NSF data concerning the entire population of U.S. doctorates. In 2006 females occupied 31 percent of the faculty positions and represented 35 percent of the S&E workforce, and they held 45 percent of the non-tenure and non-faculty positions. The data on faculty appointments are consistent over time, with the percentage of female faculty appointment about 2 percentage points below their numbers in the overall population, but in the early 1980s when they represented about 20 percent of the workforce, they held about 40 percent of the non-tenure and non-faculty positions, and that percentage has varied between 40 and 45 percent over the past 25 years. Women are recruited into tenure-track assistant professor positions to a reasonable degree, but several studies have shown that the fraction of females in associate and in full-professor positions declines substantially, and these numbers have not changed very much over the past 20 years or so. A detailed study of the reasons for these observations was published recently in a study of female academics in the California system.[7]

The Diversity of the Workforce

The number of underrepresented minorities in the basic biomedical workforce has increased significantly, from 2.5 percent of the workforce in 1973 to 6.2 percent in 2006.[8] These numbers reflect the increasing numbers of minorities in postdoctoral positions, which have grown from 1.6 to 6.8 percent during the same period. Given that the number of minority biomedical Ph.D. recipients is also increasing, we may expect the workforce number to increase. Nonetheless, despite the growth in recent years, minorities still remain a small fraction of the overall workforce. At the current rate of increase of minorities obtaining the Ph.D. degree, it is conceivable that the production rate could reach 14 percent, but this may well become a "pipeline" ceiling, as this is the fraction of minorities presently earning the B.S. degree in biological sciences. Clearly, additional representation in the workforce will depend on the issues of attracting additional minority undergraduate students into science and reducing dropout rates. These are major challenges, but they are beyond the scope of this report. Although the data concerning diversity are encouraging, there continues to be a serious problem.

PHYSICIAN RESEARCHERS

To this point the discussion has addressed only individuals with a Ph.D. in one of the fields listed in Appendix C, and has not taken into consideration physicians who are conducting basic biomedical research. It is difficult to get a complete picture of this workforce, because there is no database that tracks physician-scientists who are actively involved in research in the same way as are Ph.D. scientists.

However, according to the American Medical Association (AMA), the number of physicians active in research rose throughout the late 1970s and early 1980s and reached 22,945 by 1985. Since then, however, the number of M.D.s (and M.D./Ph.D.s) identifying research as their primary professional activity has steadily declined, dropping to 14,434 in 1997. This figure remained about the same until 2008 at about 14,880 (12 percent) of the faculty engaged in research. However, these numbers have to be interpreted conservatively as the AMA's "physicians active in research" may mean many things, including participation as workers, not leaders of clinical trials.

Although these data do not distinguish between physician-scientists holding an M.D. and those with M.D./Ph.D.s, it is highly likely that the proportion of these researchers who hold two degrees is increasing. Because the first formal M.D./Ph.D. training programs were introduced in 1964, opportunities for dual-degree training have steadily increased, and by 2009 some three-fourths of all medical schools offered their students an opportunity to earn both degrees; 40 of these programs currently receive funding as a Medical Scientist Training Program (MSTP) from the NIH. In 2009 M.D./Ph.D.s in medical schools represented 8.1 percent of the 18,957 faculty in basic sciences departments and 7.6 percent of the 118,559 faculty in clinical departments.

A recent study[9] published by members of the M.D./Ph.D. Section of the AAMC Group on Graduate Research Education and Training discusses the success of the MSTP. It reports on career choices of trainees who had received both M.D. and Ph.D. degrees from 24 MSTPs enrolling 43 percent of current trainees and representing about 50 percent of the MSTPs. Of 2,383 alumni from these programs only 16 percent were in private practice, while 68 percent were in academic centers, 8 percent in industry, and 5 percent in research institutes. Of those with academic appointments, 82 percent were conducting research. This level of research activity is reflected in an estimated 73 percent with research funding. This is higher than the 58 percent of the faculty with Ph.D. degrees from the Research-Doctorate Study who reported research grant support. Because M.D./Ph.D. programs were envisioned as a means of fostering transitional or clinical research, the study of M.D./Ph.D. recipients found that 56 percent were conducting basic research, 41 percent were conducting transitional research and 43 percent were conducting clinical research (percents do not add to 100 percent because combination of areas could be selected).

In addition, Dickler et al.[10] found that M.D./Ph.D. applicants for both first and second R01 grants had a higher success rate than applicants with either an M.D. or Ph.D. alone, and that the number of first-time M.D./Ph.D. applicants for NIH R01 grants has become almost equal to that of M.D.s only by 2006. The findings are consistent with those of an earlier study by the National Institute of General Medical Sciences (NIGMS) in 1998 of graduates from MSTPs, which found that by almost all measures the MSTP-trained graduates were better than the other control groups. They entered graduate training more quickly and took less time to complete the two degrees than comparable degrees for the other groups. In terms of research activity, the NIH data showed that the MSTP graduates applied for research grant support from the NIH at a greater rate, and they were more successful in receiving support. These outcomes provide a remarkable testimony to the success of M.D./Ph.D. programs in training physician-scientists, who after graduation continue to

[7] See http://www.americanprogress.org/issues/2009/11/women_and_sciences.html.

[8] NSF. *Survey of Doctorate Recipients, 1973-2006.* Washington, DC: NSF.

[9] Brass, L. 2010. Are the M.D.-Ph.D. programs meeting their goals? *Academic Medicine* 85(4):692-701.

[10] Dickler, H.B., D. Fang, S.J. Heinig, E. Johnson, and D. Korn. New physician-investigators receiving national institutes health research projects grants. *Journal of the American Medical Association* 297(22): 2496-2501.

participate successfully in a broad spectrum of research and research-related activities.

Over the past decade the MSTPs have also begun to make significant strides in terms of including minority students. The racial distribution for the cohort of students who matriculated into an M.D./Ph.D. program in 2009 is shown in Table 3-10.

The proportion of URM students in M.D./Ph.D. programs is considerably lower than that in the general population of the United States. However, it is perhaps more relevant to compare the compositions of these programs to the proportion of URMs among those who graduate with B.S. degrees in biology. Table 3-10 shows that in the group of M.D./Ph.D. programs the proportion of URMs is only slightly less than that of URMs in the pool of B.S. degree graduates in the biological sciences, a major pool from which the programs recruit their students. Nevertheless, these data show that the total number of URMs in M.D./Ph.D. programs represents only about 0.7 percent of the biological sciences B.S. pool and less than 0.1 percent of the total pool of B.S. graduates. Thus, there is clearly both an opportunity and the need for increased effort to attract URMs into M.D./Ph.D. programs (both MSTP and non-MSTP). Women accounted for 37 percent of the current trainees in the programs participating in this study, and they had the same attrition rate as men (approximately 10 percent). These successful women who hold both degrees serve as outstanding role models for female scientists in training and underscore the need for M.D./Ph.D. programs to continue aggressively to pursue the goal of gender equity in this area. Given the increases of the number of woman gaining Ph.D. degrees in the biomedical sciences, along with the fact that women earn the B.S. degree at a higher rate than men, we may expect that parity should be reached in these programs over the next decade.

On average, M.D./Ph.D. students take about 8 years to complete their degrees, during which time most receive tuition waivers and a stipend from a combination of public and private funding sources. As a consequence, on completion of their training, overall indebtedness levels reported by M.D./Ph.D.s are about half (or less) of those of their medical school classmates, and they enter the job market on better financial footing and with better job prospects than investigators with only one degree.

Moreover, unlike their counterparts with a Ph.D., who often have difficulty obtaining faculty positions, M.D./Ph.D.s are reportedly in great demand as medical school faculty members, particularly in clinical departments (Brass et al.), and they are very well represented among clinical division heads and department chairs. Graduates of M.D./Ph.D. programs are now a critical and very successful component of the clinical, translational, and basic research workforces in medical schools and major teaching hospitals. They are in demand as medical school faculty members and are well represented among clinical division heads and department chairs.

However, in spite of their success, the training in MSTPs has declined over the past few years from a maximum of 933 full-time trainee positions in 2002 to 911 positions in 2009. The current number of trainees is at the 2006 level. Since 2006 the program has been co-funded by other institutes, and the number of positions has ranged from 48 in 2006 to 71 in 2009. The total funding of M.D./Ph.D. programs by the NIGMS in NIH has not increased in 1990 dollars from 1990 to 1997 and increased during the doubling of the NIH budget by 38 percent, has declined in recent years (see Figure 3-15). From 2008 to 2009 it actually decreased in actual dollars and the result was a decrease in training positions from 923 to 911.

U.S. CAPACITY TO IDENTIFY OUTSTANDING APPLICANTS TO M.D./PH.D. PROGRAMS

Among the 16,127 students who graduated in 2007 from all medical schools, 494 (3.1 percent) received M.D./Ph.D.s. NIH estimates that only 350 of these graduated from NIH-supported MSTPs, while 150 future physician-scientists graduated with both degrees from M.D. and Ph.D. programs that do not receive NIH funding. To support programs currently training this non-NIH funded pool of future physician-scientists to the same degree as the NIH funded pool, the MSTP would have to increase by 40 percent. This raises the

TABLE 3-10 Compositions of M.D./Ph.D. Programs in United States by Race[a]

Program	URM[b]	%	Asian	%	White	%	Total[c]
MSTP[d]	52	14.4	93	25.7	217	59.9	362
Non-MSTP[d]	20	10.7	52	27.8	115	61.5	187
All MD/PhD[d]	72	13.1	142	25.9	332	60.4	549
B.S. Degrees (All Sciences)	73,835	18.3	37,050	9.2	268,783	66.4	404,494
B.S. Degrees (Biological Sciences)	11,841	15.4	11,572	15.0	49,771	64.6	77,015
USA Population 2008[e]	86,878,906	28.6	13,549,064	4.5	199,491,458	65.6	304,059,724

[a] Percentage values are based on total values in column one.
[b] URM values are the sum of Black African American + Hispanic + Native American and Alaskan Native + Hawaiian and Pacific Islander.
[c] Total number of students minus foreign students and those who gave no response to race.
[d] Data are from the Association of American Medical Colleges (AAMC) for classes entering 2009.
[e] Data are from the U.S. Census Bureau for 2008.

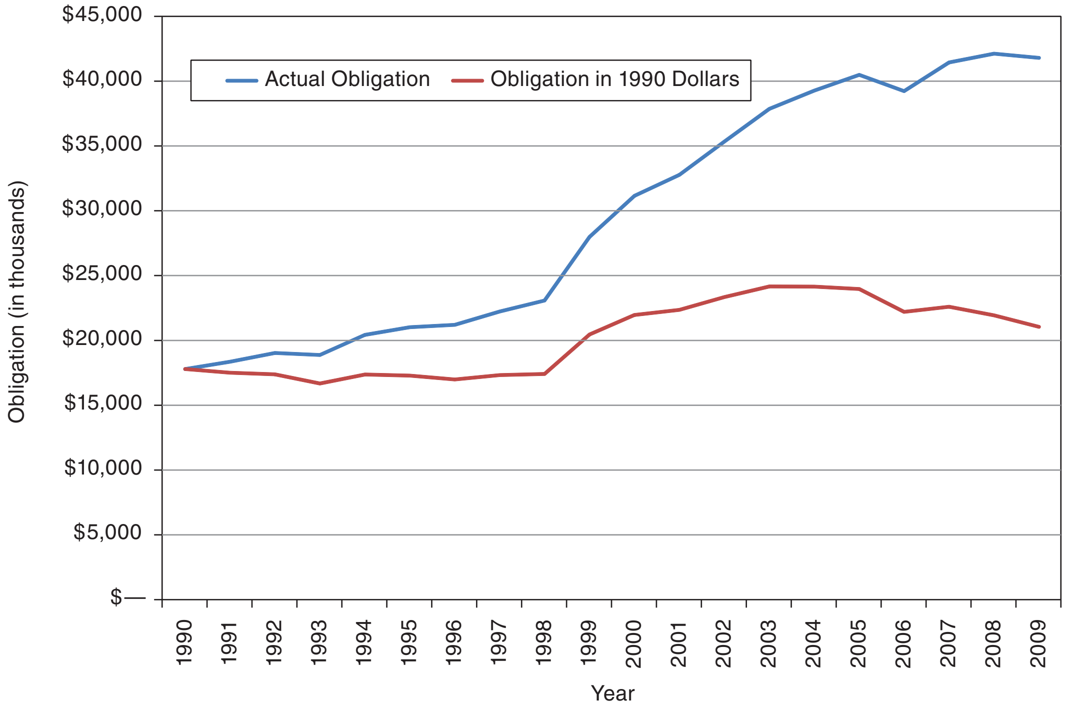

FIGURE 3-15 NIH funding of the Medical Sciences Training Program (dollars in thousands).
SOURCE: Data obtained from the National Institute of General Medical Sciences.

question of whether there are a sufficient number of highly qualified applicants to expand the MSTP by this amount.

For the class entering in 2009 there were 1,703 applications to M.D./Ph.D. programs, of which 601 matriculated into an M.D./Ph.D. program (397-MSTP; 204 non-MSTP supported M.D./Ph.D. program) leaving 1102 who did not join one of these programs. Several qualifications of applications are examined to identify those that have the highest probability of success in an M.D./Ph.D. program. Among these are prior research experience, undergraduate and graduate GPA, and evidence of sustained motivation toward a career as a physician-scientist. An additional important parameter is the MCAT score. Although on its own it is of limited predictive value for success, it does give a good estimate of a student's performance in the United States Medical Licensing Examination Step 1. AAMC data for those students matriculating in 2009 are shown in Table 3-11.

In 2009, there were 258 applicants to M.D./Ph.D. programs who did not matriculate into an M.D./Ph.D. program even though they obtained an MCAT score of 34 or higher (which is within the range of students joining an MSTP). Recognizing that no MCAT score should be considered as a cutoff for acceptance into an M.D./Ph.D. program and that other factors are taken into account when students are selected, it does appear that there are about the same number of applicants with MCAT scores of 32 or higher to M.D./Ph.D. programs who did not join an M.D./Ph.D. program as joined an MSTP. To take this line of thought further, there were 607 applicants who applied to, but did not join an M.D./Ph.D. program, who obtained an MCAT score of 30 or higher, which is close to the average of all medical school matriculants. These data, together with the fact that there are presently 204 students in non-MSTP-funded programs, strongly indicate that there is a sufficiently deep applicant pool, and that the size of the MSTP could easily increase by 30 percent or more by accepting students whose acceptance did not demand a lowering of the program's rigorous academic standards.

Moreover, the committee felt strongly that in today's climate of changing strategies to provide more extensive health care coverage while simultaneously controlling the costs of medical care, it is vitally important to expand the M.D./Ph.D. program to include the behavioral and clinical research workforce. As a result of these considerations the current committee endorses the intent of the recommendation of the previous committee with the modification that MSTP funding be expanded by more than 20 percent. There is no intent to add extra support to extant programs, which might not lead to an increased number of trained individuals. Thus, we strongly recommend that there be assurance that this increase in funding will result in an increase in the total number of M.D./Ph.D. students trained, especially in excellent programs at institutions not currently supported by the MSTP. A significant portion of this increase in funding should be targeted at trainees in the social and behavioral sciences, as well as dual-degree programs in dentistry and

TABLE 3-11 MCAT Scores

	Number	Average	Median
All medical students who matriculated into medical school	18,390	30.8	31
All medical students who matriculated into an M.D./Ph.D. program (MSTP plus non-MSTP)	601	34.3	34
All students who matriculated into an MSTP program	397	35.3	35
All students who matriculated into a non-MSTP-funded M.D./Ph.D. program	204	32.3	32

SOURCE: Association of American Medical Colleges data. 2010.

nursing. Certainly, standards must remain high, and if there is an insufficient number of highly qualified applicants for this increased level of funding, NIGMS should redirect unused funds to support other categories of its sponsored research training programs. Also see the section "The Role of the National Research Service Award Program" in Chapter 5.

FINANCIAL SUPPORT OF BIOMEDICAL TRAINING AND THE NATIONAL RESEARCH SERVICE AWARD PROGRAM

Exciting advancements in biomedical research, together with a generally strong economy in the 1990s and again in the early part of this decade after 2002, were reflected in increased research and development support from the NIH. The NIH budget and its funding of extramural research and training doubled in nominal dollars from a little over $10 billion in 1998 to $20.2 billion in 2004, during which time total NIH expenditures grew from $13.0 billion to $27.2 billion. Measured in constant 1998 dollars, the extramural increase was 65 percent from $10.0 billion to $16.5 billion. The change in the budget for training during the period increased from $428 million to $604 million in 1998 dollars. Increases in the NIH extramural budget over the years following the doubling were exceedingly small and actually declined in constant 1998 dollars to $14.5 billion in 2009, with research grant funding at $14.0 billion and funding for training at $518 million. The decline in total training support was not reflected in the number of training position, which remained almost constant, but in the stipends that remained constant and declined when adjusted for inflation and in the capped tuition support. The President's budget request for fiscal year (FY) 2011 is aimed at correcting the stipend problem with a 6 percent increase over FY 2010 in the NRSA funds that are directed at training stipends, and a decrease of about 1 percent in the number of awards. Corresponding changes are seen in the data for academic research and development (R&D) expenditure in the biological sciences. R&D expenditures in constant 1998 dollars increased slightly in the early 1990s from a little over $4 billion in 1990 to $5 billion in 1998, and then increased during the doubling of the NIH budget to almost $8 billion in 2005. Since 2005 there has been a decline to about $7.5 billion in 2008.

Essentially all graduate students in the biomedical sciences receive funding of one sort or another. There is no comprehensive data source for the funding of students in doctoral programs, but the Research-Doctorate Study collected data from the institutions that are heavily invested in biomedical research. Across the fields that correspond to the biomedical sciences in that study, almost all students are supported in their first year (see Table 3-12). This funding pattern continues during their doctoral studies with few students receiving partial or not support (see Table 3-13).

TABLE 3-12 First-Year Support for Doctoral Students in the Biomedical Sciences

	Percent		
Field	Full Support	Partial Support	No Support
Biochemistry, Biophysics, and Structural Biology	96	3	1
Biomedical Engineering and Bioengineering	86	7	7
Cell and Developmental Biology	97	1	2
Genetics and Genomics	93	4	4
Immunology and Infectious Disease	95	4	1
Integrated Biomedical Sciences	97	1	2
Microbiology	96	2	2
Neuroscience and Neurobiology	96	3	1
Nutrition	88	10	2
Pharmacology, Toxicology, and Environmental Health	94	4	2
Physiology	96	2	2
Total	95	3	2

SOURCE: NRC. 2010. *A Data-Based Assessment of Research-Doctorate Programs.* Washington, DC: The National Academies Press.

TABLE 3-13 Funding Across Graduate Studies in the Biomedical Sciences, Fall 2005

	Percent					
Field	Fellow or Trainee	Teaching Assistant	Research Assistant	Combination Funding	Less than Full Funding	Unfunded
Biochemistry, Biophysics, and Structural Biology	20.9	10.8	39.8	25.7	1.1	1.7
Biomedical Engineering and Bioengineering	17.5	7.6	46.0	19.6	3.2	6.1
Cell and Developmental Biology	21.7	8.3	40.4	27.0	1.0	1.6
Genetics and Genomics	22.7	7.9	42.9	24.4	0.4	1.7
Immunology and Infectious Disease	29.6	4.1	33.2	29.9	2.1	1.2
Integrated Biomedical Sciences	18.3	26.3	30.4	20.7	1.1	3.2
Microbiology	17.5	15.1	41.9	22.3	1.4	1.8
Neuroscience and Neurobiology	28.8	6.6	31.1	30.8	1.3	1.3
Nutrition	15.9	11.0	41.9	20.9	3.2	7.1
Pharmacology, Toxicology, and Environmental Health	23.5	9.7	41.6	22.7	1.1	1.4
Physiology	22.3	6.6	37.6	29.6	2.0	1.9
Total	21.9	10.9	38.4	25.0	1.4	2.3

SOURCE: NRC. 2010. *A Data-Based Assessment of Research-Doctorate Programs.* Washington, DC: The National Academies Press.

When the NRSA was established in the 1970s, the majority of the graduate student funding came from these fellowships and traineeships, with additional support from research grants (graduate research fellowships) and from institutional teaching assistantships. This began to change in the early 1980s when support of training from research grants became more common and quickly grew in share until in 2006 it represented the means of support for most graduate students in the biomedical sciences (see Table 3-14). Specifically, research grants funded about 40 percent of all students in the early 1980s and 70 percent by 2006. This increase mirrors increased overall NIH funding during this period and the corresponding increase in graduate student numbers overall (see Figure 3-16). The greatest growth in research assistantships, however, occurred from 2000 to 2004, during and toward the end of the NIH budget doubling. Given that the majority of graduate students are trained while being supported by R01 grants, it does not seem unreasonable to expect that the same high standards expected of T32 trainees should be applied to these students, and this reasoning is the basis of a recommendation outlined in Chapter 2. It is also worth noting that predoctoral fellowships amounted to only 2.7 percent of the NRSA support in 1974, but currently contributes 20 percent, and that since 2006 there has been a decline in the number of R01-supported graduate students.

FUNDING OF POSTDOCTORAL FELLOWS

Information on overall funding patterns for postdoctoral fellows in the basic biomedical sciences is not as complete as that for graduate students, because academic institutions are the only source of data, and their information almost certainly is an underestimate because of the varieties of appointment titles for postdoctoral trainees. Figure 3-17 shows the type of postdoctoral support in doctoral-granting institutions for both U.S. doctorates and doctorates with degrees from foreign institutions. As is the case for graduate student support, the fraction of postdoctoral support from federal funds derived from training grants and fellowships has actually diminished

TABLE 3-14 NRSA Trainees and Fellows by Broad Field (Basic Biomedical Sciences), 1975-2008

	Predoctoral		Postdoctoral		
	Trainees	Fellowship	Trainees	Fellowship	Total
1975	1,009	27	474	1,106	2,616
1980	4,184	21	2,200	1,982	8,387
1985	4,026	80	2,128	1,583	7,817
1990	4,701	123	2,232	1,483	8,539
1995	5,095	411	2,191	1,679	9,376
2000	4,628	400	2,310	1,598	8,936
2005	4,845	862	2,598	1,365	9,670
2006	4,516	962	2,463	1,374	9,315
2007	4,937	1,074	2,386	1,291	9,688
2008	5,390	1,154	2,475	1,284	10,303

SOURCE: NIH Database.

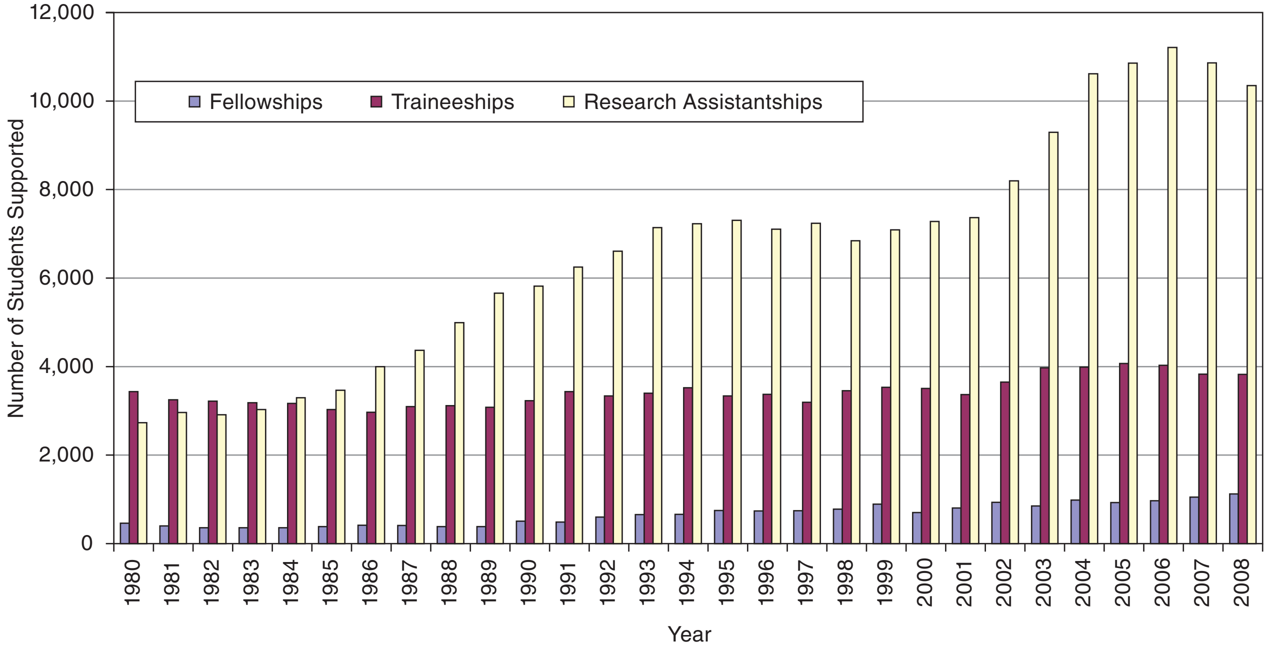

FIGURE 3-16 NIH support of graduate students.
SOURCE: NSF. 2008. *Survey of Graduate Students and Postdoctorates in Science and Engineering*. Washington, DC: NSF.

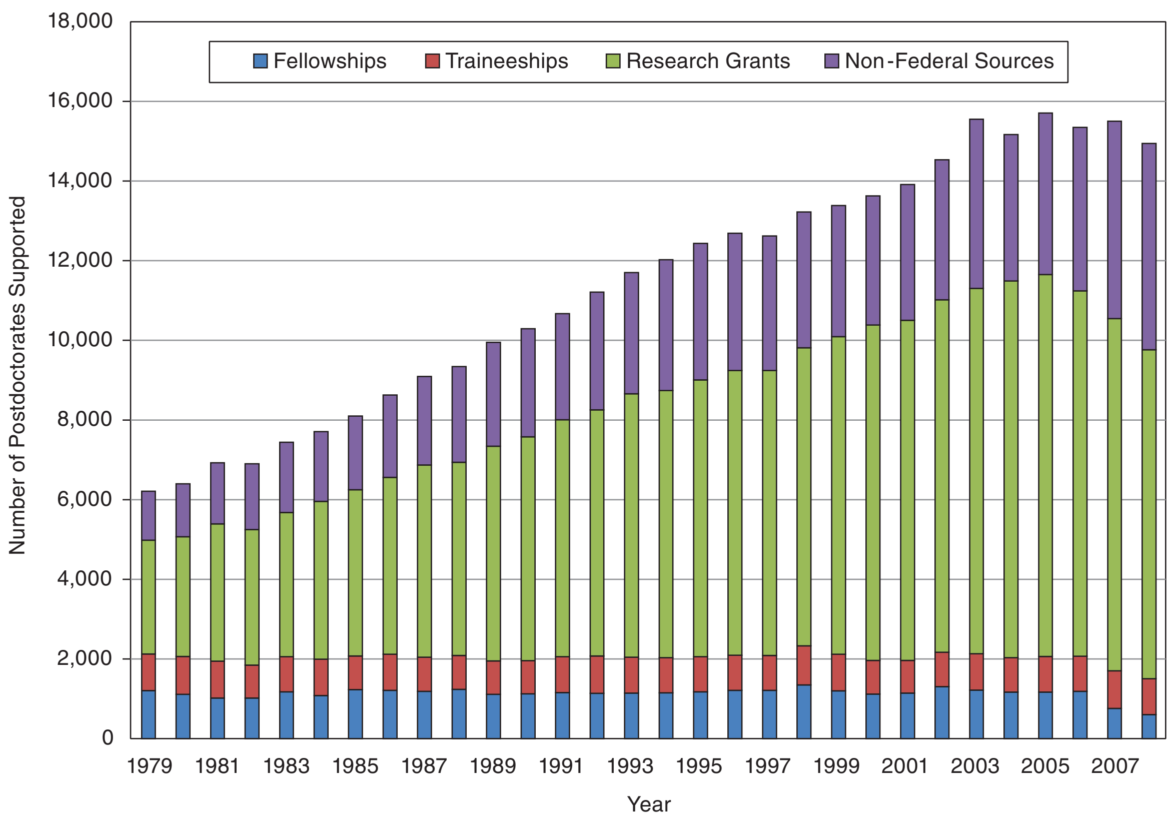

FIGURE 3-17 Postdoctoral support in the biomedical sciences.
SOURCE: NSF. 2008. *Survey of Graduate Students and Postdoctorates in Science and Engineering*. Washington, DC: NSF.

because of the dramatic increase of trainee funding from research grants. In 1979, 2,217 (or 31 percent) of the total 6,698 federally funded university-based postdoctoral fellows received their training on a fellowship or traineeship. Over time the trainee and fellowship support has remained fairly constant at around 2,000, but in 2007 and 2008 there was a decline, and in 2008 only 1,502 postdoctorates were supported on these mechanisms and represented 8 percent of the federal support. The remaining 96 percent came in the form of research grants. From 1979 to 2006 the share of non-federal funding for postdoctoral positions had been almost constant at about 25 percent but increased to 35 percent in 2008.

Over the past 25 years, research grants awarded by the NIH and other Health and Human Services agencies have more than doubled.[11] With the increase in the amount of laboratory work required to meet the aims of these grants, principal investigators have come to depend increasingly on graduate students and postdoctoral fellows: the trainees have in essence become the academic research workforce. As a result, the number of universities awarding Ph.D.s in the basic biomedical sciences, and the number of Ph.D.s awarded by existing programs, has grown. Thus, federal funding policies provided universities an incentive to appoint students and postdoctoral fellows to research assistantships in addition to training grants or fellowships. Indeed, there is a cost-benefit to the university and to the federal sponsor to support students on research grants because the indirect cost rate for institutional training grants is capped arbitrarily at 8 percent, far below the significantly higher negotiated rates on research grants, and below the administrative and facilities costs incurred by the institutions that could justifiably be allocable to "training." However, this is likely not the driver in this case.

Rather, as mentioned above, the growth in training support from research grants reflects the fact that graduate students and postdoctoral fellows are the backbone of the biomedical research workforce, and the increase in student trainees/workers simply reflected the additional research that can be performed with the additional federal support. The large increase in the fraction of the postdoctoral workforce that is supported by RPGs brings to the forefront the need to ensure that all postdoctorates, no matter how funded, should benefit from the expected enrichments offered to postdoctorates by the NRSA training programs.

As described in Chapter 1, the number of graduate students and postdoctoral fellows who have been provided research training through NRSA training grants and fellowships has been deliberately limited over most of the past 25 years with the (utterly unrealistic) goal of controlling the number of independent researchers entering the workforce. However, if that was really the goal, it has been singularly unsuccessful. As Massy and Goldman concluded in their 1995 analysis of science and engineering Ph.D. production (and as one might expect when the trainees are a major component of the academic workforce), the size of doctoral programs is driven primarily not by the labor market for Ph.D.s.[12] but rather by individual faculty needs for research and (to a lesser extent) teaching assistants, and in the biomedical arena it is largely the former that is driving the size of graduate student and postdoctoral pools.

Despite this massive shift in relative federal support of training over the past 30 years, NRSA training grants to institutions are highly prized and competitively sought. They bring prestige to institutions that have them, and they add stability to graduate programs, because they are usually for 5 years and allow for future planning. In addition they have been immensely potent forces stimulating the development of creative approaches to graduate education and providing focus on the need to apply evaluations of post-graduation outcomes in assessing the success of the programs. In addition, they have been a strong motivator in the quest to diversify the biomedical workforce, and nowhere has this been more successful than in those schools aggressively competing for training grant support. On the other hand, only U.S. citizens and permanent residents now qualify for support under NRSA training grants and fellowships, and because a growing number of graduate students and fellows with temporary resident status make up the research workforce, these temporary residents have necessarily been supported by research grants.

Another factor in the shifting patterns of federal research training support is the type of education that students receive. From their inception, NRSA predoctoral training grants in the basic biomedical sciences have been multidisciplinary—emphasizing the importance of having students exposed to a wide range of fields and technologies in the biomedical sciences, and even to fields in other branches of science. At a time when many of the frontiers of science demand multidisciplinary and interdisciplinary research capabilities to produce significant advances, this requirement becomes ever more pressing. Although the amount and quality of multidisciplinary training may vary from program to program, students in programs supported by training grants might arguably have a better and more complete educational experience than those on a research assistantship.

Given the fact that more than half of the graduate student and postdoctoral fellow training is not funded by the NRSA mechanism, it is legitimate to ask if the training that these individuals receive is preparing them optimally for their future roles in the biomedical workforce. The majority of graduate students in the biomedical sciences who receive their funding support as RAs are situated within departments and as such are subject to the rules and expectations of their graduate schools and departmental programs. In

[11] Unpublished tabulation from the NIH IMPAC System.

[12] Massy, W.F., and C.A. Goldman. 1995. *The Production and Utilization of Science and Engineering Doctorates in the United States.* Stanford Institute for Higher Education Research Discussion Paper. Stanford, CA.

this sense, the expectations for their overall performance are not radically different from those of students supported by NRSAs. Although the training may be less interdisciplinary and may lack the same emphasis on exposure to Responsible Conduct of Research (RCR), career planning, and quantization in science, we may nonetheless expect that these programs should be comparable academically to the NIH-funded programs.

It is not so immediately apparent that these same conclusions necessarily apply to the postdoctorate workforce. Postdoctoral fellows are recruited to individual labs and are rarely involved in a highly structured program comparable to the graduate education model. For well-trained individuals, this is an opportunity to broaden their experience and develop their independence and can be a valuable component of their professional development. Nonetheless, as was indicated in Table 3-14, a significant number of U.S. national postdoctoral fellows are trained as fellows or on training grants, each with explicit NIH-mandated components (such as diversity and exposure to multidisciplinary research and RCR). However, the pool of postdoctoral fellows who are the most responsive to rapid deployment of recently received research funds is the international pool—a group that now makes up the majority of the postdoctorate component of the workforce. There is a need to ensure that the programs in which these trainees find themselves are adequately developed, indeed that there is a training component, and to ensure that the caliber of work is high, that the expectations of the NIH are met, and that the interests of the international postdoctoral fellows themselves for training in RCR, quantitation, and career planning are met.

POSTDOCTORAL REMUNERATION AND BENEFITS

A discussion of postdoctoral education would be incomplete without a discussion of the byzantine ways that universities have been compelled to categorize and appoint postdoctorates by the stipendiary nature of the NRSA. At any one time an institution will likely have the following types of postdoctorate, all of whom might be doing comparable research and being exposed to similar enrichment and other appropriate training activities. There are U.S. national postdoctorate trainees who are not supported by an NRSA and international postdoctorates on J-1 visas who cannot be supported by an NRSA, and both groups are treated (or should be) as postdoctorate employees in training. Finally, since 1990 there has been an increasing number of H1-B employees, who are usually also classified as postdoctorates. These international scientists are allowed into the United States in response to a defined shortage of workers in high-tech fields. As such they are admitted because institutions assure the Departments of Labor and Homeland Security that they are already trained and that they will fulfill a workforce need not satisfied by the current pool of U.S.-trained workers. However, the reality is that these international scientists really should not be in "training" programs as they were admitted on the assurance that they are fully trained!

Adding to the confusion in terms of pay and benefits for postdoctorates is the federal mandate that NRSA recipients are stipendiary, and because they are not categorized as employees, they do not pay the Federal Insurance Contributions Act (FICA) tax and do not receive employee benefits, such as health insurance and contributions to retirement funds. Many institutions have successfully attempted to address this situation by providing separately negotiated medical insurance, but the retirement benefits usually have to be secured independently by using the savings from not paying FICA to cover the cost of a personal investment mechanism. Postdoctorates who are not supported by NRSA are treated as employees, but, depending on the institution, they may be offered full or sometimes, restricted employee benefits. Following prompting by the NRC report *Trends in the Early Careers of Life Scientists,* many institutions have moved to provide employee postdoctorates with health benefits comparable to those provided to the rest of their employees. However, there remains the paradox of postdoctorates who perform similar tasks but who are remunerated in different fashions depending upon their NRSA status. Faced with the difficulty of turning NRSA trainees into employees, some institutions have paid such trainees an additional, nominal salary, which can give them access to employee health plans, while others have converted all the postdoctorates into a common classification as trainees. However, in order to satisfy IRS rules these fellows must receive a formal education component for which they pay tuition cost. Also, given the H1-B issue referred to above, this may be an increasingly complicated and perhaps even questionable strategy. Obviously, different institutions have attempted to develop individual strategies best fitted to their own cultures. Possibly the best solution is to combine an excellent health insurance scheme for all postdoctorates (which is eminently doable) with transparent explanations of the different financial circumstances which, while different for the different categories, ultimately end up with all the postdoctorates in a more or less similar financial position.

CAREER OUTCOMES FOR GRADUATE STUDENTS AND POSTDOCTORAL FELLOWS

As was mentioned earlier in the chapter, graduate students and postdoctoral fellows have traditionally tended to seek careers in academic or industrial research. This paradigm has been changing over the past decade, and the current turmoil in the economy will likely additionally affect career outcomes for our trainee workforce. The factors of concern are: (1) the economic distress has hit both industry and academia hard, and it is likely that these sectors will not increase their rates of hiring in the near term; indeed some downsizing seems almost unavoidable, and (2) the downturn in the world economy has had less severe impact on several Asian countries that are rapidly diversifying and making major purposeful investments in science and in new technologies as a high national priority. Indeed their investments in education and in research and technological infrastructure may soon exceed our own, and as the major recession continues, the difference in investment may only increase. It is thus not inconceivable that the influx of foreign postdoctorates may well slow, and the effect could be severe as we have come increasingly to depend on this source of fellows to "titrate" our research workforce needs in response to changes in R01 funding. In addition, because of the economic distress, faculty at the end of their careers are resisting retirement because their 401(k) funds were depleted at the same time that university capacity to create new faculty slots was sharply diminished. All of these factors add up to bleaker prospects for those of our trainee workforce who are ready to enter the traditional job market.

A crisis can oftentimes provide an opportunity for creative, new, and unexpected solutions. The review committee felt very strongly that postdoctorates must be provided opportunities to learn about other, less traditional career options. Prominent among these is K-12 science education, generally agreed to be in a sorry state in this country. Accordingly, the NIH and other federal agencies, including the Department of Education, should devise mechanisms that enable senior postdoctorates to meet requirements to gain accreditation in teaching and should develop incentives (e.g., educational loans forgiveness) to encourage these trainees to enter high school science teaching. These trainees are highly knowledgeable, well trained, and possess unusual capabilities unlikely to be found in individuals with B.S. or M.S. degrees. Not only might this provide an attractive option to some in the trainee workforce, but it could also begin to address a major problem in our educational system that threatens the future scientific prowess and economic competitiveness of our country.

RECOMMENDATIONS

In the light of this discussion we propose the following recommendations:

Recommendation 3–1: The total number of NRSA positions in the biomedical sciences should remain at least at the fiscal year 2008 level. Furthermore, we recommend that future adjustments be closely linked to the total extramural research funding in the biomedical, clinical, and behavioral sciences. In recommending this linkage, the committee realizes that a decline in extramural research would also call for a decline in training.

Recommendation 3–2: Peer reviewers in evaluating training grant applications, especially competing renewals, should be instructed to broaden their concept of "successful" training outcomes to recognize nontraditional outcomes that meet important national priorities and needs related to the biomedical, behavioral, and clinical sciences.

Recommendation 3–3: One highly needed and extremely valuable outcome would be for graduates of the biomedical training workforce to become involved in a career teaching K-12, and especially middle and high school science. The NIH and the Department of Education should work to provide incentives to attract trainees to careers in K-12 science and should lead a national effort to accelerate the processes of "teaching accreditation" that the committee recognizes is controlled by the individual states.

Recommendation 3–4: The size of the MSTPs should be expanded by at least 20 percent, and more if financially feasible.

Currently there are 911 MSTP slots at an average cost of $41,806 per slot. An increase by 20 percent to about 1,100 slots would increase the MSTP budget by about $7.6 million or 1 percent of the NRSA budget. If phased in over time, the impact would be less.

Recommendation 3–5: The M.D./Ph.D. MSTP should be encouraged to include basic behavioral and social sciences training relevant to biomedical research, including the neurosciences.

Recommendation 3–6: MSTPs should be encouraged to intensify their efforts to identify and recruit qualified nontraditional, underrepresented groups (women and minorities). These efforts should be documented, and they should be a factor in the evaluation of all requests for MSTP funding increases and be conditions for receipt of any MSTP funding increases. Success depends on having a critical mass (not isolated examples) of underrepresented trainees in any given MSTP.

Recommendation 3–7: All institutes are encouraged to make F30 fellowships accessible to qualified M.D./Ph.D. students.

4

Behavioral and Social Sciences Research

INTRODUCTION

Basic behavioral and social sciences research is indispensible to the mission of the National Institutes of Health (NIH). Not only do psycho-social-biological factors directly affect disease outcomes per se, but also behavioral and social processes are linked to molecular, genetic, and neural processes affecting health and disease. Basic behavioral and social sciences research promotes health by predicting, preventing, and controlling illness, and by minimizing the impact of disease. A range of empirical investigations convincingly show that social and behavioral factors interact robustly with essentially every aspect of health and illness, spanning the entire disease process from vulnerability to diagnosis, treatment, course, prognosis, interface with health care systems, rehabilitation, and quality of life. The economic costs and human burdens of physical and mental disease result disproportionately from interrupting normal behavioral and social functioning.

Basic behavioral and social sciences research aims to measure, understand, and control processes that may later be applied to health and illness. As with all basic science, the direct link between fundamental research and health outcomes results from incremental discoveries that accumulate as an investment over time. There exist many examples of how basic behavioral and social sciences research has already increased knowledge about health and illness, including: (a) animal learning research has contributed to empirically validated behavioral treatments of various mental disorders, from phobias to addictions; (b) basic research on emotion explains disruptions by physical and mental illness, pointing to new treatments; (c) basic perception research informs diagnosis and treatment of neural disorders; (d) reliable results show how social networks shape all kinds of health behavior and psychobiological outcomes, from prevention to treatment to survival; (e) fundamental research on intergroup relations reveals underlying patterns and unconscious causes of health disparities for ethnic minorities, older adults, and sexual minorities; and (f) persuasion research reveals automatic processes that influence interactions with health care providers and determine both prevention and treatment outcomes.

Impressive gains in the science of brain, mind, and behavior provide new insights into health and illness, as well as new measurement methods, such as neuro-imaging and epigenetic indicators. At a much more macro level, environmental contexts and psychological, social, and cultural processes facilitate or constrain vulnerability to disease, risk behaviors, health promotion, proper health care, and re-entry into the community.

The behavioral and social sciences are as complex and variable as the natural sciences; not only do many factors affect individual and social behavior, but also these factors combine and interact in complicated ways. Partly because of the overall complexity of these sciences and partly for historical and cultural reasons, research support and research training in the behavioral and social sciences has lagged well behind those in other sciences. However, as noted, behavioral and social sciences contribute substantially to health research, primarily in psychosocial vulnerability, prevention behavior, treatment maintenance, and psychobiological response to treatment. Moreover, recent years have seen a tremendous leap in the sophistication of methods and tools in these sciences, leading to significant contributions regarding health behavior and contexts, as well as a realistic expectation that even more useful and effective answers to fundamental health questions will result from an investment of research training in these areas.

At the same time that these sciences have been maturing, our society has come to realize the absolute necessity of the research findings they produce for the understanding, treatment, and prevention of its health problems. As a result, scientists in these areas have been called on for advice to an ever-increasing degree by government agencies. Just one example is provided by the number and range of government-commissioned committees, panels, and reports assigned to the Division of Behavioral, Social, and Economic Sciences (DBASSE) at the National Research Council. In the past 10 years there have been more than 300 publications (books) in response to DBASSE assignments, covering a wide range of areas that are directly or indirectly related to health concerns, including: children and families; education, employment, and training; environment; health and behavior; human performance; international studies; law and justice; national statistics; and population and urban studies. Their level of focus ranges from the individual level to the societal level, and they cover the entire range of social and behavioral sciences and extend even to such related fields (such as ecology and criminology). A few examples of reports directly relevant to health concerns include: *Reducing Underage Drinking: A Collective Responsibility*; *Educating Children with Autism*; *Informing America's Policy on Illegal Drugs: What We Don't Know Keeps Hurting Us*; *Preventing Reading Difficulties in Young Children*; *Protecting Youth at Work: Health, Safety, and Development of Working Children and Adolescents in the United States*; *Work-Related Musculoskeletal Disorders: A Review of the Evidence*; *Understanding Risk: Informing Decisions in a Democratic Society*; *Understanding Violence Against Women*; *Preventing HIV Transmission: The Role of Sterile Needles and Bleach.*

As described in the 2005 NRSA report:

> The social and behavioral sciences deal with the most complex and the least predictable phenomena that affect the nation's health. One tends to think of mental health in this context, and indeed mental health is an important concern at NIH (in NIMH in particular) and in the government and private sector generally. Yet mental health is only one part of a much larger picture, because many of the most important health problems we face are determined and strongly affected by behavioral, social, and economic factors. Consider just a few examples: At the level of behavior of the individual, the behavioral and social sciences produce knowledge about health issues, such as drug and alcohol abuse, obesity, violent behavior, smoking, maintenance of drug treatment regimens, stress management, ability to cope with illness, and health decision-making. There are many critical health issues that emerge at a larger scale. The economics of health care and delivery critically determine what diseases and problems are attacked, what research is carried out, and which populations are given treatment. The government has recognized these factors with multi-million-dollar investments in surveys such as the Health and Retirement Survey, the National Longitudinal Survey, and the National Survey of Families and Households. The social sciences provide critical insights and knowledge concerning our ability and willingness to deal with disability, choices that promote well being, the use of and willingness to expend income and assets for health purposes, distribution of health care (geographically, sociologically, and economically), use and misuse of nursing homes, health provider behavior, psychological and social effects on morbidity and mortality, social and psychological effects on treatment and recovery, transfer of assets and beliefs across generations, social support mechanisms, economics of alternative health-care systems, care-taking approaches, bereavement and its effects, and health decision making. Societal, behavioral, and economic factors all work together to produce such problems as drug abuse, smoking, alcohol abuse, anorexia/bulimia, and obesity. Treatable diseases are making a comeback in more virulent form because reliable methods cannot be found to insure that drugs are taken over their entire recommended time period. Social and sexual diseases, such as AIDS/HIV, are a large and increasing problem. Even crime and violence are in good part a health problem that requires behavioral and social science research. It is now accepted that many diseases that have historically been considered mainly a matter for biomedical research, diseases such as heart disease, lung disease, drug addiction, tuberculosis, and malaria, cannot be treated and understood without understanding provided by behavioral and social research. When these far reaching health implications of behavioral, social, and economic factors are added to the more direct implications of research for mental illnesses such as depression, schizophrenia, and various neurological illnesses, it is no surprise that the research demand in the behavioral and social sciences has grown rapidly in recent years.

The National Institute of Mental Health (NIMH) traditionally provided primary support for research in the behavioral and social sciences, and with secondary support from the National Institute on Aging (NIA) and the National Institute of Child Health and Human Development (NICHD). Other institutes provide support to a lesser degree, and recently there has been increasing support from the National Institute of General Medical Sciences (NIGMS). It should be noted that the primary mission of NIMH is research into prevention and treatment of mental disorders, and of NIA and NICHD is research into the health problems of young and aging populations; thus none directly supports research into key factors underlying such societal health problems. It is not the task of this committee to make recommendations concerning the allocation of research support in various institutes of NIH. It is the committee's task, however, to make recommendations concerning research training and its funding, and the implications of social and behavioral research for such a wide array of health problems demand that research in most NIH institutes be informed by scientists knowledgeable in the basic techniques and methods of, and the findings of, the behavioral and social sciences. This particularly includes empirical design and quantitative and statistical methodology that has been so effectively refined in the social and behavioral sciences. Thus in institutes that do not presently have a direct focus on research in the behavioral and social sciences, at least some training needs be directed toward researchers with this focus.

CHARACTERISTICS AND DATA

Behavioral and Social Sciences Research Workforce

The behavioral and social sciences workforce is difficult to identify, since data sources do not distinguish between

Ph.D.s in the behavioral and social sciences or between scientists who are conducting basic or applied health-related research (or other research) and those who are involved in clinical practice. In studying the research training needs in the behavioral sciences, the workforce is defined as Ph.D.s trained in anthropology, sociology, the speech and hearing sciences, and psychology, with the exception of clinical, family, and school psychology. However, the committee believed that most non-research-oriented doctorates are now receiving Doctor of Psychology (Psy.D.) degrees, and so it decided to include clinical psychology in its assessment, although not the other practice-oriented fields. See Appendix C for a list of fields in the behavioral and social sciences. This decision was also supported by a small experiment in which NIH was asked to identify whether the research topic for the theses of a sample of the Ph.D. population in the above listed fields, including clinical psychology, would be considered for NIH funding. This analysis showed that about 90 percent of the research topics could be funded, and this led to the conclusion that a large portion of the clinical psychology Ph.D.s could pursue research careers. This may be an over estimate of the workforce, but it might provide a more accurate assessment.

Even in the treatment of what are to be considered biological diseases, behavior is a factor in getting patients to take their medicine or participate in physical activities that would help their condition. However, research in these areas is not isolated to the behavioral and social sciences but has an interdisciplinary component that can include fields in the life sciences, other social sciences, and even the physical sciences. This factor complicates the analysis, because people trained outside the social and behavioral science may be conducting research in this area. There is also a convergence of research areas across broad fields, such as the convergence between the psychology and neuroscience. This factor may lead to an undercount of doctorates in the behavioral sciences. For this study the behavioral and social sciences workforce is defined as graduates from universities in the United States with Ph.D.s in the fields listed in Appendix C, and those in or seeking careers in science and engineering fields.

Educational Trends

The pool of college graduates in the behavioral and social sciences from which graduate programs draw has increased from about 71,000 in 1986 to a little more than 160,000 in 2008 in the fields of psychology, sociology, and anthropology. In 1986, 11.4 percent, or 8,152, of these graduates matriculated to graduate programs in doctoral-granting institutions; by 2008 that fraction had dropped to about 7.3 percent or 11,700 students (see Figure 4-1).

This first-year enrollment has resulted in a total full-time graduate enrollment of about 40,847 in 1986, and it grew to about 69,300 in 2008. A portrait of the gender makeup of the full-time graduate students (Figure 4-2) shows a significant change over the past 30 years, from approximate gender parity

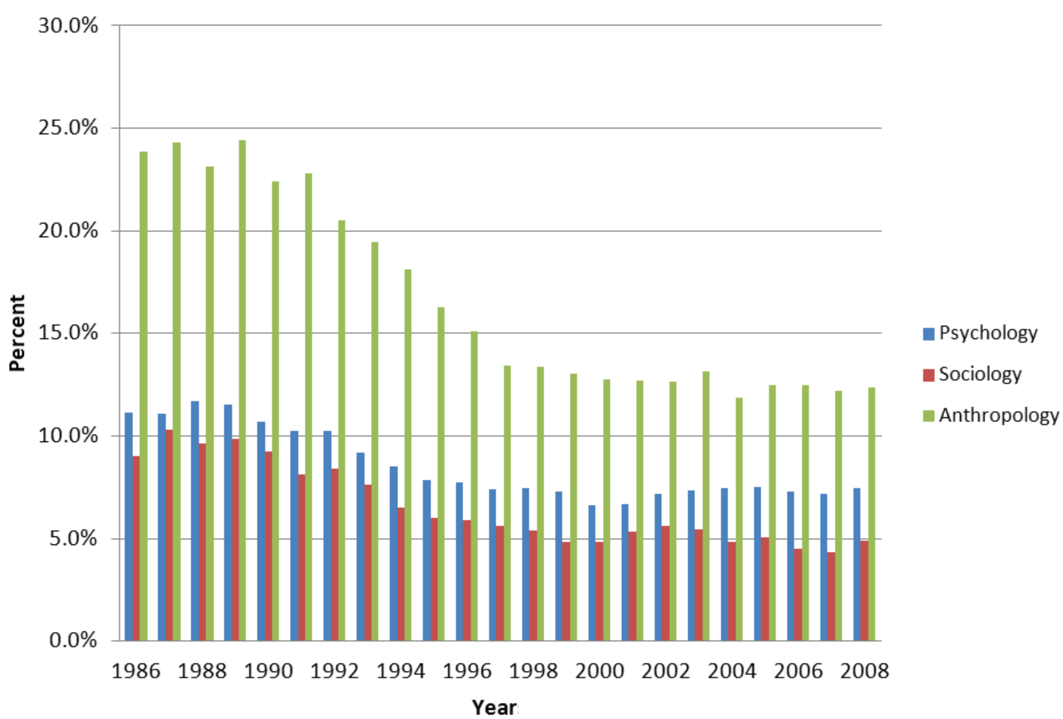

FIGURE 4-1 Percentage of college graduates that enroll as first-year graduate students by field in the behavioral and social sciences.
SOURCE: NSF. 2008. *Survey of Graduate Students and Postdoctorates in Science and Engineering*. Washington, DC: NSF.

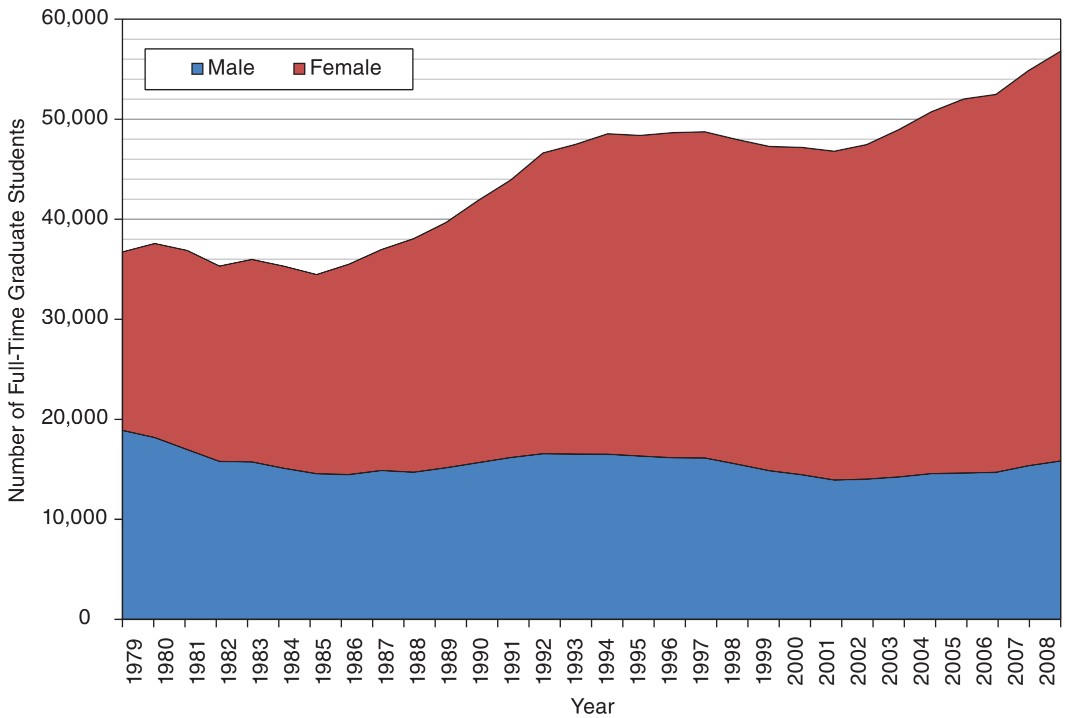

FIGURE 4-2 Gender of full-time graduate students in the behavioral and social sciences, 1979-2008.
SOURCE: NSF. 2008. *Survey of Graduate Students and Postdoctorates in Science and Engineering*. Washington, DC: NSF.

in 1979, to a student population in 2008 where females outnumbered males by almost 3 to 1. Although there have been variations from year to year, the total number of male graduate students in this area hardly changed from 1992 to 2008.

These NSF data include all students in behavioral and social sciences programs at doctoral-granting institutions and therefore include students who do not complete a degree or receive a master's degree and who do not pursue a doctorate. Clearly then these data must overestimate the pool of students who go on to earn a Ph.D. The National Research Council's study of research-doctorate programs collected data on the number of students working toward a doctorate. These data cover only one year, 2006, but they are likely the best source that we have for information about students involved in research activities (see Table 4-1). They indicate that a little less than half, or 24,841 of the 52,000 graduate students in 2006, were in doctoral programs. They also show that the ratio of female to male doctoral students was 2 to 1, and in particular, was not as reported above.

The picture of financial support for graduate education at doctoral-granting institutions in the behavioral and social sciences is very different from that in the biomedical sciences (Figure 4-3). Traditionally about half of the graduate students are supported by their own funds or other sources that they have identified themselves, and teaching assistantships support as many students as fellowships, traineeships, and research grants. The proportion of support from these different mechanisms has changed little except for some recent growth in the students who are self-supported. This has implications both for post-graduation debt and for incentives to enroll in a postdoctoral program.

These data, like the data on enrollment, are useful in showing trends over time, but they include master's degree students who may not receive financial support for their studies. Data from the Research-Doctorate Study for 2006 show a different pattern of financial support from the above. Of those programs reporting data, 78 percent said they fully support their doctoral students, and only 15 percent of such students are unfunded (see Table 4-2).

Doctoral Degrees Awarded

After steadily increasing through much of the 1970s, the number of doctoral degrees awarded in the behavioral sciences remained remarkably steady over much of the next 30 years (Figure 4-4), although there may have been a small decline in the past decade. The gender distribution in the number of doctoral degrees awarded since 1970 reflects the gender makeup of the graduate population in general as reflected in the number of doctoral degrees (Figure 4-4). From just a few hundred in 1970 the number of doctoral degrees to women grew to almost 3,000 by 2008, and at the same time degrees to men dropped from a high of about 2,700 in the mid-1970s to a low of about 1,400 in 2008.

TABLE 4-1 Number of Doctoral Students by Gender as Reported in 2006 for the Research-Doctorate Study

Field	Male	Female	Number Doctoral Students
Anthropology	1894	3098	5039
Psychology	4320	9646	14000
Sociology	2189	3605	5802
Total	8403	16349	24841

SOURCE: NRC. 2010. *A Data-Based Assessment of Research-Doctorate Programs*. Washington, DC: The National Academies Press.

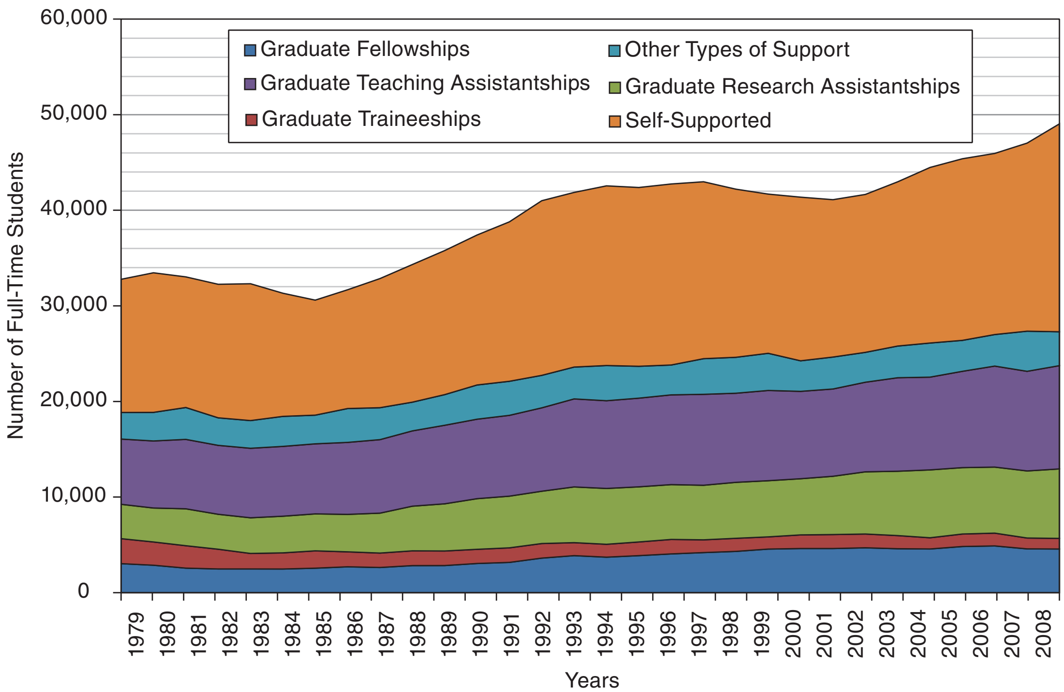

FIGURE 4-3 Financial support of full-time graduate students in the behavioral and social sciences, 1979-2008.
SOURCE: NSF. 2008. *Survey of Graduate Students and Postdoctorates in Science and Engineering.* Washington, DC: NSF.

TABLE 4-2 Financial Support of Students in the Behavioral and Social Sciences in 2006 as Reported in the Research-Doctorate Study

Field	Fellowship or Traineeship	Teaching Assistant	Research Assistant	Combination	Less Than Full Support	Unfunded	Total
Anthropology	807	921	241	1087	379	1005	4440
Psychology	2236	3341	2055	3718	775	1739	13864
Sociology	761	1458	648	1186	418	807	5278
Total	3804	5720	2944	5991	1572	3551	23582

SOURCE: NRC. 2010. *A Data-Based Assessment of Research-Doctorate Programs*. Washington, DC: The National Academies Press.

The time to degree for the doctorates in the behavioral and social sciences has been relatively constant during the past few years at about 9 years in psychology and 10 years in sociology, but these numbers are about 2.5 years higher than they were in the mid-1990s. These increases were greater than the corresponding increases in the biomedical sciences by about one-half a year. It is possible that these data on the time to degree also reflect time when a student is not actively working on the degree, and data from the Research-Doctorate Study show a time that is shorter by several years (see Table 4-3).

The median age at time of degree increased to almost 33 by the late 1990s and remained at that level up to at least 2008. These figures include such workers as clinical-practice

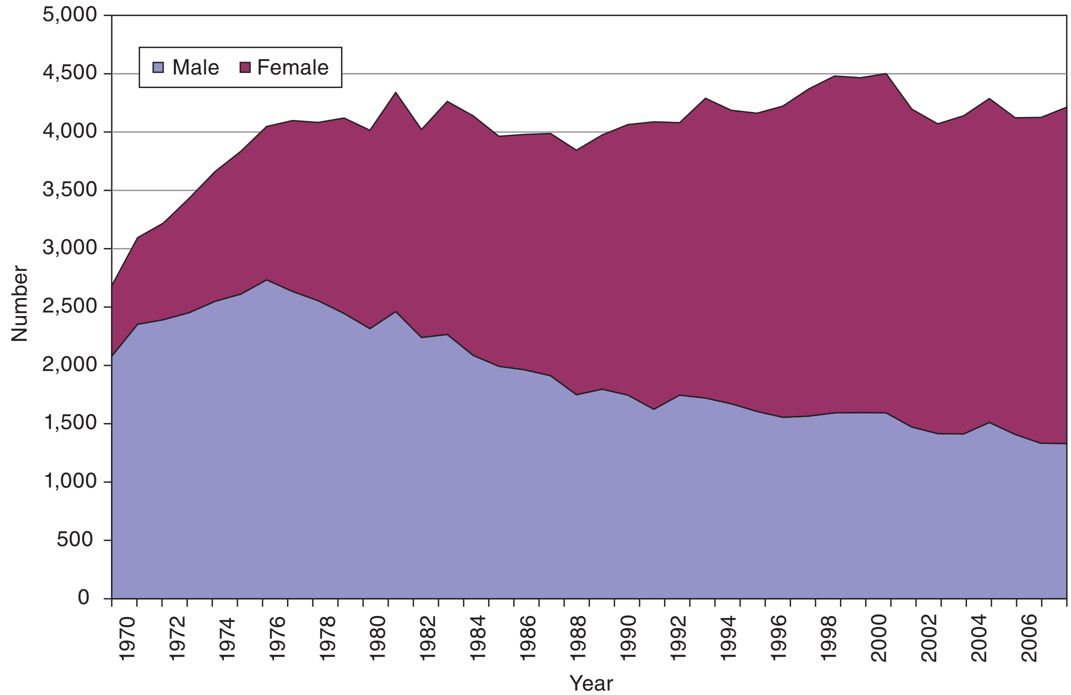

FIGURE 4-4 Doctorates in the behavioral sciences.
SOURCE: NSF, 2008. *Survey of Earned Doctorates, 2008*. Washington, DC: NSF.

TABLE 4-3 Average Median Time to Degree for the Doctorates 2004 to 2006 in the Behavioral and Social Sciences as Reported for the Research-Doctorate Study

Field	Full- and Part-Time Students	Full-Time Students
Anthropology	7.85	7.16
Psychology	5.82	5.79
Sociology	6.69	6.15
Total	6.43	6.13

SOURCE: NRC. 2010. *A Data-Based Assessment of Research-Doctorate Programs*. Washington, DC: The National Academies Press.

trainees in psychology and industry-employed trainees in the various behavioral and social sciences, which may have biased the data on the time to degree.

POSTDOCTORAL TRAINING

Between 1970 and 2008, the fraction of Ph.D.s in the behavioral and social sciences who were planning on a postdoctoral position increased from 223, or 11 percent of all Ph.D.s in the field, to 1,108, or 46 percent. Not surprisingly, females now make up about three-quarters of all Ph.D.s planning such additional training. In an earlier section, we offered a number of reasons for including clinical psychology in the behavioral and social sciences taxonomy. Another reason is the increased participation in postdoctoral training by individuals with degrees in clinical psychology (Figure 4-5). The fact that the proportion of Ph.D.s in the behavioral and social sciences who plan postdoctoral training increased from 20 percent in 1990 to nearly 50 percent in 2008 points to its importance in their career plans.

The large and increasing number of female Ph.D.s and females seeking postdoctoral training, as well as the increase in dual-career couples, suggests that the behavioral and social sciences may be a leading indicator of the need for employers to accommodate the work-life realities of the current generation of both women and men. Otherwise, training will be adversely affected by withdrawals of significant numbers of well-trained researchers—both male and female—for such purposes as child rearing. Afterwards, the rapid advances of science may make it difficult for such trained researchers to return to the workforce.

One positive trend is the increase in minorities with Ph.D.s. In the 1970s only 1 or 2 percent of the doctorates went to minorities, but that has changed, and in 2007 almost 15 percent of the doctorates were awarded to minorities (see Figure 4-6). Although this percentage is slightly higher than in the biomedical sciences, it needs to be higher still if the percentage of minority researchers is to more closely reflect the percentages of minorities in both the serving and served populations. Increasing the percentage of minority researchers will, of course, require an increased fraction of minorities in the B.S. degree pool.

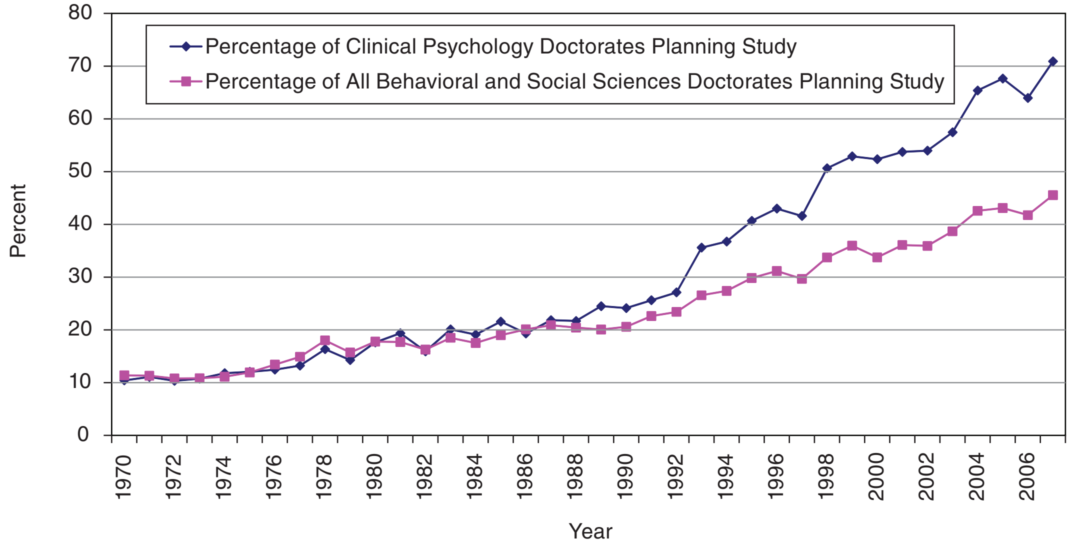

FIGURE 4-5 Postdoctoral plans for clinical psychology and all behavioral and social science doctorates.
SOURCE: NSF. 2008. *Survey of Earned Doctorates, 2008*. Washington, DC: NSF.

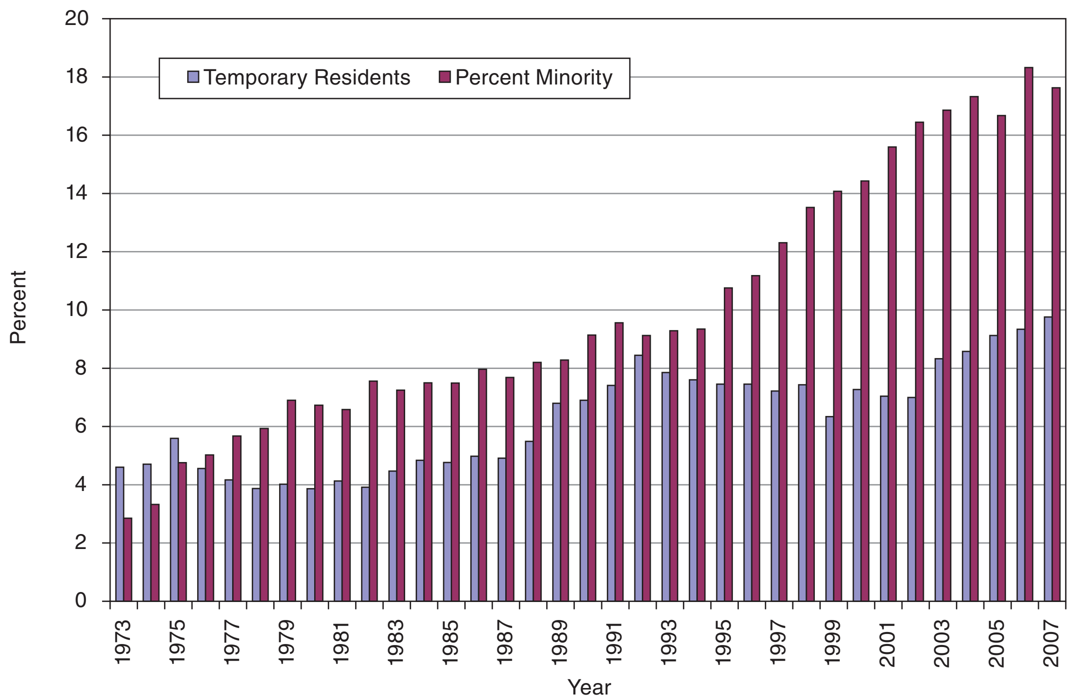

FIGURE 4-6 Percentage of the behavioral and social sciences doctorates by citizenship and race/ethnicity.
SOURCE: NSF. 2008. *Survey of Earned Doctorates, 2008*. Washington, DC: NSF.

The pattern of increasing numbers of Ph.D.s in the biomedical sciences going to researchers with temporary resident status is not apparent in the behavioral and social sciences. There was an increase in temporary resident Ph.D.s in these fields in the 1980s, but the proportion has remained about the same—8 to 10 percent—since that time.

Postdoctoral Appointments

Figure 4-7 shows the number of postdoctoral appointments by employment sector in the period 1973-2008; all sectors show a pattern of increases since 1991. The number of appointments has varied somewhat in recent years in the aca-

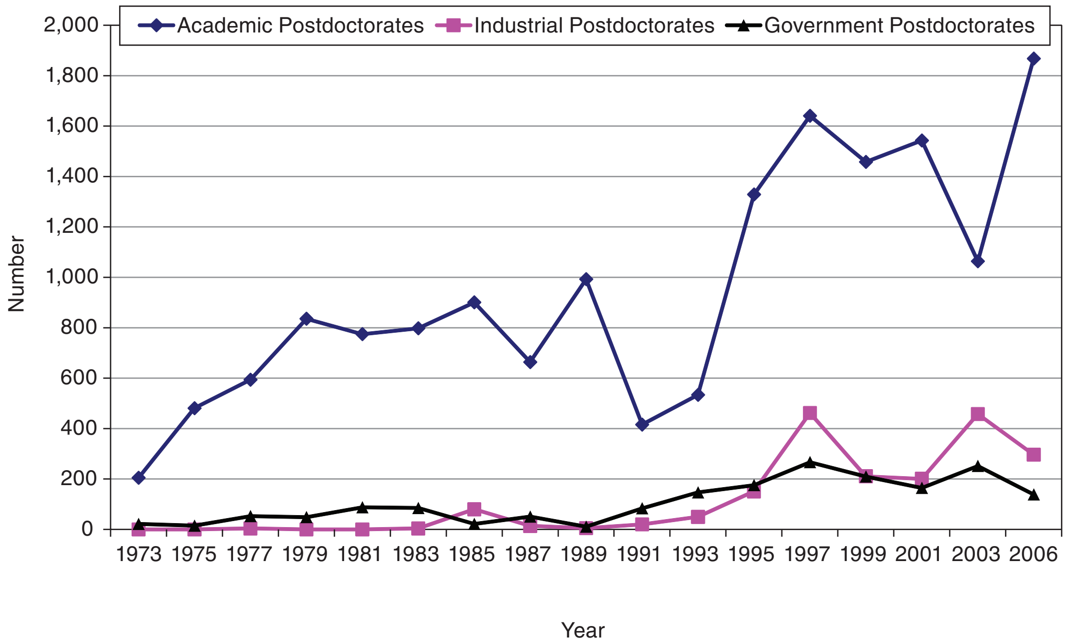

FIGURE 4-7 Postdoctoral appointments in the behavioral sciences.
SOURCE: NSF. *Survey of Doctorate Recipients, 1973-2006.* Washington, DC: NSF.

demic and industrial sectors. The academic sector accounts for three-quarters of the appointments, but there is growing participation in the industrial sector. A notable difference between the biomedical and the behavioral and social sciences fields is the ratio of citizens and permanent resident postdoctorates to temporary resident postdoctorates in academic institutions. Because the fraction of temporary resident Ph.D.s in the behavioral and social sciences is generally less than the fraction in the biomedical sciences, there are proportionally more citizens and permanent residents in postdoctoral positions in the behavioral and social sciences. The ratio in the biomedical sciences is 1.6 to 1, with more temporary residents, while in the behavioral and social sciences the ratio is 3.3 to 1, with more citizens and permanent residents. Looking at the overall behavioral and social sciences workforce, which approaches 90,000 individuals it is clear that the postdoctoral component is quite small, so clearly most did not seek additional postdoctoral training, although the number of postdoctorates is slowly increasing.

Table 4-4 shows the composition of postdoctoral positions in research doctorate programs in 2006. The total number is about half the number for all academic positions. Although females receive twice as many doctorates in the behavioral and social sciences as males, the number of males and females in postdoctoral positions are approximately the same.

EMPLOYMENT TRENDS

The behavioral and social sciences workforce has grown steadily from 27,356 in 1973 to a peak of 108,339 in 2006. Female Ph.D.s made up an increasingly large fraction of the total during these years (Figure 4-8). In 2006, they became the majority in the workforce.

The workplace distribution of the overall workforce is very different in the behavioral and social sciences than in the biomedical sciences (Figure 4-9). While academic employment is still the largest sector, industrial employment has grown at a rapid rate, and the non-profit or other sector

TABLE 4-4 Postdoctoral Appointments in Research Departments in the Behavioral and Social Sciences in 2006 as Reported for the Research-Doctorate Study

Field	Male	Female	U.S. Citizen	Permanent Resident	Temporary	Citizenship Unknown	Total
Anthropology	50	53	60	6	33	4	107
Psychology	438	480	565	37	255	60	944
Sociology	27	36	45	1	9	9	67
Total	515	569	670	44	297	73	1118

SOURCE: NRC. 2010. *A Data-Based Assessment of Research-Doctorate Programs*. Washington, DC: The National Academies Press.

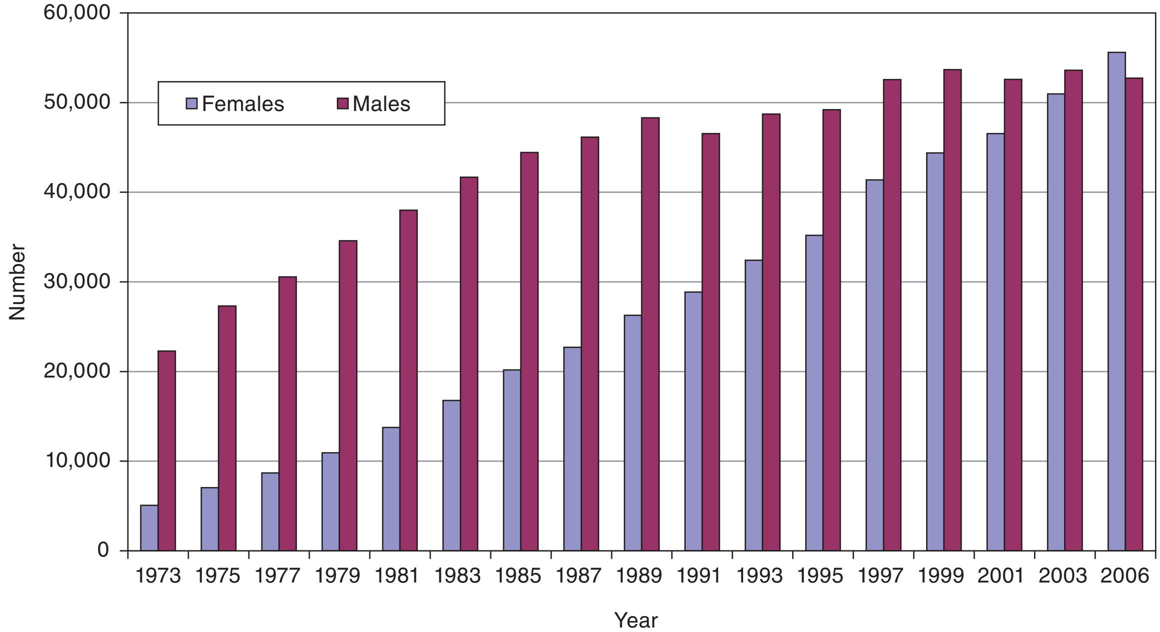

FIGURE 4-8 Distribution of behavioral and social scientists in the workforce by gender.
SOURCE: NSF. *Survey of Doctorate Recipients, 1973-2006.* Washington, DC: NSF.

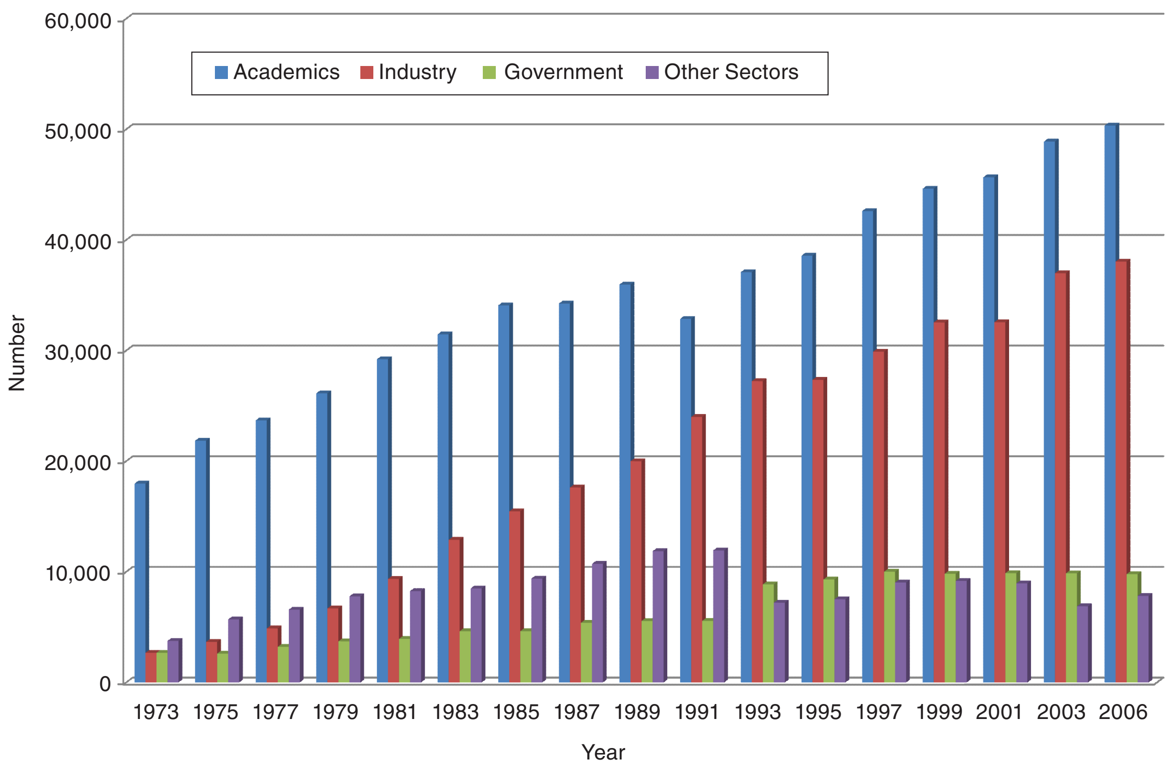

FIGURE 4-9 Employment sectors in the behavioral and social sciences.
SOURCE: NSF. *Survey of Doctorate Recipients, 1973-2006.* Washington, DC: NSF.

is comparatively larger than in the biomedical sciences. The overall workforce in the behavioral and social sciences is almost as large as in the biomedical sciences.

In 1985, the age distribution for the workforce, excluding postdoctoral appointees, was similar for the behavioral and the biomedical sciences, but by 2006, the median age in the behavioral and social science workforce was 2.5 years greater than in biomedical sciences (Table 4-5). Another way to look at the aging of the behavioral workforce is to compare the age distribution over time. There may be significant retirement in the next 10 years from the 51 to 76 age group, although, as noted previously, the concern for retirement portfolios and the improving health of older faculty may affect such a projection. (Figure 4-10; also see projections in Appendix D and E).

DETAILS OF ACADEMIC EMPLOYMENT

Academic employment in the behavioral and social sciences increased by more than 50 percent from 1973 to 2001, after which there has been a slow decline. However, much of the growth has been in non-tenure positions and in "other" academic categories, and by 1999 these categories represented about a third of the academic staff. These contingent faculty (adjunct, lecturer, and part-time staff) are disproportionately female, often involved exclusively in teaching, under-paid, without benefits, contract-vulnerable, and not necessarily involved in research. Data from the Research-Doctorate Study also show that females are underrepresented on the faculty of research departments (see Figure 4-11). While females were in faculty positions at a rate consistent with the proportion of Ph.D.s in the 1970s and early 1980s,

TABLE 4-5 Median Age Cohort for the Biomedical Sciences and the Behavioral and Social Sciences

	Median Age in 1993	Median Age in 2006
Biomedical Sciences	48.9	52.3
Behavioral and Social Sciences	49.8	55.4

SOURCE: NSF. *Survey of Doctorate Recipients, 1973-2006*. Washington, DC: NSF.

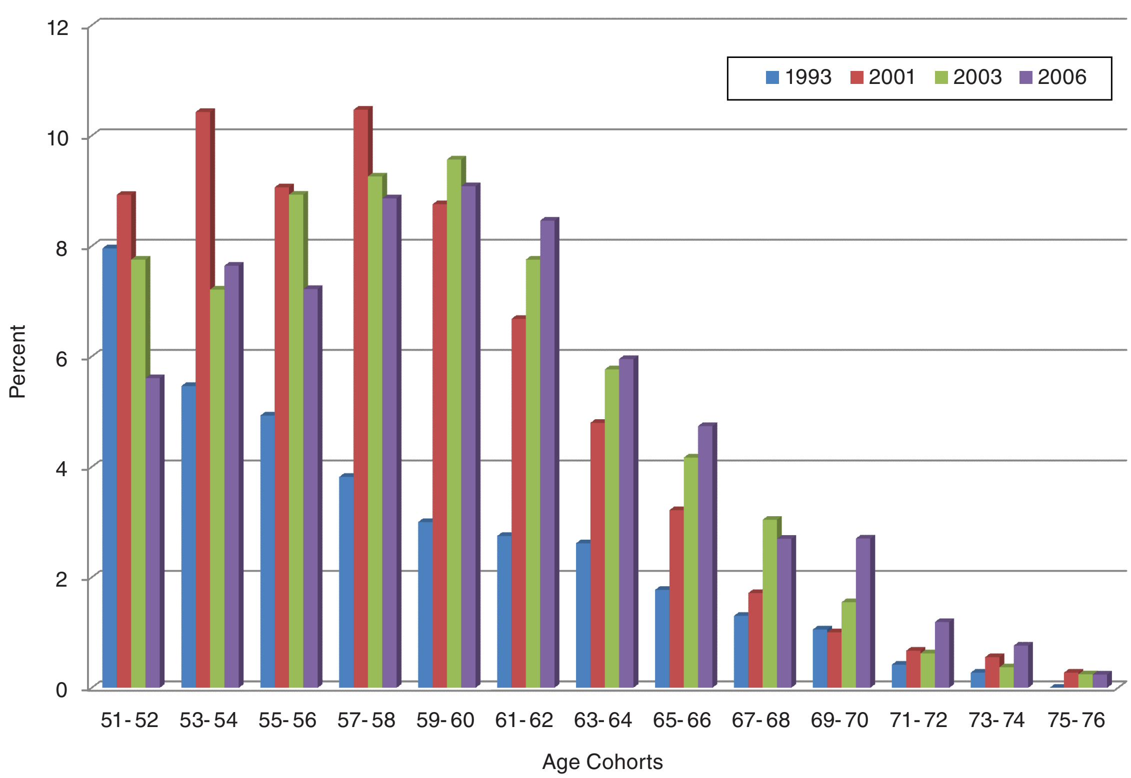

FIGURE 4-10 Age distribution of tenured behavioral and social sciences faculty.
SOURCE: NSF. *Survey of Doctorate Recipients, 1973-2006.* Washington, DC: NSF.

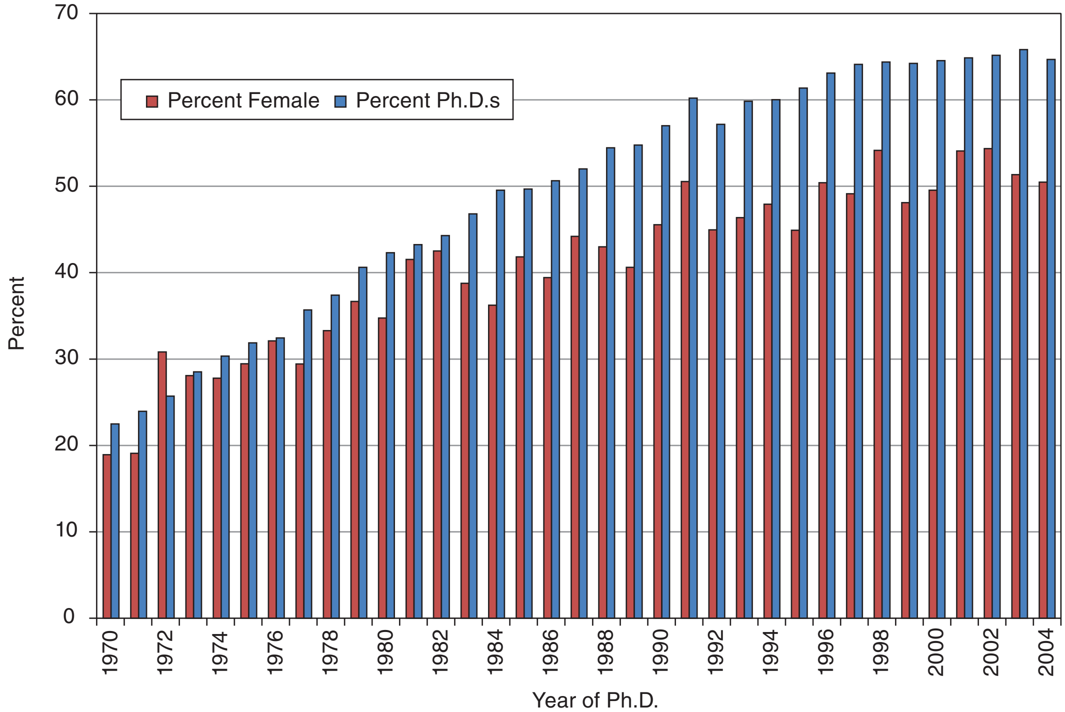

FIGURE 4-11 Percentage of female faculty in 2006 in the behavioral and social sciences by year of Ph.D. compared with the number of Ph.D.s in the same year.
SOURCE: NRC. 2010. *A Data-Based Assessment of Research-Doctorate Programs*. Washington, DC: The National Academies Press.

females in recent years are not in faculty positions in proportion to the number of Ph.D.s.

In contrast, the size of the tenured and tenure-track staff has been almost constant since the early 1990s (Figure 4-12). Over the past 10 years, as mentioned above, two-thirds of doctorates have been awarded to women, and this is reflected in academic appointments with about 60 percent of the combined tenure-track, non-tenured and other academic positions being held by women (Figure 4-13). However, women are over-represented in the combined "non-tenured and other" tracks. Those in tenured positions now make up 40 percent of the academic workforce, which is below their 53 percent representation in the academic workforce. Over time, however, this should change as more women in tenure-track positions receive tenure.

The number of underrepresented minorities in the behavioral and social sciences workforce has increased dramatically in the past several decades, from 520 in 1975 to 8,960 in 2006. For a number of years the number of minorities in the workforce has grown at a substantially greater rate than the total workforce.

RESEARCH TRAINING AND THE NATIONAL RESEARCH SERVICE AWARD PROGRAM

In general, the National Research Service Award (NRSA) program plays a smaller role in research training in the behavioral and social sciences than in the basic biomedical fields. The number of awards in the behavioral and social sciences as displayed in Table 4-6 are about one-tenth of those in the biomedical sciences. About 1 percent of the 26,600 graduate students in the behavioral and social sciences in 2008 had an individual NRSA, as compared with 9.3 percent in the biomedical sciences. It has been argued that much of the research in the behavioral and social sciences is not health related, but an analysis done during the 2005 NRSA study showed that 90 percent of the reviewed dissertation abstracts of behavioral and social sciences Ph.D.s were considered fundable by NIH personnel.

Since NIH has historically tended to focus on research that relates to the physical structure of the body and hence to fields in the biomedical and clinical sciences, the behavioral and social sciences have received less research and training support. This may also be seen in the fact that the NIH does not have an institute or center with the mission devoted to the support of basic and applied research in the behavioral and social sciences. Research training exists in institutes with other missions, such as NIMH, NIA, the National Institute on Drug Abuse, the National Institute on Alcohol Abuse and Alcoholism, and the National Cancer Institute, but it has decreased in recent years, as can be seen in Table 4-6. Even within the institutes that support training in the behavioral and social sciences, such training is directed at particular

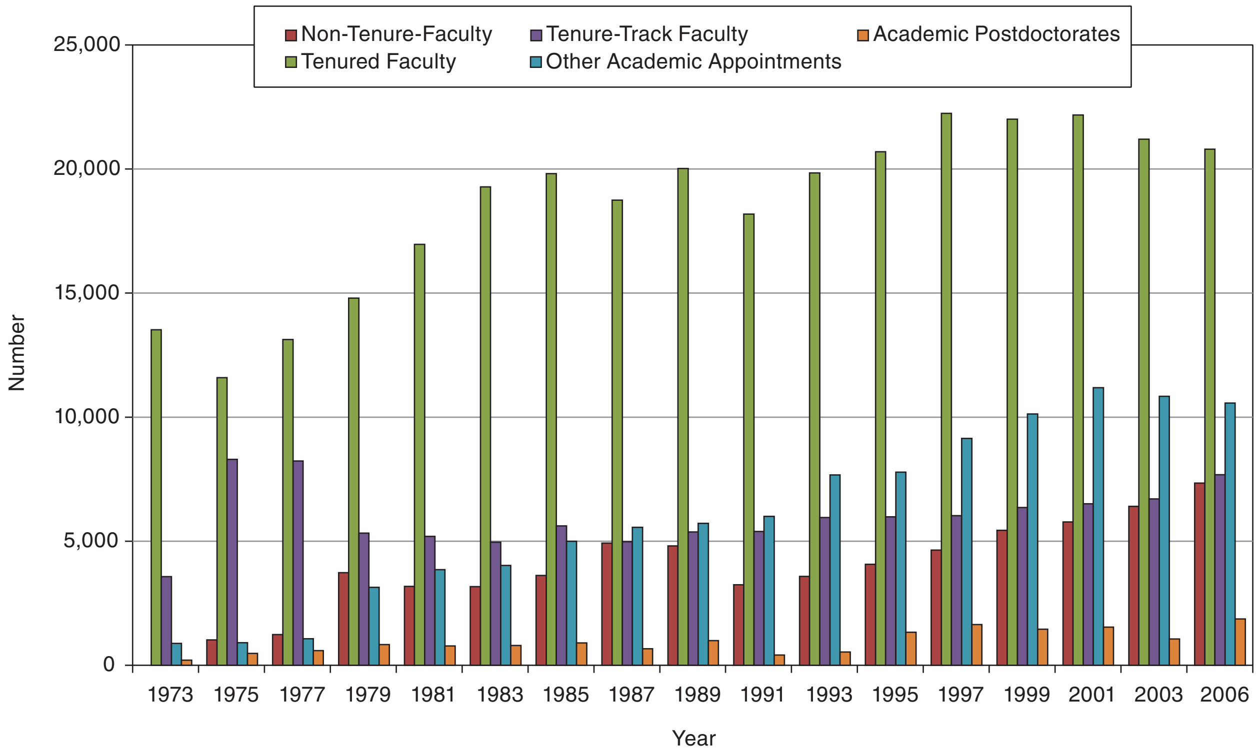

FIGURE 4-12 Academic employment in the behavioral and social sciences.
SOURCE: NSF. *Survey of Doctorate Recipients, 1973-2006.* Washington, DC: NSF.

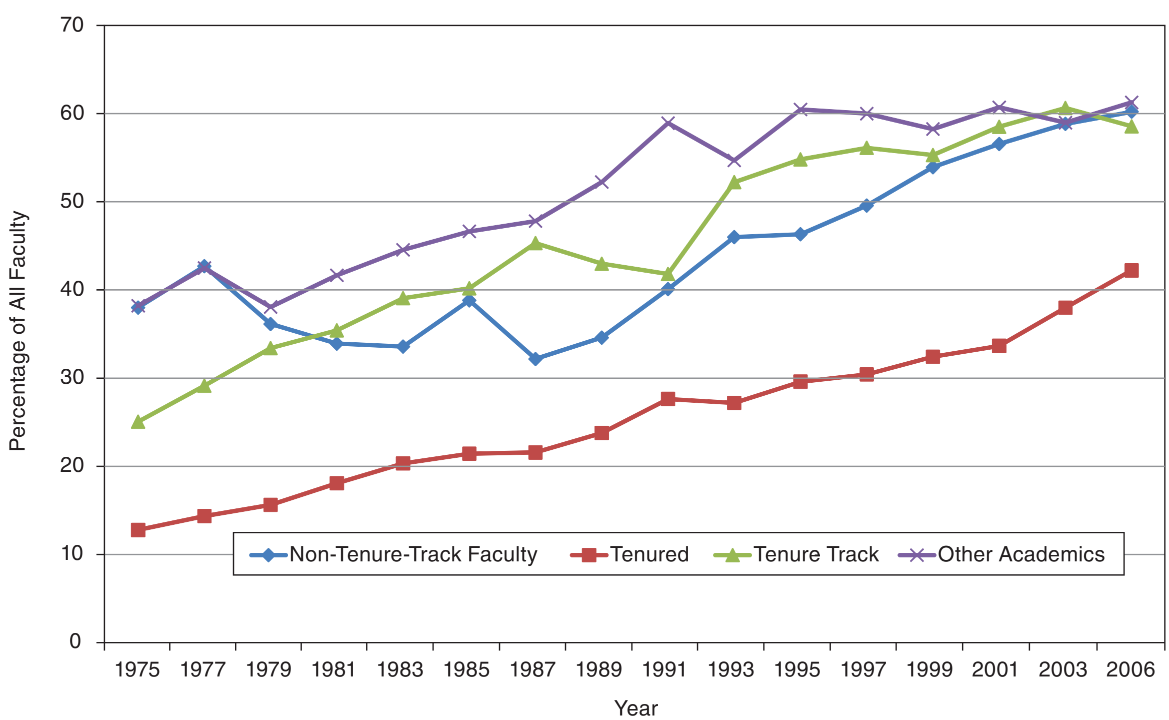

FIGURE 4-13 Female faculty positions in the behavioral and social sciences.
SOURCE: NSF. *Survey of Doctorate Recipients, 1973-2006.* Washington, DC: NSF.

TABLE 4-6 NRSA Trainees and Fellows, by Broad Field (Behavioral and Social Sciences), 1975-2008, Fiscal Year (Percentages are based on total NRSA funding at the NIH by mechanism)

	Predoctoral				Postdoctoral				Both	
	Trainees	%	Fellowship	%	Trainees	%	Fellowship	%	Total	Total %
1975	208	16.2	125	80.6	32	3.8	146	10.0	511	13.6
1980	655	12.8	74	76.3	368	9.2	131	5.5	1228	10.6
1985	501	10.2	41	31.5	392	9.2	86	4.6	1020	9.2
1990	619	10.8	58	17.3	398	10.1	78	4.7	1153	9.9
1995	505	7.8	101	16.2	411	9.9	112	6.0	1129	8.6
2000	451	8.0	207	28.0	465	11.0	114	6.3	1237	10.0
2005	506	8.4	214	16.7	460	9.2	104	6.4	1284	9.2
2006	522	9.2	183	13.4	401	8.3	77	4.9	1183	8.8
2007	421	6.9	154	10.6	350	7.5	50	3.4	975	7.1
2008	416	6.3	147	9.6	301	6.3	50	3.4	914	6.3

SOURCE: NIH database.

subfields and often does not require the interdisciplinary or multidisciplinary character of the training grants in the biomedical or clinical sciences.

Efforts are being made by the Office of Behavioral and Social Science Research (OBSSR) to foster interdisciplinarity by bringing together the biomedical, behavioral, and social sciences communities to work collaboratively to solve complex pressing health challenges. OBSSR is leading efforts in: biopsychosocial interactions, community-based participation research, systems science, genes, behavior and environment, social and cultural factors in health, health and behavior, and translational research. However, the office does not have the resources to support training in these areas and must depend on other institutes. In recent years NIGMS has increased its funding in the behavioral and social sciences but it does not have the resources to carry out the mission outlined by OBSSR.

As was shown earlier in Figure 4-2, less than a quarter of the graduate student population in the behavioral and social sciences in doctoral-granting institutions who have some type of support are supported on fellowships, traineeships, and research grants. Of this support it is generally thought that the National Science Foundation (NSF) provides a large portion of this support, but in reality, the support from NSF is only about a tenth of the total federal support and a third of the support provided by NIH (Figure 4-14). These data also show a decline in support by NIH and NSF in 2008.

It should also be noted that total graduate support declined in the 1980s, and the increase back to the earlier level is due mainly to NIH and other federal agency support. Much of the early decline was caused by reductions in the non-NIH part of the Department of Health and Human Services (HHS). By 2006, NIH research grants formed more than two-thirds of the support (Figure 4-15), which was a major shift from the early 1980s when the major source of support came from traineeships.

As is the case at the predoctoral level, NRSA support of postdoctoral training in the behavioral and social sciences is a fraction (between 10 and 15 percent) of that in the biomedical sciences (see Table 4-2). There are no data on the general postdoctoral support from NIH, but the picture for postdoctoral training support from all federal sources shows a growth in research grant support and a decline in trainee and fellowship support until 1990, with essentially constant support thereafter. The NIH's efforts in the late 1970s and 1980s to shift research training in the behavioral and social sciences from the predoctoral to the postdoctoral level can be seen by comparing the level of predoctoral support in Figure 4-15.

RECOMMENDATIONS

Recommendation 4–1: Training programs in basic behavioral and social sciences that cut across disease and age categories should be housed at NIGMS consistent with the NIGMS congressional mandate. Given its disciplinary expertise, OBSSR should cooperate in this effort. NIGMS needs funds and appropriate staff dedicated to this new effort.

Recommendation 4–2: Training programs in basic behavioral and social sciences that bear specifically on particular diseases and age cohorts should be housed in all the relevant institutes and centers. Both basic and translational research training can be specific to institutes and centers. Given both its disciplinary expertise and its role in connecting institutes and centers, OBSSR should cooperate in this effort.

Recommendation 4–3: The target numbers to be trained in OBBSR should increase back to the 2004 baseline. In the case that an infusion of funds results from current

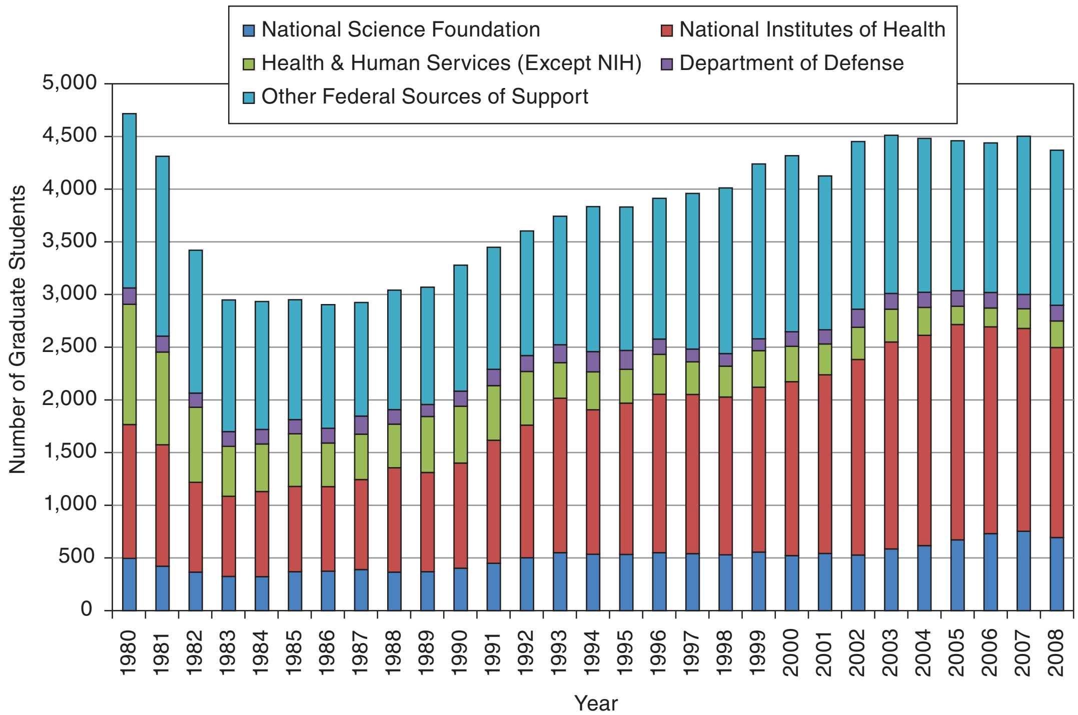

FIGURE 4-14 Federal sources of support in the behavioral and social sciences.
SOURCE: NSF. 2008. *Survey of Graduate Students and Postdoctorates in Science and Engineering.* Washington, DC: NSF.

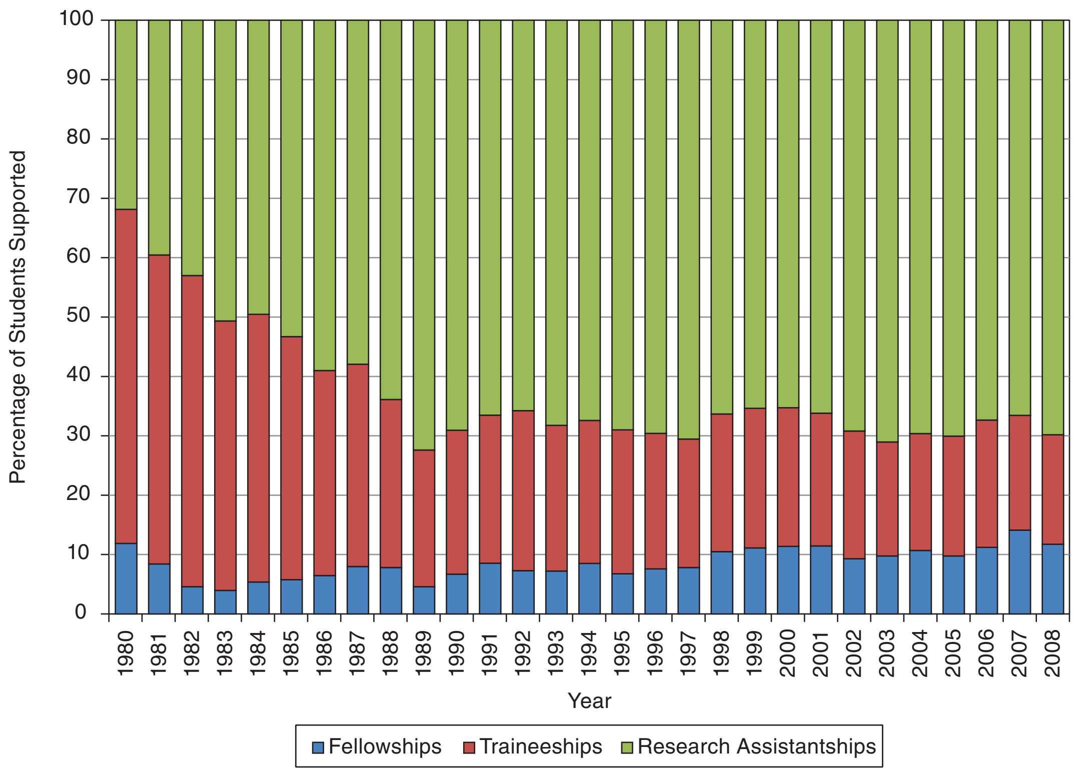

FIGURE 4-15 Types of support from the NIH in the behavioral and social sciences.
SOURCE: NSF. 2008. *Survey of Graduate Students and Postdoctorates in Science and Engineering.* Washington, DC: NSF.

federal health initiatives, the targets should increase to reflect the new positions that will open as a result. Future adjustments should be closely linked to the total extramural research funding in the biomedical, clinical, and behavioral sciences.

Bringing the level of support in the behavioral and social sciences in 2008 up to the level in 2004 will require the addition of about 370 training slots at a cost of about $15 million. Also, in recommending linking the number of NRSA positions to extramural research funding, the committee realizes that a decline in extramural research would also call for a decline in training.

Recommendation 4–4: All institutes are encouraged to make F30 fellowships accessible to qualified M.D./Ph.D. students. The F30 program should also be extended to clinical behavioral scientists in M.D./Ph.D. programs.

The F30 awards have proven to be a good way for students in M.D./Ph.D. programs to gain NIH support for their activities. They also provides a means of support for students at institutions that do not have an MSTP. Unfortunately this fellowship is not awarded by all NIH institutes, which restricts its overall value.

5

Clinical Sciences Research

Reseach in the clinical sciences helps put into practice the discoveries that arise from the research in the fields described in the three previous chapters. Because the term "clinical research" is used to cover such a broad and diverse array of activities, its definition has proved to be controversial, primarily over the issue of whether the research does or does not require direct interaction with living patients or other human research subjects. The most expansive definition of clinical research is that agreed upon in 1998 at the Graylyn Clinical Research Consensus Development Conference, organized by the Association of American Medical Colleges (AAMC), the American Medical Association (AMA), and the Wake Forest University Medical Center. The Graylyn conferees defined

> clinical research as a component of medical and health research intended to produce knowledge valuable for the understanding of human disease, preventing and treating illness, and promoting health. Clinical research involves interactions with patients, diagnostic clinical materials or data, or populations in any of the following areas: (1) disease mechanisms (etiopathogenesis); (2) bi-directional integrative (translational) research; (3) clinical knowledge, detection, diagnosis and natural history of disease; (4) therapeutic interventions including clinical trials of drugs, biologics, devices and instruments; (5) prevention (primary and secondary) and health promotion; (6) behavioral research; (7) health services research, including outcomes, and cost-effectiveness; (8) epidemiology; and (9) community-based trials.[1]

This definition was adopted by the U.S. Congress in the Clinical Research Enhancement Act (P.L. 110-148) of November 2000.

In response to this definition, those determined to carve out and distinguish research requiring direct interaction with living patients coined the term *patient-oriented research*. Another distinction is commonly made for *translational research*, which describes research that explores the applicability of the results of basic research to clinical care (for example, in clinical trials, especially early Phase 1 or 2 trials). In addition, translational research may also include studies of how to facilitate the introduction of newly established clinical knowledge into broad clinical practice and the obstacles thereto, or it may describe studies of the clinical effectiveness or cost effectiveness of new knowledge applied in clinical practice across very large and diverse populations. A publication authored by members of the Institute of Medicine's Clinical Research Roundtable[2] proposed that the first two of these different kinds of translational research, with their different strategies, technologies, time scales, training, and resource requirements, be distinguished as T1 and T2 and that the obstacles encountered be referred to as T1 blocks and T2 blocks, respectively. Subsequently, others have carried this terminology further by designating T3 blocks and even T4 blocks. This terminology has become widely accepted.

Despite the critical role that clinical research in all its forms plays in achieving the nation's health goals, the clinical research enterprise has for years been underdeveloped. Recent scientific advances have begun to set the stage for a dramatic transformation of our capacity to diagnose, prevent, and treat disease and disability. But accomplishing this transformation will not only require the translation and wide-scale application of these increasingly remarkable basic research advances into health care practice, but will also demand profound changes in individual and group behaviors. The latter will not be achievable without substantially enhancing our understanding of individual and population behaviors, which in turn will require significantly greater investment in the

[1] Summary of Report of the Graylyn Development Consensus Conference, November 1998, from Report 13 of the Council on Scientific Affairs (I-99), Update on Clinical Research. Available online at: http://www.ama-assn.org/ama/pub/article/2036-2392.html.

[2] Sung, N.S., W.F. Crowley, Jr., M. Genel, P. Salber, L. Sandy, L.M. Sherwood, S.B. Johnson, V. Catanese, H. Tilson, K. Getz, E.L. Larson, D. Scheinberg, E.A. Reece, H. Slavkin, A. Dobs, J. Grebb, R.A. Martinez, A. Korn, and D. Rimoin. 2003. Central challenges facing the national clinical research enterprise. *JAMA* 289:1278-1287.

social and behavioral sciences to accomplish the transformation of our health-care system from its primary focus on individual *health care* to a concentration on individual and population *health maintenance*.

Health services research, which involves the study of the efficiency, effectiveness, and costs of health care practices and systems, has become indispensable to understanding and informing the future of health care. Despite the promises of a more rational and equitable health care marketplace envisioned in the Health Care Reform Act, health care costs have been rising steadily for decades and consuming an increasing fraction of the nation's gross domestic product. Expenditures in the United States on health care surpassed $2.3 trillion in 2008, more than three times the $714 billion spent in 1990, and over eight times the $253 billion spent in 1980. This relentless growth in costs, coupled with the aging of the American population, the severe economic recession, and the sharply rising federal deficit, is placing great strains on the private-sector, state, and federal systems used to finance health care, including private employer-sponsored health insurance coverage and public insurance programs such as Medicare and Medicaid.

The quality of the nation's health care system has been an issue for many years. In 2001, the IOM, launched an effort to examine and recommend improvements in the nation's quality of care. Successive IOM reports have highlighted the unacceptably poor status of our health care system as a whole, the high frequency and costs of medical errors resulting as much from systemic as individual failures, the almost unique failure of the health care industry in comparison with other sectors of the U.S. economy to adopt and exploit powerful new information technologies, and the shameful and adverse consequences of the continuing problem of the uninsured. Another effort to highlight the quality of health care began in 2003 with the publication of a series of reports by the Agency for Healthcare Research and Quality (AHRQ) that address the state of health care from the perspective of quality and disparity. These reports describe in great detail the impact of the organizational, administrative, financing, safety, access and other deficits of our cobbled-together health-care "system" on individuals, communities, businesses, and the entire nation. The need to address these major problems makes it imperative that "clinical research" be broadly conceived to encompass the assessment of health outcomes, cost-effectiveness, finance, access, information strategies, and other research related to the organization, deployment, utilization and quality of the nation's health-care systems and services. At this time it is difficult to estimate the impact of the 2010 Patient Protection and Affordable Care Health Care Reform Act on the opportunities and challenges in clinical research.

There are many factors contributing to the continued underdevelopment of the clinical research enterprise. These include: (a) the extra time and expense required for clinical research training along with the inherent complexity, difficulty, and costs of patient-oriented clinical research, and the challenges these pose in competing successfully for sponsored research support, especially from National Institutes of Health,[3] (b) the sharply declining ability to cross-subsidize clinical research from hospital and faculty clinical practice income as a result of the major changes wrought in health care financing over the past 20 years, (c) the debt burden that inclines many physicians in training to forgo clinical research careers for the more likely rewards of clinical practice, and finally, (d) the still uncertain status of the full spectrum of clinical research within the culture of the academic health center, where traditionally, basic science and clinical prowess have often been valued more highly than clinical research. Notwithstanding this formidable array of deterrents, abundant anecdotal evidence indicates that physician-scientists who leave research careers often do so because of insufficient institutional support, a perceived lack of available mentors, licensure regulations, and role models and the attendant discouragement.[4]

The need for increased investment in clinical research has been increasingly recognized in diverse funding programs—public, private, and philanthropic—as well as in academic medical and health centers.[5] These issues were addressed by Task Force II, a group assembled by the AAMC to analyze the problems posed by the need to develop the full potential of clinical research. A number of the recommendations of Task Force II have been realized, including the requirement by the accrediting bodies of medical schools (ACME) and residency programs Accreditation Council for Graduate Medical Education (ACGME), respectively, that all medical students and all residents be exposed to the principles of clinical research; having medical schools assume central oversight of clinical research training programs in order to ensure the "protected time" of trainee; and that academic medical centers invest in shared core facilities to support translational and clinical research.

Nevertheless, that this underinvestment continues is indicated by the remarkably small fraction of the total annual expenditures directed to health care that is invested in clinical research. The NIH is the single largest public-sector source of funding for clinical research, and its commitment to clinical research has increased substantially since the late 1990s, driven in part by the recommendations of the highly influential report of the NIH Director's Panel on Clinical Research, chaired by David G. Nathan and released in December 1997. Although NIH support of clinical research awards during

[3] Kotchen, T.A., T. Lindquist, A. Miller Sostek, R. Hoffmann, K. Malik, and B. Stanfield. 2006. Outcomes of National Institutes of Health peer review of clinical grant applications. Journal of Investigative Medicine, 54:13-19.

[4] Dickler et al. 2007. "New Physician-Investigators Receiving National Institutes of Health Research Project Grants." JAMA 297(22):2496-2501.

[5] AAMC. 2006. "Promoting Translational and Clinical Science: The Critical Role of Medical Schools and Teaching Hospitals." Washington, DC: AAMC; and Dickler, H, Korn, D, and Gabbe, SG, PLoS Med. 2006;3. e378.

BOX 5-1
Recommendations from the Association of American Medical Colleges Task Force II Report, ***Promoting Translational and Clinical Science: The Critical Role of Medical Schools and Teaching Hospitals***

Recommendation 1: Every future physician should receive a thorough education in the basic principles of translational and clinical research, both in medical school and during residency training.

Recommendation 2: The Liaison Committee on Medical Education (LCME) should add education in translational and clinical research to the requirements for medical school accreditation, and the Accreditation Council for Graduate Medical Education (ACGME) should embed understanding of translational and clinical research within its required core competencies.

Recommendation 3: Training for translational and clinical investigators should comprise completion of an advanced degree with a thesis project (or an equivalent educational experience), tutelage by an appropriate mentor, and a substantive postdoctoral training experience.

Recommendation 4: Sufficient support should be given to new junior faculty who are translational and clinical investigators to maximize their probability of success.

Recommendation 5: Training in translational and clinical research should be accelerated through comprehensive re-structuring so that these scientists can become independent clinicians and investigators at the earliest possible time.

Recommendation 6: Institutions, journals, the NIH, and other research sponsors should take steps to facilitate appropriate academic recognition of translational and clinical scientists for their contributions to collaborative research.

Recommendation 7: The NIH should modify the K23 and K24 awards to enhance their value in supporting clinical and translational research training and mentoring.

the proceeding two decades had remained largely constant at about 34 percent of total extramural research dollars, the NIH has now launched several well-received training awards for junior and mid-career physician scientists. There are also other support mechanisms, most notably the Clinical and Translational Science Awards (CTSAs), directed by the National Center for Research Resources (NCRR) and launched in 2006, all of which are transforming the quality and quantity of support of physician-scientists in universities and academic health centers. Much of the NIH funding for the CTSA has been recovered from closing down the General Clinical Research Centers (GCRC) program, begun in the 1960s to create a national network of such centers, situated primarily in academic health centers, and targeted initially to support what was then cutting-edge studies of metabolic diseases in human research subjects.

As of July 2010, 55 CTSAs had been funded in universities and academic health centers across the country, creating local, regional, and national systems to increase the efficiency and productivity of clinical and translational research and to develop ways to reduce the time it takes for clinical research to become available for use in treatments for patients. The NIH intends that there will be 60 centers when this program becomes fully implemented in 2012, although that number may increase. The CTSA—which require partnerships not only among academic medical institutions and health centers with other components of universities, but also with community hospitals, clinics, and health care practices—are truly creating increasing interest and excitement in clinical research across universities and their community partners, as well as attracting non-biomedical investigators from across universities into multidisciplinary clinical research programs. However, it is too early to predict the ultimate success of this program or whether it will achieve its ambitious goals.

Notwithstanding these positive steps to enhance training and support for physician-researchers in the clinical sciences, the past two decades have been particularly challenging for the funding of all academic health professionals and especially for the support of research activities in the clinical environment that are not clearly tied to specified funding streams. Clinical research, broadly defined, has yet to achieve the breadth and depth of currency it deserves.

To develop the nation's clinical research capacity will require a sufficient workforce of highly trained clinician investigators in the several health research professions as well as Ph.D.s in the diverse areas of knowledge that are encompassed in the expansive definition of "clinical research." Building this workforce will require enhanced support across the clinical research disciplines and will especially require supporting clinician-scientists, who must be accomplished in both their clinical and their scientific disciplines.

DEFINING THE CLINICAL RESEARCH WORKFORCE

The clinical research workforce is as varied as the definition of the field. It consists of individuals with doctorates in the basic sciences, graduates of professional degree programs (mostly M.D.s), graduates of health sciences and public health programs, and dual- or multiple-degree holders. These scientists play an important role in improving the capabilities and the delivery of the nation's health care, because their research spans the spectrum from discovery to delivery to critical assessment of delivery and the functioning of the health care enterprise. Some areas of research, however, are purely clinical, such as health services, oral health, and nursing, and they will be addressed in later chapters of this report. We also address individuals who fit the expansive Graylyn definition, which embraces research in health services and in the social and behavioral sciences; these topics likewise will similarly be addressed in later chapters of this report.

With this definition in place, it has proved difficult to analyze the specific number of individuals in the clinical research workforce because current workforce databases focus on their current research areas. Therefore, the basic workforce analysis for this report will include Ph.D.s with degrees in the health fields listed in Appendix C, as well as that fraction of the M.D. population in medical school clinical departments that conduct NIH-supported clinical research, along with doctorates with a degree from a foreign institution that are in some way identified as clinical researchers. A major shortcoming of this approach is that does not capture the complete workforce, especially M.D.s who are involved in the design and oversight of clinical trials and as well as those conducting research in non-medical areas of an academic institution or in industrial laboratories.

EDUCATIONAL BACKGROUND OF THE CLINICAL RESEARCH WORKFORCE

The problems discussed in identifying those currently engaged in clinical research make it difficult to assess the educational background of clinical researchers in the same detail as is done for researchers in the biomedical and behavioral and social sciences, because such studies can only be done for those individuals who are currently participating in or have completed graduate programs that offer a Ph.D. in the clinical fields. The difficulty of such an approach to computing the overall workforce is underscored by the increasing numbers of Ph.D.s (both postdoctoral workers and faculty) from the basic biomedical sciences who are pursuing careers in clinical departments of medical schools and at major teaching hospitals. There are presently more of these Ph.D.s employed in the clinical departments than in basic sciences departments.

Many of these Ph.D.s, however, are likely to be involved in basic biomedical research, which happens to be performed in the labs of M.D. or M.D./Ph.D. scientists involved in biomedical research, albeit in a clinical department environment. At present there is no way of distinguishing between Ph.D.s conducting basic biomedical research from those involved in clinical research (see Figure 5-1).

GRADUATE STUDENTS

The following discussion draws on data from the *National Science Foundation Survey of Graduate Students and Postdoctorates in Science and Engineering* and records individuals who are studying in clinical departments (as defined in Appendix C). The graduate student population in these clinical departments at doctoral-granting institutions grew by 67 percent from 2000 to 2008 (see Figure 5-2). The growth in the number of graduate students is greater than that in the other broad fields in this study where the size of the graduate population has increased more slowly. It should also be noted that the robust growth is primarily reflects an increase in the number of female graduate students (see Figure 5-2). (Nursing graduate students were excluded from the data, because many of these students will not receive a doctorate, and the pool of students pursuing a doctorate is discussed in the nursing chapter.)

However, one has to be very cautious in interpreting the data of Figure 5-2. Given the fact reported below that only about 2,000 students graduated with a Ph.D. and that the best available evidence suggests that the time to degree was not much more than six years, we have to assume that 40 percent of the students listed in Figure 5-2 either quit or graduated with an M.S. degree. This is supported by the observation (see Figure 5-3) that typically 30 to 40 percent of these students were self-supporting, a circumstance more characteristic of master's students than of those pursuing the Ph.D. The type of financial support the students in the clinical sciences receive is quite different from that in the other fields (Figure 5-3).

GRADUATE SUPPORT AND THE ROLE OF THE NRSA IN TRAINING

Figure 5-3 shows the mechanisms of support for full-time graduate students in the clinical sciences. The number of traineeships and fellowships for graduate support in the clinical sciences has held relatively constant, at about 4,000 students each year over the past decade. Support for the increased number of students has largely come from increased teaching assistantships, research assistantships, and, especially, from self funding. The sources of external support have also changed over time with NIH support growing from 10 percent in 1979 to 25 percent in 2008, and non-federal support (excluding self-support) growing from 25 percent to 60 percent over the same time period (see Figure 5-4).

NIH data for traineeships and fellowships shows a smaller number of National Research Service Awards (NRSAs) slots ranging from 823 in 2005 to 1,035 in 2008 (see Table 5-1). Like the other two broad fields in this study, support was rather constant in the 1990s. The decline in 2000 might be the result of higher stipend levels and the fixed NRSA budgets for the training programs. The difference among the numbers shown in Tables 5-1, 5-2, and Figure 5-4 is

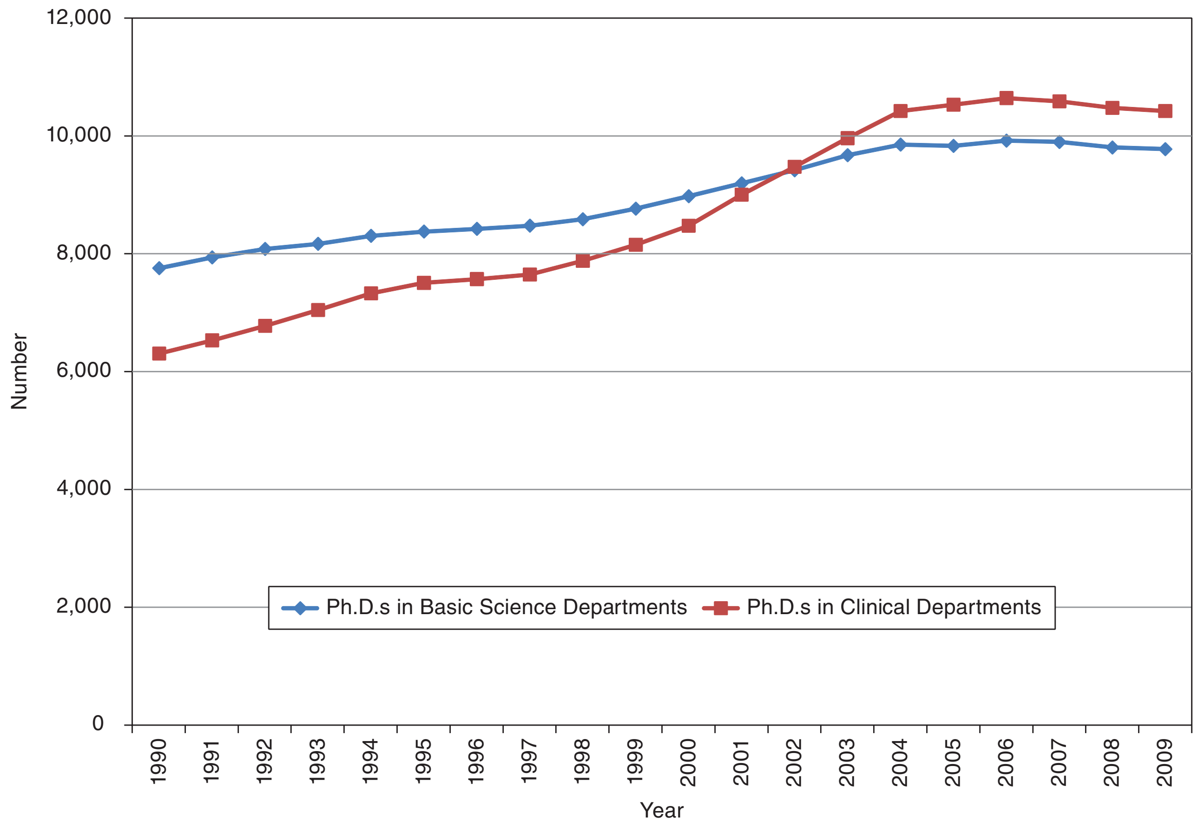

FIGURE 5-1 Tenured and tenure-track faculty by type of medical school department, 1990-2009.
SOURCE: AAMC. *Association of American Medical Colleges Faculty Roster, 2009.*

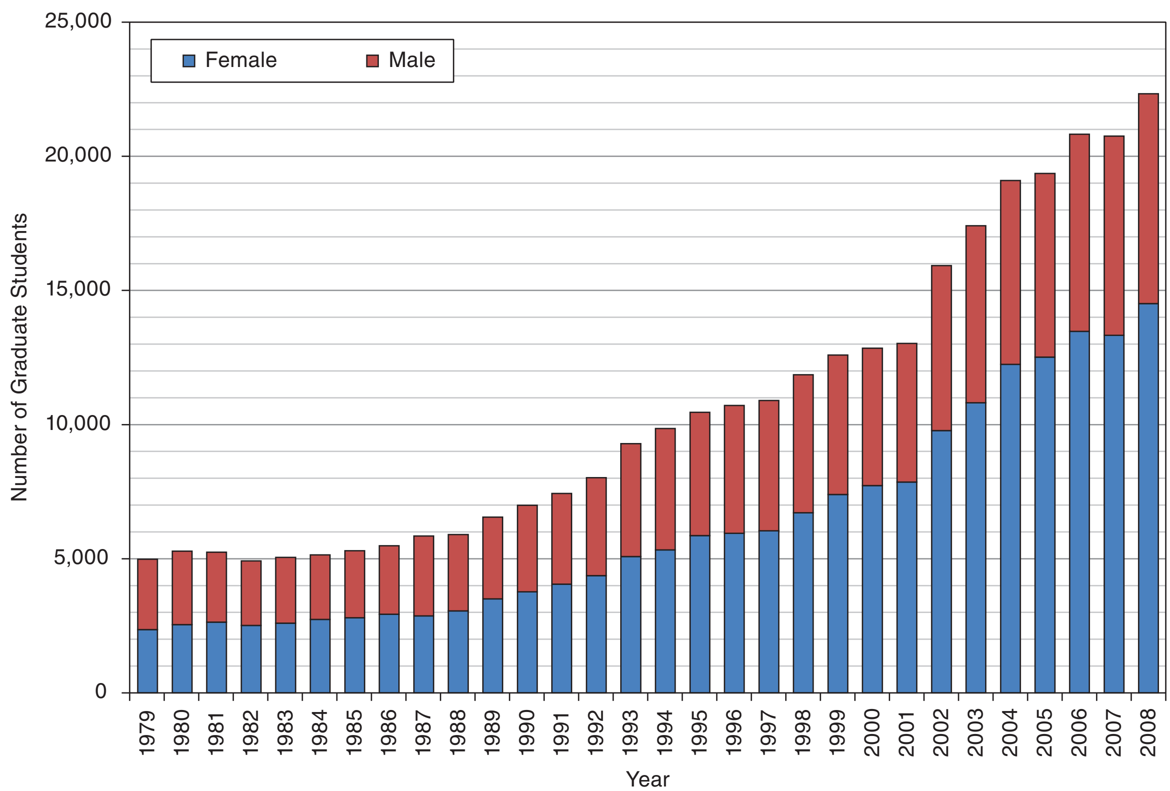

FIGURE 5-2 Full-time graduate enrollment in the clinical sciences.
SOURCE: NSF. 2008. *Survey of Graduate Students and Postdoctorates in Science and Engineering.* Washington, DC: NSF.

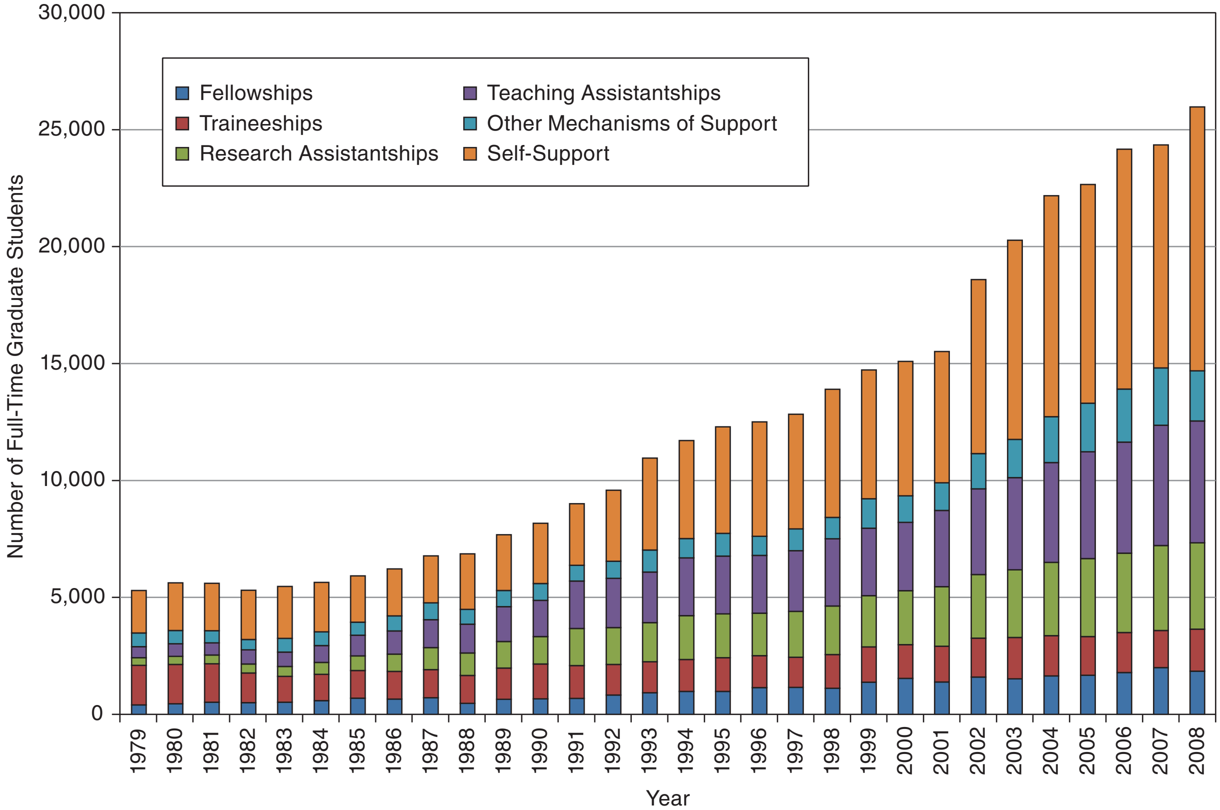

FIGURE 5-3 Mechanisms of support for full-time graduate students in the clinical sciences.
SOURCE: NSF. 2008. *Survey of Graduate Students and Postdoctorates in Science and Engineering*. Washington, DC: NSF.

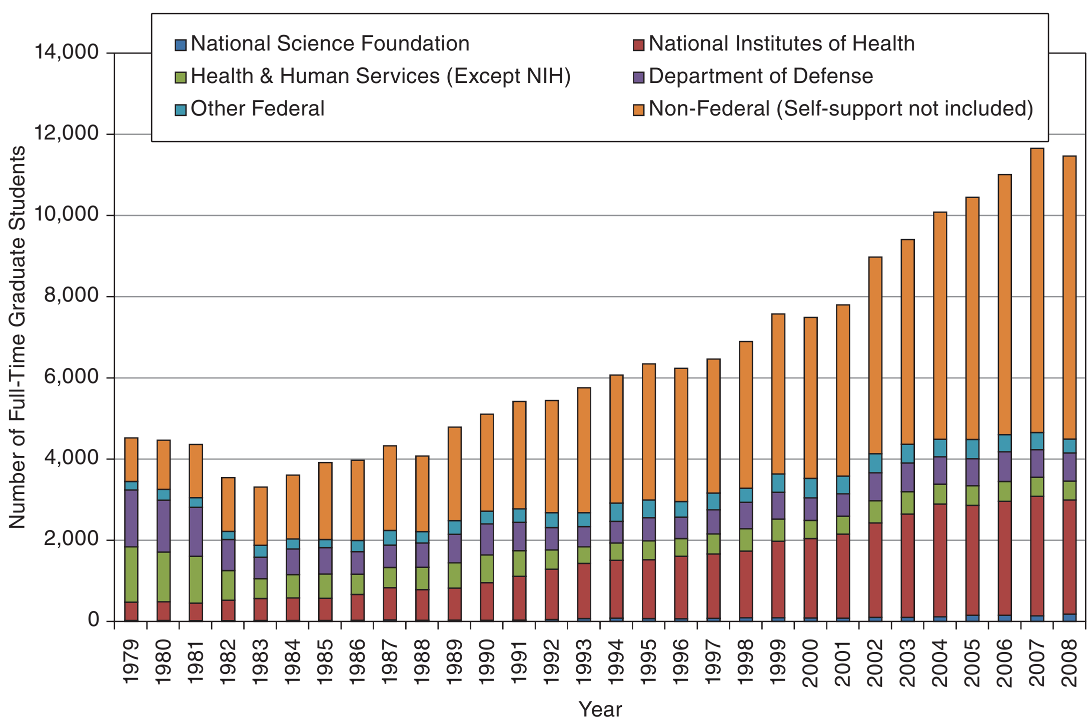

FIGURE 5-4 Sources of internal and external support of full-time graduate students in the clinical sciences.
SOURCE: NSF. 2008. *Survey of Graduate Students and Postdoctorates in Science and Engineering*. Washington, DC: NSF.

TABLE 5-1 NRSA Predoctoral Trainee and Fellowship Support in the Clinical Sciences (Excluding Health Services)

	Trainees (T32)	Fellowship (F30, F31)	Total
1990	385	153	538
1995	830	108	938
2000	558	123	681
2005	633	190	823
2006	602	209	811
2007	711	222	933
2008	807	228	1035

SOURCE: NIH database.

TABLE 5-2 NRSA Postdoctoral Trainee and Fellowship Support in the Clinical Sciences (Excluding Health Services)

	Trainees (T32)	Fellowship (F32)	Total
1990	1287	99	1386
1995	1553	75	1628
2000	1467	93	1560
2005	1893	140	2033
2006	1930	131	2061
2007	1872	137	2009
2008	1968	143	2111

SOURCE: NIH database.

the result of NRSA support through other HHS agencies, primarily AHRQ.

The growth in the graduate population is naturally reflected in the number of doctoral degrees in the clinical sciences fields, with more than a six-fold increase from the early 1970s, and much of the increase involves an increased participation by women. The modest increase in male Ph.D.s is similar to what has happened in the graduate population more generally (Figure 5-5). The citizenship of doctorates in the clinical sciences differ from those in the biomedical sciences with about 16 percent awarded to temporary residents and 6 percent to permanent residents. However, minority participation accounted for about 12 percent of the degrees in 2008.

POSTDOCTORAL FELLOWS

Among Ph.D.s in the three fields, reviewed in this report, those in the clinical sciences are the least likely to have postdoctoral training, because less than 20 percent have traditionally planned such study versus the 30 percent and nearly 70 percent in the behavioral and biomedical sciences, respectively. It is likely that this small number of individuals specifically educated in research in the clinical sciences represents a minimum estimate of those involved in this type of research. One might add two additional categories to this postdoctoral pool, namely (a) individuals educated in basic biomedical research who have shifted to clinical research (and who may be expected to reside in clinical departments) and (b) international postdoctoral researchers trained in clinical research. One might be tempted to compute these numbers from the number of postdoctoral fellows in clinical departments. However it is clear that over the past two decades many Ph.D. postdoctorates and faculty in clinical departments have in fact conducted basic biomedical research, although the exact fraction of the total pool involved in clinical research is impossible to determine from the available data sources. Reflecting this point is the fact that the fraction of all postdoctoral fellows with medical degrees (not resident fellows) in clinical departments decreased from 61 percent in 1983 to 22 percent in 2008, while the number of foreign-educated postdoctoral fellows increased from 25 percent in 1983 to 45 percent in 2008.

Detailed data are not collected on the source of clinical research training support at the postdoctoral level by individual federal agency, but the type of training support, at least in academic institutions is available (Figure 5-6). The traineeships and fellowships portion has been increasing at a slow rate, while in contrast the number of individuals on research grants has increased five-fold since the late 1970s. The NRSA contribution to postdoctoral training support mirrors the general trend for fellows and trainees, but at a lower level, because support is available from sources other than NRSA (see Table 5-2).

THE CLINICIAL RESEARCH WORKFORCE

It is extremely difficulty to determine the number of individuals contributing to the clinical research workforce from the available data. The primary sources of data are the *NSF Survey of Doctorate Recipients* and the *AAMC Faculty Roster*. In the former dataset Ph.D.s are classified by the area in which they receive their degree as defined according to the fields listed in Appendix C. Since these are considered to be clinical fields, we surmise that they are likely to be conducting clinical research. The AAMC dataset is comprehensive with regard to Ph.D.s in clinical departments in medical schools, but as mentioned earlier conducting research in a clinical department does not imply that the research is clinical. Indeed, it is quite likely that individuals with Ph.D.s in either basic sciences or clinical departments are conducting biomedical research. With this in mind, because individuals with different degrees conduct clinical research and no data source comprehensively captures their activities, it is best to look at the workforce from the perspective of the different degrees that lead to a clinical researcher. The basic clinical workforce, as described by the NSF data, is composed of those 23,282 individuals in 2006 with a Ph.D. in those clinical fields characterized in Appendix C. This number is the potential workforce of individuals employed or seeking employment. Those employed in S&E number 22,229. More

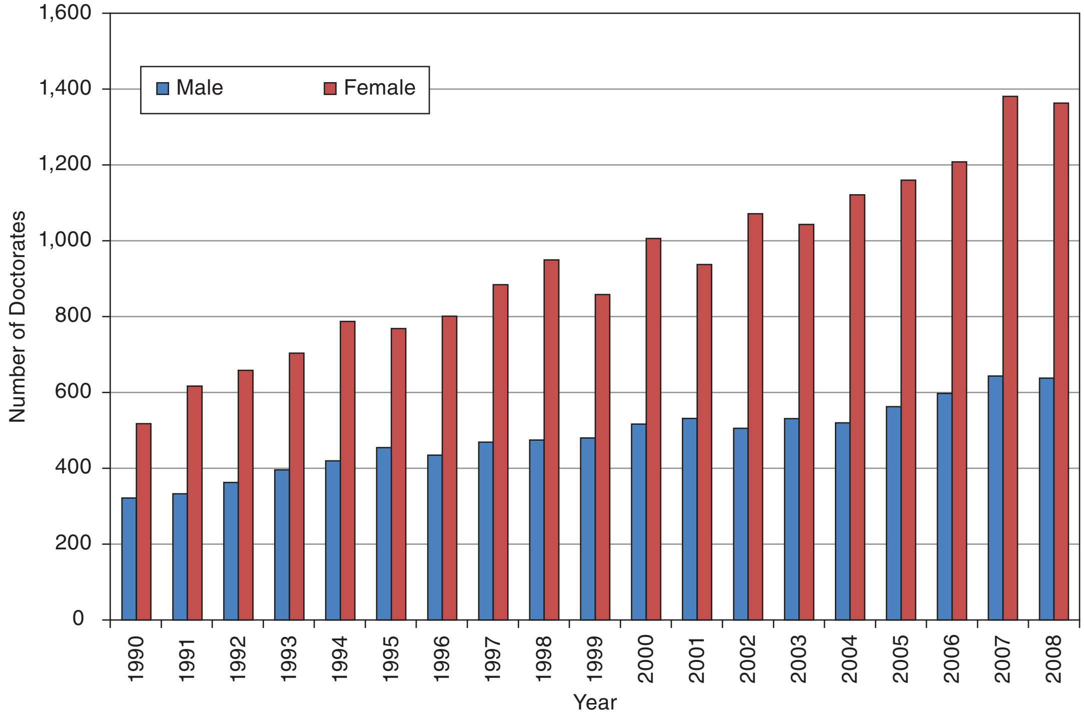

FIGURE 5-5 Doctoral degrees awarded in the clinical sciences.
SOURCE: NSF. 2008. *Survey of Earned Doctorates.* Washington, DC: NSF.

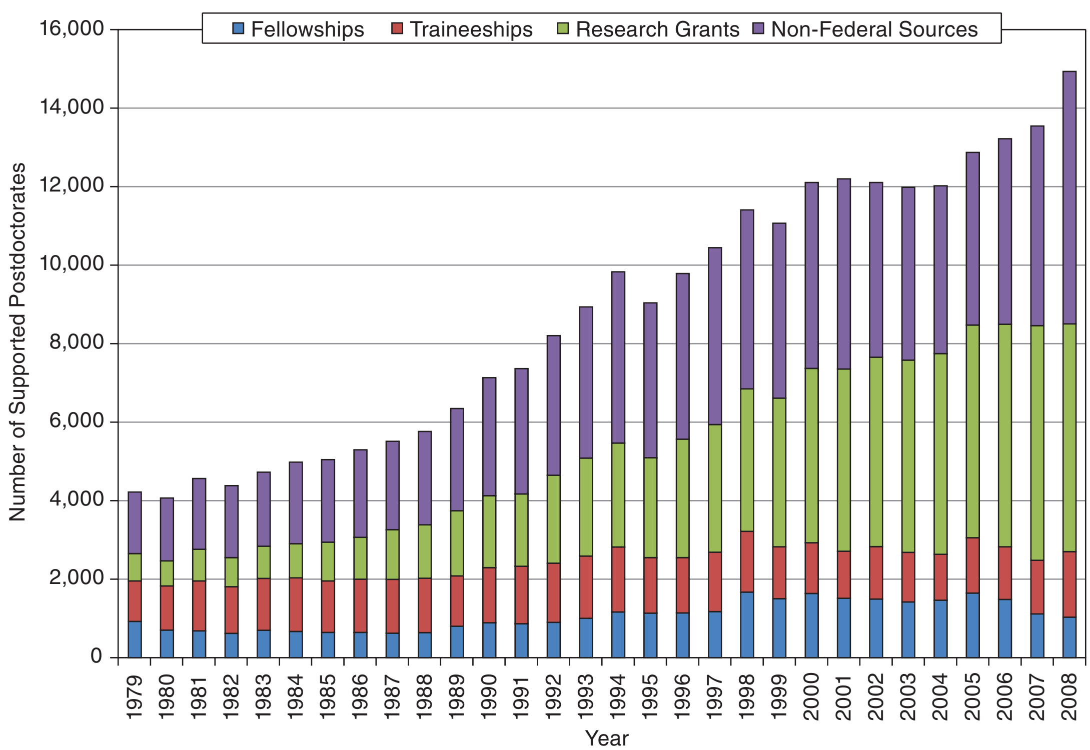

FIGURE 5-6 Academic postdoctoral support in the clinical sciences, 1979-2008.
SOURCE: NSF. 2008. *Survey of Graduate Students and Postdoctorates in Science and Engineering.* Washington, DC: NSF.

current data on the Ph.D.s in the workforce are not available, but the AAMC roster of medical school faculty has data through 2009. The number of M.D.s conducting clinical research in medical schools can be estimated from the number with R01 support in 2006 at about 2,950 and 2,850 in 2009. In addition there were about 1,450 M.D.s in 2006 and 1,550 in 2009 with other non-R01 forms of grant support from the NIH. A longitudinal examination of NIH data[6] over a 40-year time span shows that the number of M.D.s applying for a first R01 grant has remained remarkably flat over most of that interval, and that in 2004 (the last year for which data were available) the number of M.D./Ph.D.s and M.D.s applying for a first R01 had become almost identical. Of course, neither of these counts captures the clinical researchers in the M.D. population that have support from non-NIH sources. As has been stressed repeatedly, even if we can ascertain the total number of M.D.s with R01 support it is still difficult to determine how many of these grants are for basic science alone.

Thus the overall workforce is composed of approximately 12,000 graduate students, 5,000 postdoctoral fellows, some 23,000 Ph.D.s beyond the postdoctoral stage, a number of M.D.s that is poorly defined but probably not more than 1,000, and an unknown number of foreign-born scientists working in this area. The total number then is at least 41,000, of which 24,000 completed their graduate and postdoctoral education (see Figure 5-7). The overall clinical workforce, including postdoctoral fellows, has grown significantly from about 2,850 in the early 1970s to the current level. Much of this growth has been in the academic sector, but the industrial sector has also shown a significant increase as is shown in Figure 5-6. As was the case with the educational characteristics of clinical Ph.D.s, data on their career progression and employment characteristics are only well known for Ph.D.s from U.S. institutions. The steady growth in the academic sector in the past decade has been due in part to the employment of non-tenure-track faculty and other academics (usually research associates) who jointly made up about 40 percent of the faculty in 2006 (see Figure 5-8).

Tenured and tenure-track faculty hold the majority of the positions, but their percentage has fallen from around 80 percent in the mid-1980s to 60 percent in 2006. This decline is not surprising, because there has been a movement by institutions toward temporary or soft money positions by institutions in many fields in recent years. This change in the composition of the faculty is confirmed in the AAMC data for medical schools, which show that from 1980 to 2009 the percentage of Ph.D. faculty in non-tenure-track positions in clinical departments increased from about 35 percent to near 60 percent (see Figure 5-9).

A concern for the clinical research workforce is the increase in the age at which individuals receive their doctorate. From 1986 to 2006 the median age of the workforce has increased from being in the 41 to 43 age cohort in 1986 to the 51 to 52 cohort in 2006 (Figure 5-10). The aging of the clinical workforce is also seen in the data from the *AAMC Faculty Roster* where the median age of the medical school faculty has increased from about 46 years to 52 years from 1989 to 2009 (see Figure 5-11).

The lower level of interest among postdoctoral training among those Ph.D. holders in fields listed in Appendix C is shown in Appendix Table F-5 and is reflected in the portion of the workforce that is working in postdoctoral positions. Only about 2 percent of the clinical U.S. Ph.D.s have held postdoctoral positions in recent years and almost all are in academic institutions. If the faculty in clinical departments is examined, the picture is somewhat different. There are about 8,000 U.S. citizens or permanent residents in these positions. The difference between in Appendix Table F-6 and Figure 5-12 is probably the result of Ph.D.s with biomedical degrees getting their training in clinical departments.

Table F-5 also shows that minorities only represented 8.6 percent of the clinical research population in 2006, even though their numbers grew from about 100 in 1973 to a little more than 1,100 in 2006. This is better than in the biomedical sciences and about the same as in the behavioral and social sciences. The data show, as they did for the other fields, a small number of temporary residents in the research population, but since the data reflect only those individuals who were trained in U.S. institutions, there may be a larger percentage of temporary residents in the workforce with foreign doctorates.

Although the number of M.D. clinical researchers is not known exactly it appears that in recent years individuals with a Ph.D. have dominated the field. In the 1970s only 2,600 Ph.D.s made up the workforce, and only a few hundred degrees were awarded each year. There did not appear to be a change in the number of M.D.s in clinical research since the 1970s, even though the Ph.D. workforce grew by a factor of seven during that time. There may be several reasons for this change, but a primary one is probably the increased educational debt of medical school graduates. Except for graduates of dual-degree (e.g., M.D./Ph.D. or D.D.S.//Ph.D.) programs, most physicians and dentists today begin their professional careers with sizable educational debts.

In 2009, the AAMC reported that the average educational debt of current graduates was $156,456, with 79 percent of the graduates having a debt of at least $100,000 and 58 percent having a debt of at least $150,000. The level of educational debt for dental students is comparable to that of medical students. In 2006, the average it was more than $130,571, and 72 percent had an educational debt of more than $100,000. The increased debt results from the practice in dental schools that requires students to purchase their dental instruments during their clinical training. Although health care professionals are permitted to postpone payments on their student loans during NRSA or other authorized research

[6] Dickler et al. 2007. "New Physician-Investigators Receiving National Institutes of Health Research Project Grants." JAMA 297(22):2496-2501.

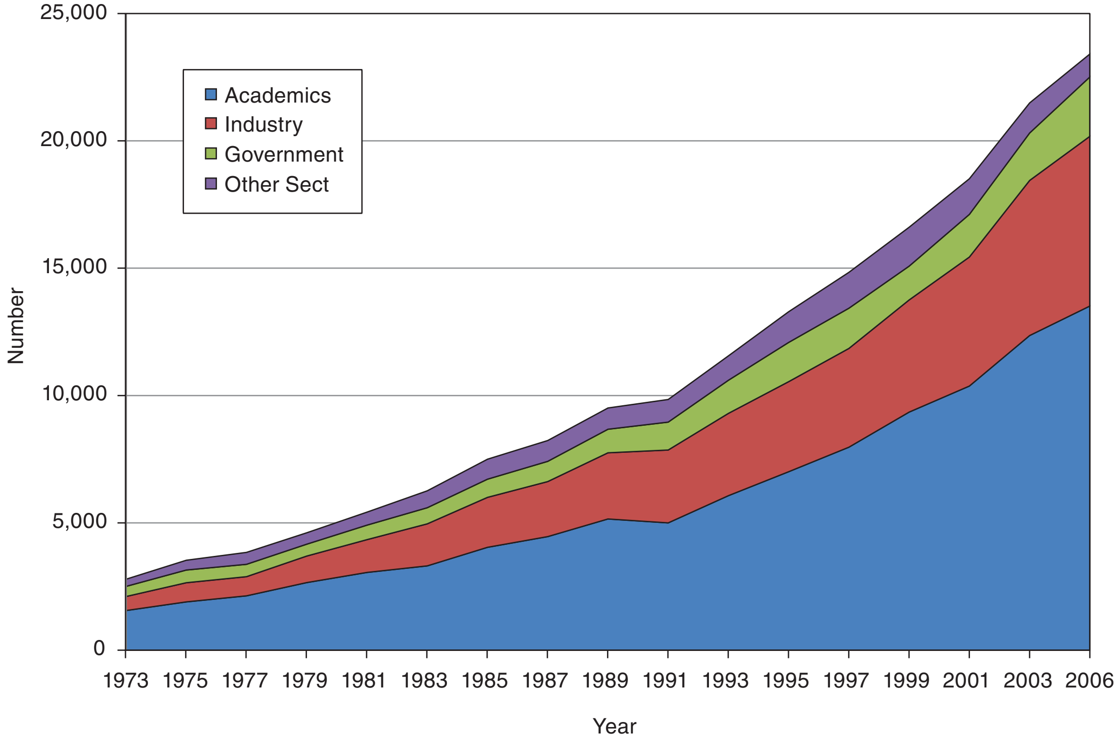

FIGURE 5-7 Employment sectors of the clinical workforce 1973-2006.
SOURCE: NSF. *Survey of Doctorate Recipients, 1973-2006.* Washington, DC: NSF.

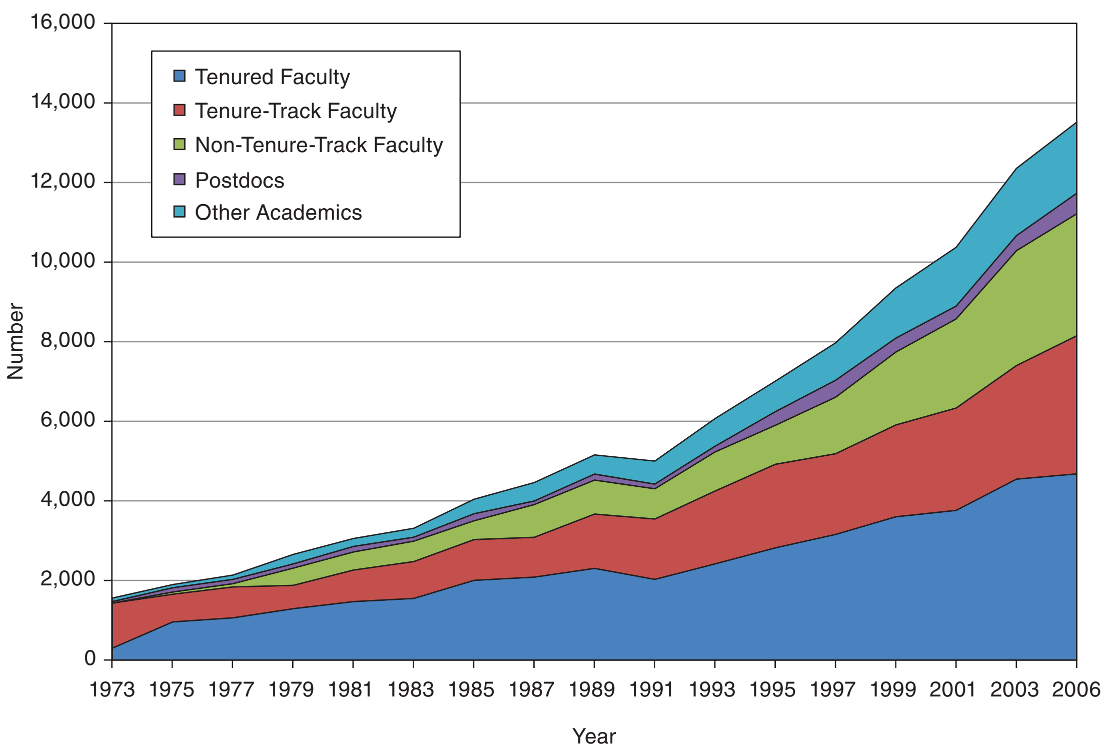

FIGURE 5-8 Academic appointments in the clinical sciences, 1973-2006.
SOURCE: NSF. *Survey of Doctorate Recipients, 1973-2006.* Washington, DC: NSF.

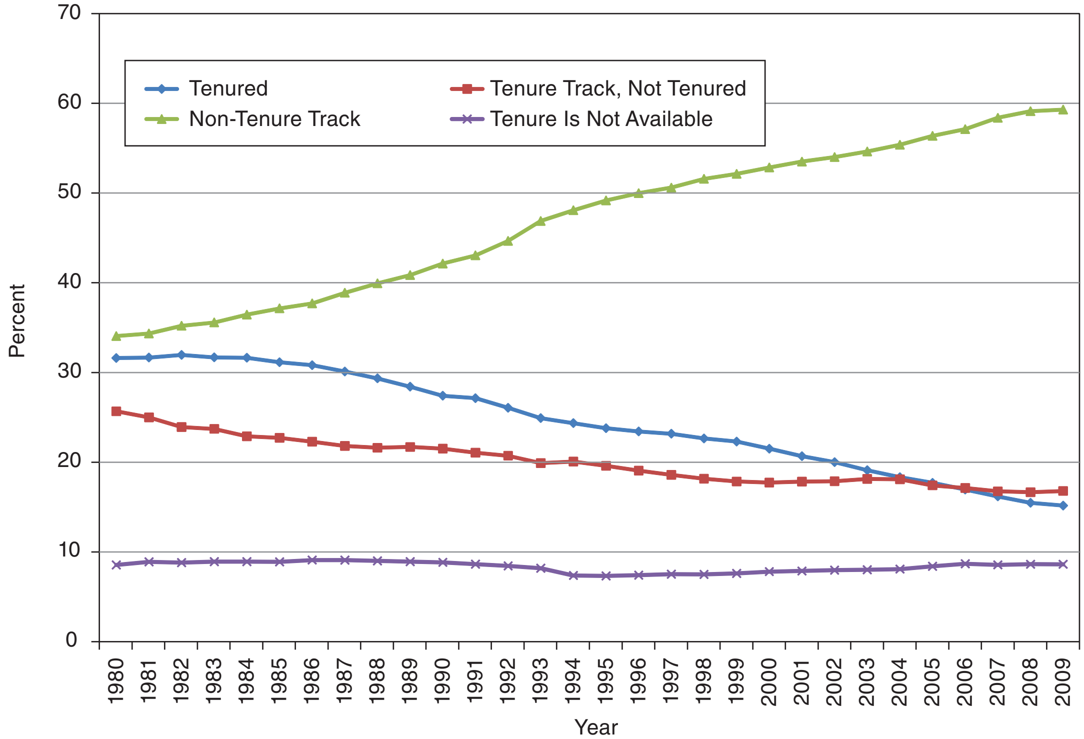

FIGURE 5-9 Tenure status of Ph.D.s in clinical departments in medical schools, 1980-2009.
SOURCE: AAMC. *Association of American Medical Colleges Faculty Roster, 2009.*

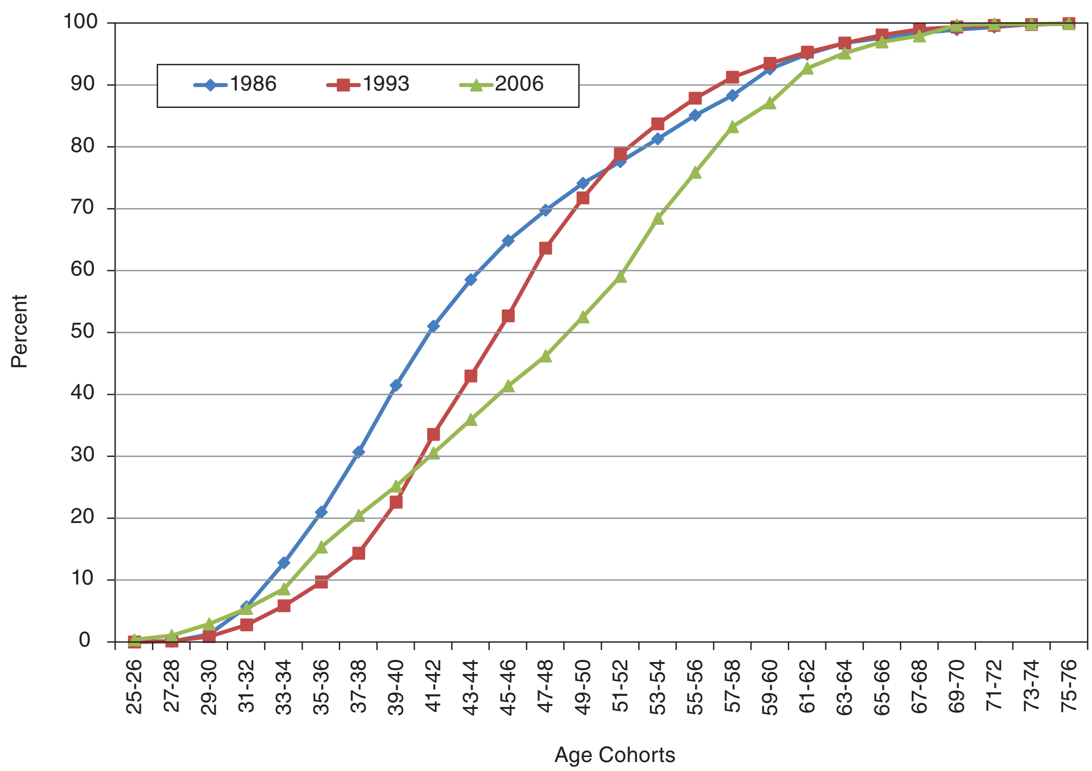

FIGURE 5-10 Cumulative age distribution for the clinical workforce.
SOURCE: NSF. *Survey of Doctorate Recipients, 1973-2006.* Washington, DC: NSF.

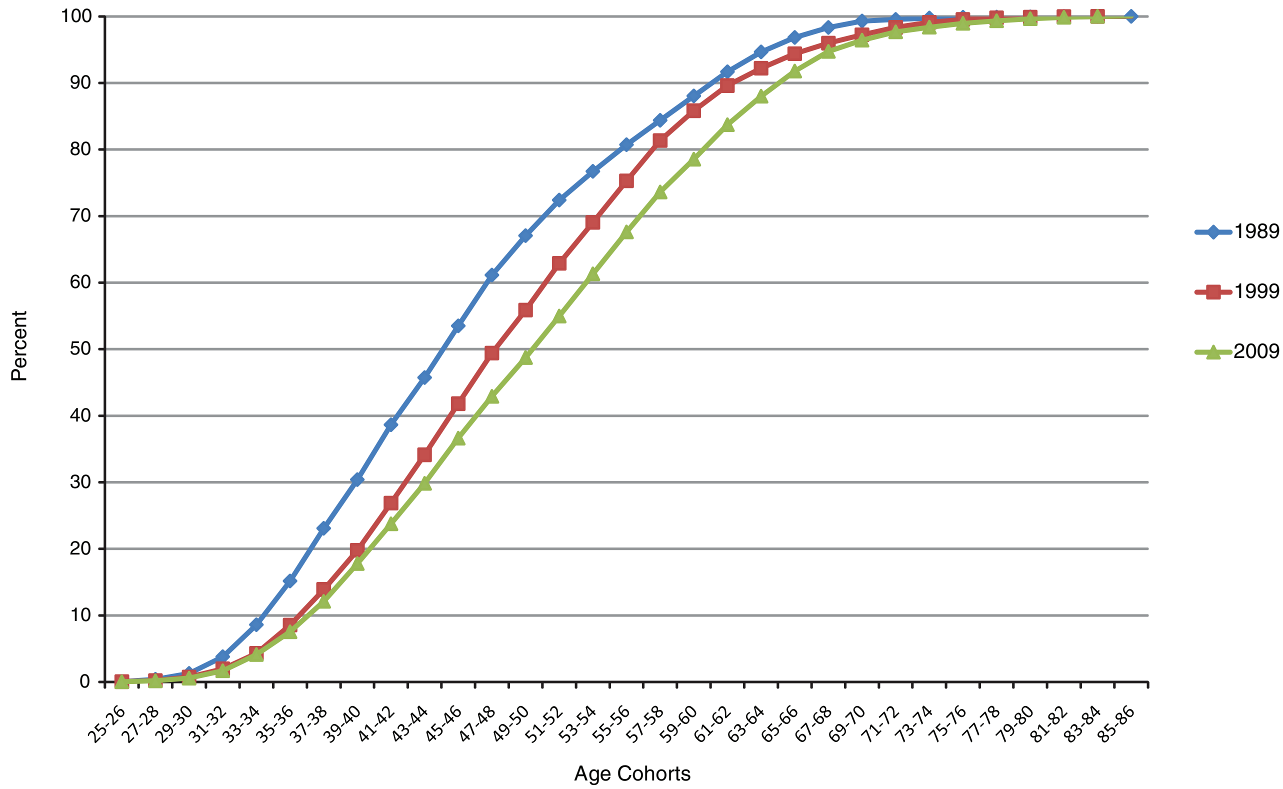

FIGURE 5-11 Age distribution of Ph.D.s on medical school faculty in clinical departments in 1989, 1999, and 2009.
SOURCE: AAMC. *Association of American Medical Colleges Faculty Roster, 2009.*

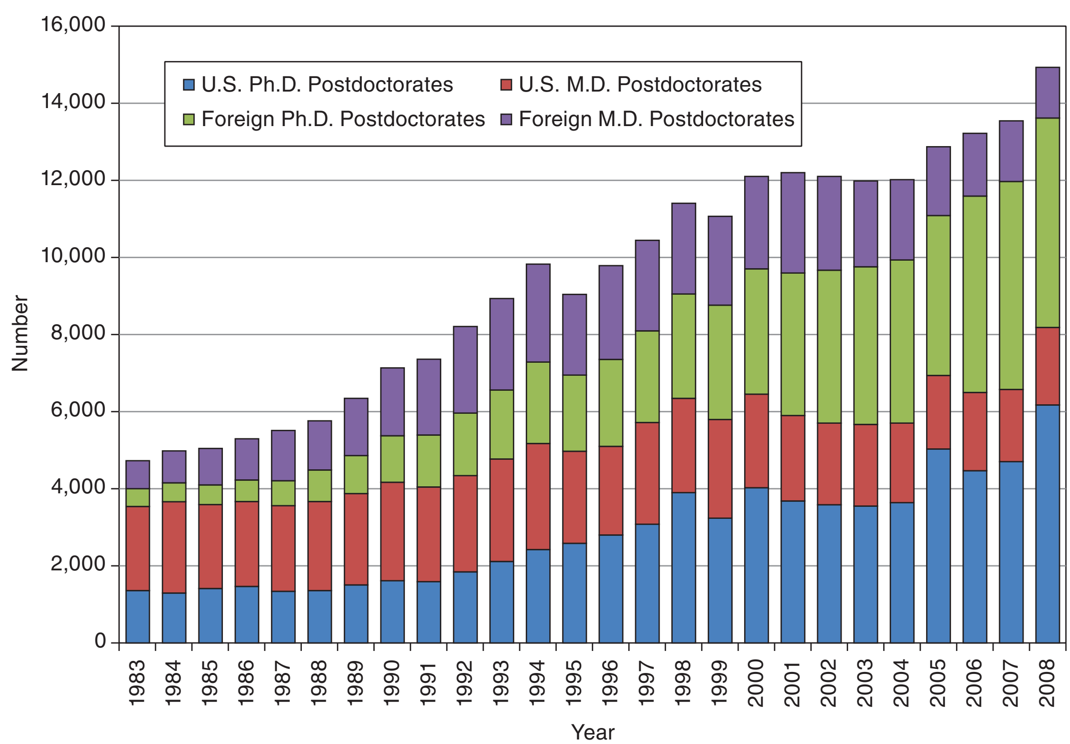

FIGURE 5-12 Clinical postdoctoral fellows by degree type.
SOURCE: NSF. 2008. *Survey of Graduate Students and Postdoctorates in Science and Engineering.* Washington, DC: NSF.

training programs, this option may not be widely used, and even if it were used, additional training places financial and other burdens on a young physician.

Congress has authorized several educational loan repayment programs for M.D.s who enter clinical research training programs, for minority M.D.s who pursue clinical training, and for others pursuing designated career paths. There are perhaps a half-dozen different programs authorized, and the NIH has been vigorous in making these programs known to successful candidates. The explicit purpose of these programs is to mitigate educational debt burdens for M.D.s pursuing clinical research training. M.D. graduates from clinical research training programs (e.g., those receiving one of the several K awards) must have protected time to develop their independent research careers, an increasingly difficult situation in today's increasingly competitive health care markets. Another obstacle is the limitation on salaries for NIH-funded physician-investigators. The cap is set annually set by Congress to be no more than that of an executive grade; this grade has varied in recent years between level II and level I. It is now set at $199,700, and although that is not an insignificant amount, it is below what many practicing clinicians or medical faculty can earn.

Dual-Degree Training

In addition to predoctoral and postdoctoral program support in the clinical sciences through the NRSA mechanism, dual-degree programs are another attractive option for health care professionals seeking clinical research training. The NIH currently, has three dual-degree training programs: (1) the Medical Scientist Training Program (MSTP), (2) individual M.D./Ph.D. fellowships, and (3) the Dental Scientist Training Program (DSTP).

These dual-degree programs are very attractive, because they provide students with several career options, and the level of educational debt that students are left with is much lower than that for regular M.D. students. The MSTP in the National Institute of General Medical Sciences (NIGMS) is the largest and oldest programs, dating back to 1964, and today it funds 880 students training at 35 medical schools and universities. An additional 31 MSTP trainees are supported by other institutes. Offering fellowships for M.D./Ph.D. training is more recent; they were instituted in 1989 by the National Institute of Mental Health, the National Institute on Alcohol Abuse and Alcoholism, and the National Institute on Drug Abuse to encourage dual-degree training in the areas of mental health, behavior, and neuroscience. The fellowship program is much smaller in scale, supporting about 140 new students each year. The latest type of dual-degree training to be introduced is the DSTP, which was created following the recommendations from the 1994 study of the NRSA program. The National Institute of Dental and Craniofacial Research supports about 90 dual-degree dental students through the T32 and F30 DSTP—in 16 different dental schools (only 2 of these schools do not have T32 DSTP trainees).

A student in a typical M.D./Ph.D. program begins intensive research training after the second year of medical school. At this point in their training, the students have had little exposure to clinical medicine and the challenges and research opportunities that are inherent therein. After three-plus years completing work required for the Ph.D. degree, the students return to the medical curriculum for the third and fourth years. For dual-degree graduates who elect to pursue full clinical specialty training, an additional three to five, or more, years typically ensue before the individuals can turn their attention fully to research. At that point, to begin an additional formal program of clinical research training is unappealing.

The M.D./Ph.D. programs were envisioned as a way to bring more M.D.s into clinical research, but in practice relatively few participants receive research training in clinical research methods, and only about 20 percent of the M.D./Ph.D.s actually go on to pursue clinical research careers. Educational debt does not appear to be the reason, because their debt averaged about $15,000 in 2006. Many have argued that these programs are not effective in training clinical researchers because of their structure. An analysis in 1996 of the fields of study chosen by MSTP participants found that nearly 60 percent of graduates from the late 1980s and early 1990s had their Ph.D.s in five basic science fields: biochemistry, neuroscience, molecular biology, cell biology, and pharmacology. As a consequence the work they were exposed to in their Ph.D. program was focused on basic research, and this attracted them to a research career in the biomedical sciences. As a result in their subsequent research careers, MSTP graduates focused almost entirely on laboratory-oriented research, albeit typically in clinical departments and in areas of relevance to that clinical discipline, and they sought NIH funding for such research projects at the same rate as Ph.D.s.

Recognizing this problem NIGMS has recommended that institutions provide broader opportunities within the M.D./Ph.D. training mechanism. The institute issued new guidelines for the MSTP that urged medical schools with such training grants to extend their programs in order to give students "a breadth of doctoral research training opportunities" in fields including computer science, the social and behavioral sciences, economics, epidemiology, public health, bioengineering, biostatistics, and bioethics. However, most M.D./Ph.D. programs have been slow to respond, and there has been little change in the descriptions of the programs. And in most cases, the basic structure of two years/three years/two years persists.

In addition to formal dual M.D./Ph.D. programs, other approaches are being tried to attract M.D.s to clinical research. Examples include master's level programs in specific clinical areas, which are becoming popular in some research-oriented medical schools and which may be designed to provide academic formal training in such areas as quantitative and methodological principles of medical genomics, epidemiology, biostatistics, clinical trial design and analysis, etc. These programs appear to be very attractive to medical students and may encourage them to pursue careers as physicians in clinical research.

Clearly, identifying optimal training mechanisms for attracting medical students to clinical research, and then structuring effective training programs to prepare the students and graduates for successful clinical research careers, remains a large challenge for the biomedical community and the funding agencies. Toward this end, the recent adoption by the ACME and the ACGME of recommendations from the AAMC's Task Force II on Translational and Clinical Research, viz., that medical students and residents should be exposed to the basic principles of translational and clinical research and to the research challenges and opportunities therein, may over time increase the population of medical graduates with a keen interest in pursuing clinical research careers. Finding mechanisms that will encourage students in these dual-degree programs to conduct clinical research continues to be a challenge.

RECOMMENDATIONS

Recommendation 5–1: The total number of NRSA positions awarded should remain at least at the 2008 level. Furthermore, training levels after 2008 should be commensurate with the rise in the total extramural research funding in the biomedical, clinical, and behavioral and social sciences. A decline in extramural research would also call for a decline in training.

Recommendation 5–2: The NIH, in consultation with academic medical leadership, should exercise leadership in identifying better training mechanisms for attracting medical students into translational and clinical research, and the NIH should fund pilot programs designed to implement promising new approaches to accomplishing that objective.

6

Oral Health

INTRODUCTION

With the publication in 2000 of *Oral Health in America: A Report of the Surgeon General*,[1] the significant impact that oral health can have on overall health and well-being came to widespread public attention. Central to that report's methodology was its effort to identify: (1) the determinants of health and disease, with a primary focus on factors such as prevention and producing health rather than restoring health; (2) the burden of oral diseases and disorders in the nation as a whole; and (3) the evidence for actions to improve oral health to be taken throughout life. With a strong orientation toward the future, the report emphasized leading-edge technologies and research that could be brought to bear in improving the oral health of individuals and communities. Implicit in its conclusions was a need to support and maintain a biomedical research infrastructure that includes research personnel of sufficient quantity, skill, and inclination to succeed in the task of diminishing oral disease and bringing about the attendant benefits that improved oral health promises for the general health of the U.S. population.

Accordingly, the Surgeon General's report envisions a biomedical research workforce that could competently address oral diseases and disorders such as dental caries and periodontal diseases; oral mucosal infections and conditions such as oral candidiasis, herpes simplex virus infections, oral human papillomavirus infections, recurrent aphthous ulcers, and oral and pharyngeal cancers and precancerous lesions; and developmental disorders such as craniofacial anomalies caused by altered branchial cleft arch morphogenesis, cranial bone and dental anomalies, craniofacial defects secondary to other developmental disorders, and craniofacial manifestations of single-gene defects. The report also recognized the need for research personnel who could devise new treatments, cures, and diagnostic methods for chronic and disabling conditions such as Sjögren's syndrome, acute and chronic orofacial pain, and temporomandibular disorders.

Research in areas of human health that have such broad scope and significance cannot rely exclusively on dental researchers as conventionally understood, but rather requires a broader biomedical research workforce that is part of, and fully integrated into, the biomedical sciences generally. Thus, there is no qualitative difference between oral health scientists and other biomedical scientists—only a quantitative need for a sufficient number of researchers who are interested in oral health problems and are willing to direct their attention to this particular field of endeavor. Lacking any intrinsic difference in training between oral health scientists and other biomedical scientists, facile movement of scientists into and out of this particular area of biomedical research should be possible as the nation's needs warrant.

The 2009 NIDCR Strategic Plan

The principles described in the 2000 Surgeon General's Report are evident in the recent strategic plan promulgated in May 2009 by the National Institute of Dental and Craniofacial Research (NIDCR).[2] That plan embraces the central goal of bringing the best science to bear on problems in oral, dental, and craniofacial health. The plan observes that dental disease itself remains quite common, with dental caries (decay) comprising the most common infectious disease of childhood (Figure 6-1). A constellation of common yet debilitating disorders requires research directed at improved approaches to treatment and prevention. Equally important, however, are technological innovations that promise breakthroughs, such as "labs on a chip," in which saliva is used as a diagnostic fluid not only for oral conditions, but also for systemic disorders as well. The prospect of bioengineered

[1] U.S. Public Health Service. 2000. *Oral Health in America: A Report of the Surgeon General*. Washington, DC: Department of Health and Human Services.

[2] NIDCR. 2009. *Strategic Plan 2009-2013*. NIH Publication No. 09-7362. Washington, DC: NIH. Available at http://www.nidcr.nih.gov/NR/rdonlyres/79812F51-8893-46BD-AE9D-2A125550533B/0/NIDCR_StrategicPlan_20092013.pdf.

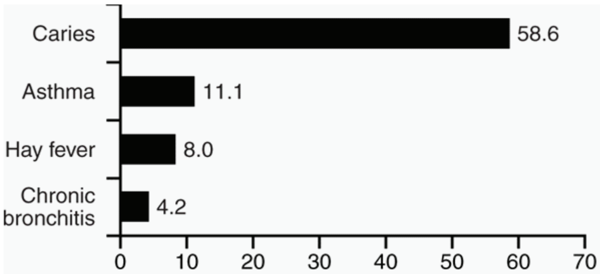

FIGURE 6-1 Dental caries among 5- to 17-year-olds.
SOURCE: National Center for Health Statistics, 1996.

tissue replacements and molecular imaging tools that utilize the oral cavity as an exceptionally accessible window into complex biological systems beyond the mouth is no longer a starry ideal, but an increasingly practical reality.

The findings of the 2009 NIDCR strategic plan mirror the thinking of the present committee in terms of its assessment of the national needs for biomedical, behavioral, and clinical research personnel. The direction set by the new NIDCR strategic plan is consistent with the committee's view of the problems related to the need for researchers in the oral health sciences and reflects both previous (2005) and current committee recommendations in this area.[3]

Although a tighter integration of research, clinical practice, and health educational communities is essential, it will be equally important to establish and maintain a critical mass of investigators possessing a unique and intimate knowledge of orofacial structures and disorders. Only in that way can schools of dentistry become more competent collaborators in the biomedical research enterprise in the quest to create vibrant research pathways for students and faculty and, ultimately, to improve the health of the public. Recent evidence, however, suggests the reverse trend; that is, a gradual deemphasis of research in the nation's dental schools. Figure 6-2 shows the proportion of NIDCR extramural grant support by type of academic institution. Although NIDCR extramural grant support increased by more than 2.6-fold between 1993 and 2008, the percentage of funding going to dental schools decreased from 68.7 percent to 46.7 percent. This suggests that the nation's dental schools are not competing as effectively for available research dollars in the oral health sciences as are other kinds of academic institutions that have gravitated to dentally related research.

Over the past 50 years the number of dental schools fluctuated between a low of 47 in 1961 and a high of 60 in 1980.[4] Between 1982 and 2000, seven dental schools closed—none having a significant research portfolio—and four have opened since 2000, with another eight under consideration for establishment. Of the 12 new and potential dental schools since 2000, 7 are associated with osteopathic medical schools.[5]

Although these data are viewed in aggregate, it appears that a redirection of dental education away from its historic mission of research, teaching, and service toward a more limited and exclusive focus on teaching may be taking place. This interpretation is corroborated by the decline in the total number of dental faculty members in the biomedical sciences from 933 in 1998 to 663 in 2008 (Figure 6-3).[6] This decline of nearly 30 percent in biomedical sciences faculty in dental schools contrasts with the nearly constant number of faculty in the dental and clinical sciences. The implications of this drop are discussed in detail below in the section on faculty shortages.

One factor that may be propelling this trend is a substantial increase in the compensation of practicing dentists, leading to a greater demand for dental education from an expanded pool of academically outstanding dental applicants for whom high compensation is a key driver in the selection of an occupation. Between 2003 and 2008 the overall college grade point average (GPA) of applicants to dental schools increased from 3.43 to 3.55 (see Figure 6-4), and the science GPA increased from 3.34 to 3.47. Existing dental schools have adapted to this market demand by admitting these highly competitive applicants. Moreover, as a further response, a new style of non-research-intensive dental school has emerged.[7] Such schools have been founded with a simple, tuition-based, financial plan, often in non-research-intensive universities. Some of these schools do not support a large resident faculty, tenure, or basic scientists. They may have little or no preclinical educational infrastructure and tend not to run large (often money-losing) student clinics or operate research laboratories. As dental schools apparently disengage, research in the oral health sciences has been undertaken by medical schools, engineering schools, hospitals, and other academic institutions.

Obviously research scientists cannot be trained in an environment in which research is not being conducted, and, as a response, the proportion of NIDCR extramural training and career development support going to dental schools decreased from 89.4 percent in 1993 to 73.1 percent in 2008 (Figure 6-5)—again, despite a near doubling of NIDCR support for this purpose.

If this trend is a manifestation of a change in the mission of existing dental schools or a reflection of new dental schools

[3] NRC. 2005. *Advancing the Nation's Health Needs: NIH Research Training Programs*. Washington, DC: The National Academies Press.

[4] IOM. 1985. *Personnel Needs and Training for Biomedical and Behavioral Research.* Washington, DC: National Academy Press.

[5] IOM. 2009. *The U.S. Oral Health Workforce in the Coming Decade: A Workshop*. Washington, DC: The National Academies Press. See in particular Chapter 4, "Current Demographics and Future Trends of the Dentist Workforce."

[6] American Dental Education Association, Center for Educational Policy and Resources, 2009.

[7] American Dental Association. 2009. *Survey of Dental Education, Volume 3: Faculty and Support Staff*. Available at https://www.ada.org/sections/professionalResources/pdfs/survey_ed_vol3.pdf.

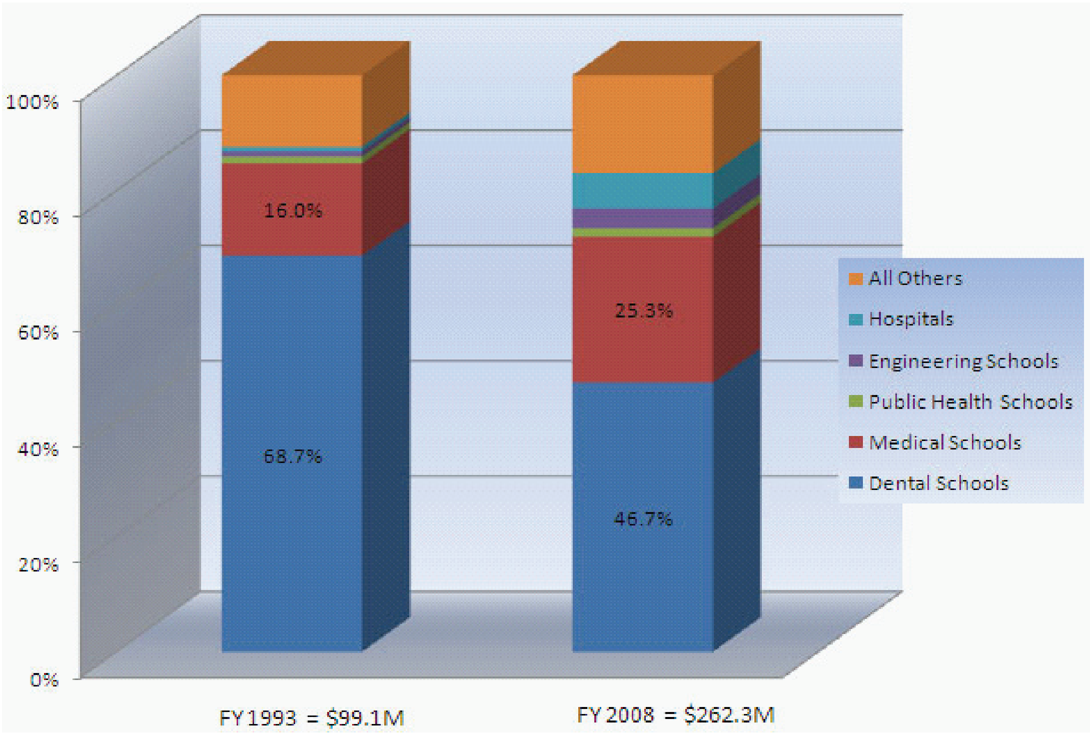

FIGURE 6-2 Extramural grant support by type of academic institution.
SOURCE: NIDCR Strategic Plan, 2009-2013.

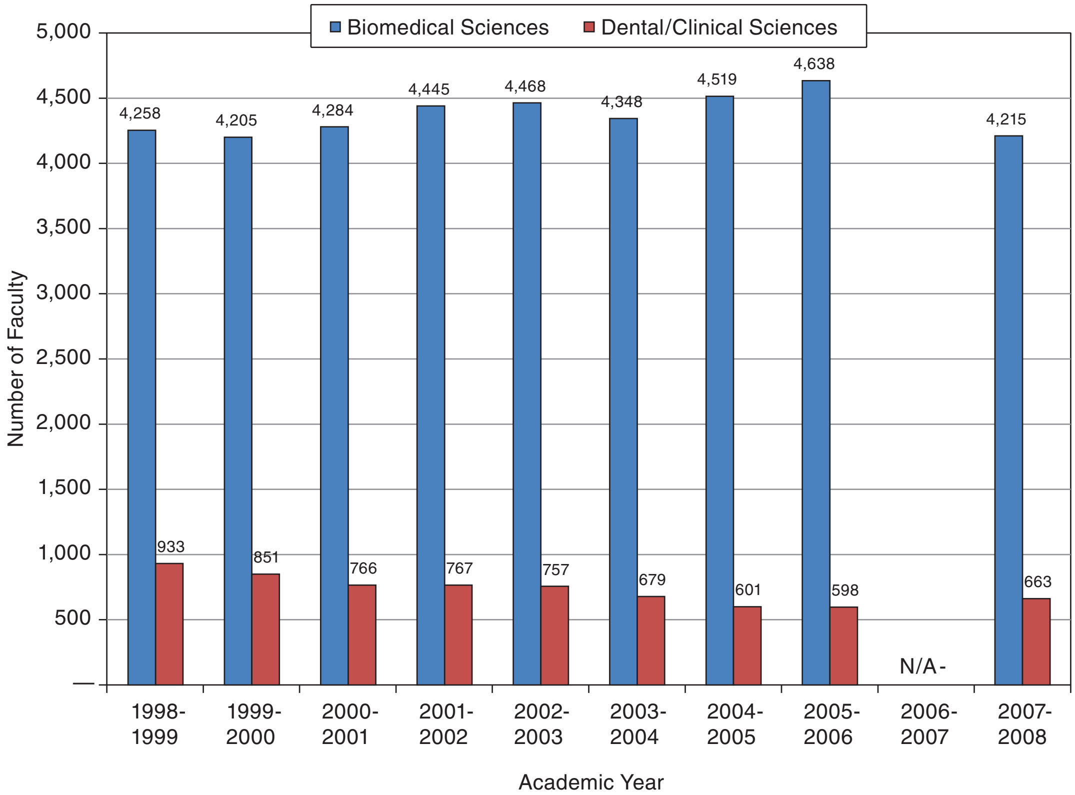

FIGURE 6-3 Biomedical science and dental/clinical science full-time equivalent faculty, 1998-1999 to 2007-2008.
SOURCE: American Dental Education Association, Center for Educational Policy and Resources, 2009.

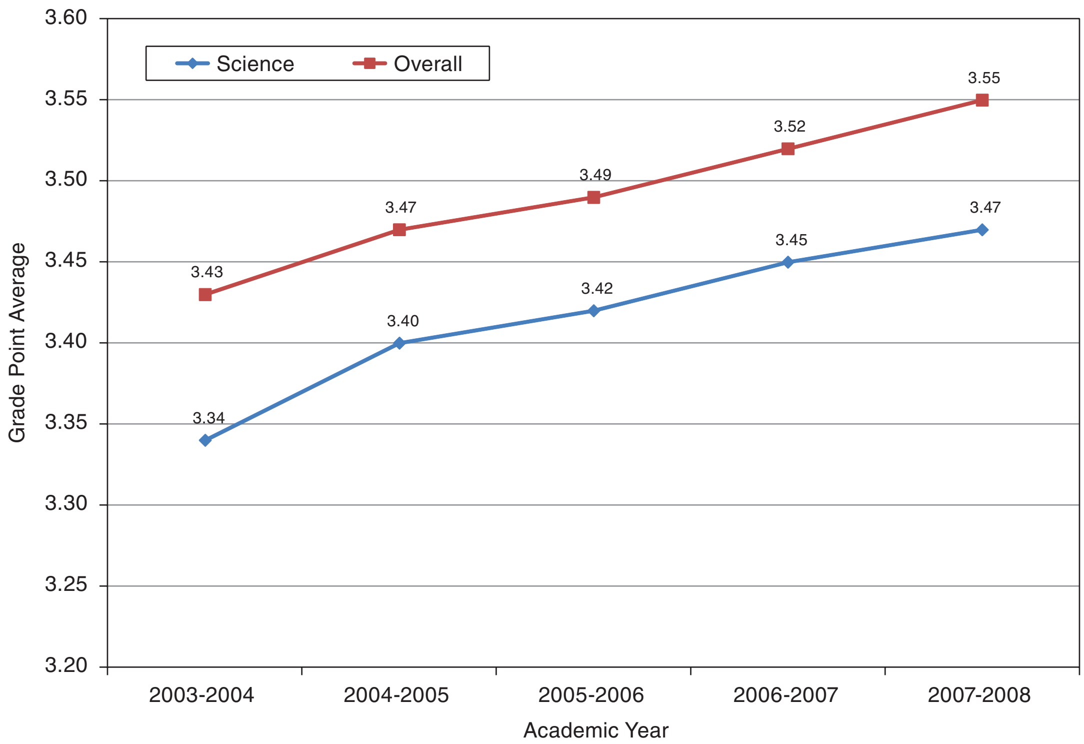

FIGURE 6-4 Average pre-dental GPA of first-year students, 2003-2004 to 2007-2008.
SOURCE: American Dental Association. 2009 (April). *2007-2008 Survey of Dental Education. Volume 2: Tuition, Admission, and Attrition.* Chicago, IL: ADA.

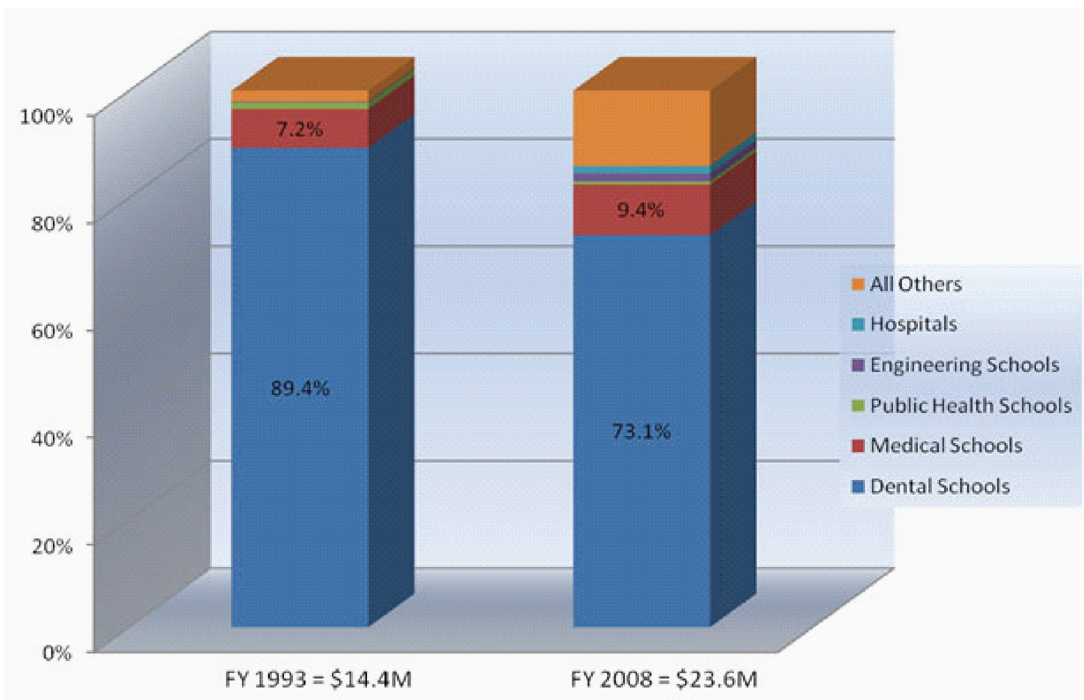

FIGURE 6-5 Proportion of NIDCR extramural training and career development support by type of academic institution.
SOURCE: NIDCR Strategic Plan, 2009-2013.

whose long-term institutional commitment coalesces around teaching the technical aspects of dentistry while minimizing research as the foundation of professional practice, then the decrease in focus on research could well continue over an extended period, undercutting the pipeline of potential research scientists coming from the nation's dental schools. This will decrease further the amount of research conducted within dental schools, thus strategically weakening the nation's oral health research infrastructure. Interestingly, should the demand for clinical dental education decline, the market forces that led to the emergence of a new model for dental schools may disappear; however, this does not suggest a return to a more research-oriented educational model. Rather, non-research-intensive dental schools may well be the survivors of a downsizing of the dental educational establishment. Based on high tuition and a robust business plan that excludes the costs associated with basic scientists, research laboratories, preclinical educational infrastructure, large student clinics, or tenured faculty, the newer schools will have far lower fixed expenses. Should demand for dental education decline in the future, it may be research-oriented dental schools that are most likely to close.

The *NIDCR Strategic Plan for 2009-2013* recognizes these trends, yet is bold in setting for itself the goals of broadening its scope of inquiry, strengthening the research pipeline, fostering novel clinical research avenues, and eliminating oral health disparities. The NIDCR strategic plan takes a step forward in recognizing the importance of closer integration among research, practice, and education communities with the goal of understanding and ameliorating disorders affecting the oral and craniofacial complex. The NIDCR strategic plan consciously recognizes unique challenges at a time when greater cross-talk, not less, is needed among clinicians, scientists, and educators in order to sustain progress. The question is whether the language and syntax of science required for such cross-talk will be intelligible to the dental clinician of the future.

Whether research in the oral health sciences emanates from the traditional dental community or from other kinds of institutions and organizations is unimportant as long as the best science is brought to bear on the critical questions of oral health. The NIDCR commitment to widening the scope of inquiry and doing so because "diseases have no disciplinary boundaries" is strongly endorsed by the present committee. Such an approach can indeed bring the best science to oral, dental, and craniofacial health through multi- and interdisciplinary collaboration, including the behavioral and social sciences. Where the researchers will come from, if they do not come from the nation's dental schools, remains an open question; however, astute investigators in many different fields inevitably gravitate to areas that are prioritized to receive funding. Thus, if NIDCR is able to provide support to maintain robust intramural and extramural research programs, researchers from different disciplines, including non-dental researchers, will undoubtedly compete for available dollars in this arena, and the oral health sciences will continue to advance.

As mentioned earlier, while supporting the best science, it does seem prudent also to encourage development of a core of researchers whose interest is, uniquely, in the area of oral health and whose commitment to this field is both continuous and unambiguous. This view is embodied in the NIDCR strategic plan's goal of strengthening a diverse pipeline of researchers in the field who will constitute a predictable and consistent source of fully committed investigators over the long term. Such individuals are likely to be the most intimately familiar with the nature of oral disease and the opportunities for oral health research. Even if the nation's dental schools seem less able or interested in competing for dental research dollars, it does not alter the fact that the investigators most committed to this subject area will still come from among the ranks of research faculty in the nation's dental schools. Assuming that this is the case, finding sufficient numbers of qualified oral health research personnel will be difficult, not only because of a re-purposing of dental education to a more narrow teaching function, but also because of a significant and longstanding shortage of dental school faculty in general.

Although the shortage of biomedical researchers in the oral health sciences and the shortage of dental school faculty may not be completely interdependent, they are almost certainly linked. For a variety of reasons, for the majority of dental students an academic research career is a less attractive career path than private practice. The NIDCR strategic plan addresses the pipeline of researchers dedicated to solving problems in oral, dental, and craniofacial health by envisioning greater collaboration with schools of dentistry, animating interest, and providing clearer pathways for students and faculty interested in research. The plan emphasizes training and career development of individuals and welcomes new disciplines poised to expand oral, dental, and craniofacial research. Accomplishing this task by encouraging vocations in dental education is discussed in detail in the Faculty Shortage section below.

Another goal of the NIDCR strategic plan—and one that is related to the issue of the pipeline of oral health researchers—is innovation in clinical research. One objective within this category is to ensure breadth and depth of the clinical research pipeline, fostering collaboration between oral health care practitioners, clinical scientists, and basic researchers. This area includes opportunities for combined D.D.S./Ph.D. training. According to the NIDCR, dentist-scientists need enhanced opportunities to obtain high-quality postdoctoral training with protected research time to help them become more competitive for independent research awards. Such postdoctoral programs are still relatively uncommon for dentists who have completed Ph.D. training, and, as a result, these research-oriented dentists have had less success in securing research funding. This was recognized and noted 25 years ago in our 1985 predecessor report, *Personnel Needs and Training for Biomedical and Behavioral Research*, which stated:

> Dentists are faced with a serious disincentive to pursue training as clinical investigators. Whereas the young physician receives a salary and benefits as a hospital resident and subspecialty fellow, similar payment for the newly graduated dentist is limited largely to hospital-based training in oral surgery and oral pathology. Training in the other specialties rarely provides compensation and may indeed require tuition payment by the trainees.[8]

Although efforts have been made since the publication of that report to place dental specialization trainees on the same footing as medical trainees through the vehicle of the Graduate Medical Education (GME) allocation to hospitals from the Medicare trust, the outcome has been decidedly mixed. More pertinent to the financing of the education of dentists pursuing training in the biomedical sciences is the insight of Grayson Marshall:

> NIH financing of D.D.S./D.M.D./Ph.D. programs needs to be encouraged as a high educational priority. To the extent that it is fiscally feasible, dental schools need to enhance stipends for graduate students without, if possible, causing students to lose eligibility for low-interest student loans. In conjoint D.D.S./D.M.D./Ph.D. programs when the clinical degree is awarded before the Ph.D., the NIH needs to be encouraged to permit postdoctoral stipend levels to apply during the post-D.D.S. phase (as opposed to the lower, predoctoral stipend levels). To the extent possible, tuition waivers (or tuition supplements) need to be found to allow most or the entire burden of D.D.S./D.M.D. tuition to be covered.[9]

In general, the greater assets available to the biomedical community as a whole have made tuition waivers and stipend supplements possible beyond the amounts provided by NIH. This has not been the case under the more constrained financial circumstances of dental schools. Marshall also suggests that supplementary clinical practice might also be a convenient way of helping to partially finance research training. Specifically, he wrote, "It is both natural and exciting for D.D.S./D.M.D./Ph.D. students to look forward to completing the D.D.S./D.M.D. phase of the program and then be allowed to engage in an intramural practice, deriving direct salary supplements from this source. This opportunity offers great motivation to complete the D.D.S./D.M.D. component of the program in as short a time as possible." He offers an example of a pilot where this was successfully tried, and he further shows that, despite the combined clinical and research elements of the program, highly motivated students "are able, unexpectedly, to complete the D.D.S./D.M.D. component of the curriculum in just four years and that the opportunity to earn practice income provides an exhilarating strategy to cope with the financial struggles dental students pursuing biomedical research training typically encounter. Placing such students into community outreach programs as salaried personnel is also an option."

Of particular importance is an analysis of training data undertaken by NIDCR to assure that the institute's research training investment is targeted to best achieve its goals. Surprisingly, it found that trainees supported by individual fellowships are more likely to obtain independent NIH research funding, particularly with respect to R01 grants, than those supported by institutional training grants. An NIDCR study reveals that a significantly higher proportion of faculty with prior NIH career development (K) awards are in full-time employment than are those who had prior NIH training grant or other NIH fellowship award support (T and F awards, respectively). Furthermore, "a recently conducted NIDCR research training program analysis highlighted the troubling pipeline trend that few NIDCR dental school trainees go on to independent research careers: The evidence suggests that dentists are not as successful as those without dental degrees in obtaining independent research funding." This revelation is as astonishing as it is disturbing. It almost suggests that the dental degree itself (or some antecedent factor that causes an individual to go to dental school) is a direct impediment to success as a researcher in the oral health sciences. Details at this level of specificity (offering individual versus institutional fellowships for instance) and related issues of format and logistics of particular fellowship opportunities provided by NIDCR to dentists seeking research careers may play an unexpected but key role in differentiating what works from what does not.

THE FACULTY SHORTAGE

There are 58 dental schools operating in the United States with roughly 4,800 full-time faculty members (Figure 6-6). This compares with 2,810 full-time faculty members distributed among 52 dental schools in 1969 and a peak of 5,706 full-time faculty members distributed among 60 dental schools in 1982. All schools award the Doctor of Dental Surgery (D.D.S.) degree or the Doctor of Dental Medicine (D.M.D.) degree, the two degrees being functionally equivalent. The number of part-time and volunteer faculty has steadily increased in recent years, from 6,167 in 2001 to 7,320 in 2006. A decision to allocate an increasing number of faculty slots to part-time faculty at the expense of full-time faculty is consistent with an increased emphasis on teaching and a decreased emphasis on research. This conclusion is founded on the reasonable presumption that most NIH-funded research conducted in dental schools is probably performed by full-time faculty. Amplifying the

[8] IOM. 1985. *Personnel Needs and Training for Biomedical and Behavioral Research*. Washington, DC: National Academy Press.

[9] G. Marshall, as cited in Bertolami, C.N. 2009. Creating the dental school faculty of the future: A guide for the perplexed. In ADEA, *Beyond the Crossroads. ADEA Commission on Change and Innovation* (pp. 90-91). Washington, DC: American Dental Education Association.

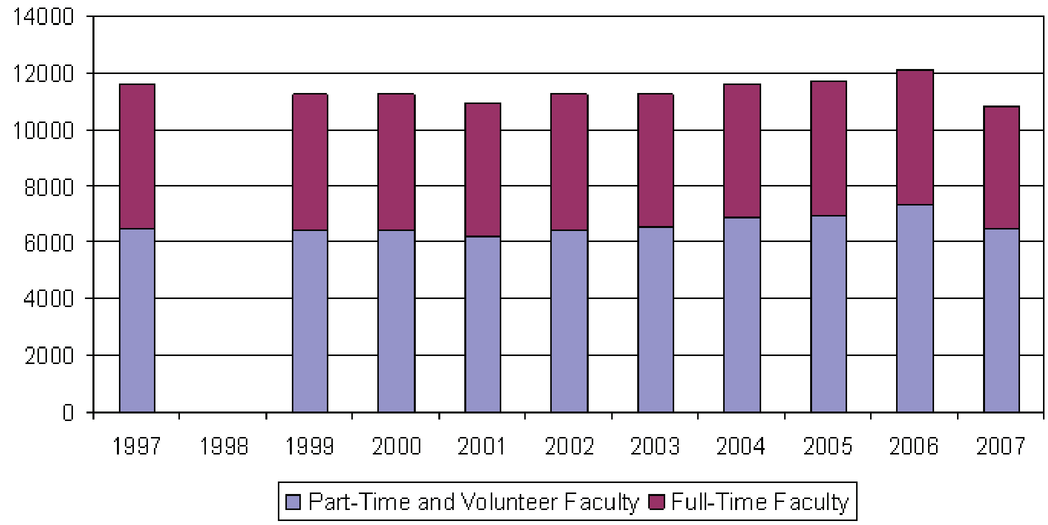

FIGURE 6-6 Full-time and part-time and volunteer faculty at dental schools, 1997-2007.
SOURCE: Data for 1997-2003 from ADEA Web site: "Trends in Dental Education" dated 2007. Data for 2004-2006 taken from JDE articles in 2006, 2008. Data for 2007 are estimates provided by ADEA.

effect of this decrease is the nearly 30 percent drop in the absolute number of biomedical science faculty discussed earlier.

The key evidence for a shortage of dentist-scientists is found in the annual number of vacant budgeted faculty positions (Figure 6-7), which totaled 316 such positions in 2007-2008 (see Table 6-1).[10] By way of comparison, the corresponding figure was 293 in 1969.[11] Although much has been made of the number of vacant budgeted faculty positions as a metric for a faculty shortage, a difference of just 23 when comparing 1969 to 2008 does not seem that impressive over a nearly 40-year time span. What is impressive, however, is that in 1969, of the 293 full-time vacant budgeted positions, 110 were in the basic sciences. By 1984, this number had decreased to 50, and by 2008 it had decreased further to just 18.[12] Such a decline could occur either by a rapidity in filling slots or by defunding them. Perhaps both approaches were in play, given some of the striking trends that are apparent over extended periods of time. As mentioned, between 1998 and 2008 the number of biomedical science faculty declined from 933 to 663—a decrease of nearly 30 percent over a 10-year period. Interestingly, there were 1,917 faculty members in basic sciences departments in dental schools in 1982. If this is chosen as the basis for comparison, it results in a dramatic 65 percent drop in biomedical science or basic science faculty in little more than 25 years. Admittedly, this last comparison needs to be made cautiously inasmuch as methodologies may have differed between the two surveying organizations (the American Dental Education Association and the American Dental Association—one looking at biomedical science faculty and the other looking at faculty in basic science departments). Nevertheless, whether viewed from the perspective of vacant slots in the biomedical sciences, the total number of basic science faculty, the proportion of full-time to part-time faculty, or the share of NIDCR funding going to dental schools, it does appear that dental education is moving away from the biomedical sciences in its educational programs.

Two presumed drivers of the difficulty of recruiting and retaining dental school faculty are compensation and student debt.

Compensation

The most recent survey of the net income of dental practitioners published by the American Dental Association in 2009 shows that 91.8 percent of all professionally active dentists are active private practitioners. The net income of dentists in 2006 (the most recent year for which data are available) amounted to $224,190, averaging both general dentists and specialists (Figure 6-8). During the 1990s, the average net income of solo private practitioners increased 78 percent, while the salaries of full-time dental clinical faculty

[10] Chmar, J.E., R.G. Weaver, and R.W. Valachovic. 2008. Dental school vacant budgeted faculty positions, academic years 2005-2006 and 2006-2007. *Journal of Dental Education* 72(3):377.

[11] IOM. 1985. *Personnel Needs and Training for Biomedical and Behavioral Research*. Washington, DC: National Academy Press.

[12] If basic science faculty are combined with a group of faculty identified as "research," the combined total for 2006-2007 would be 54 vacant positions, and the total for 2007-2008 would be 59.

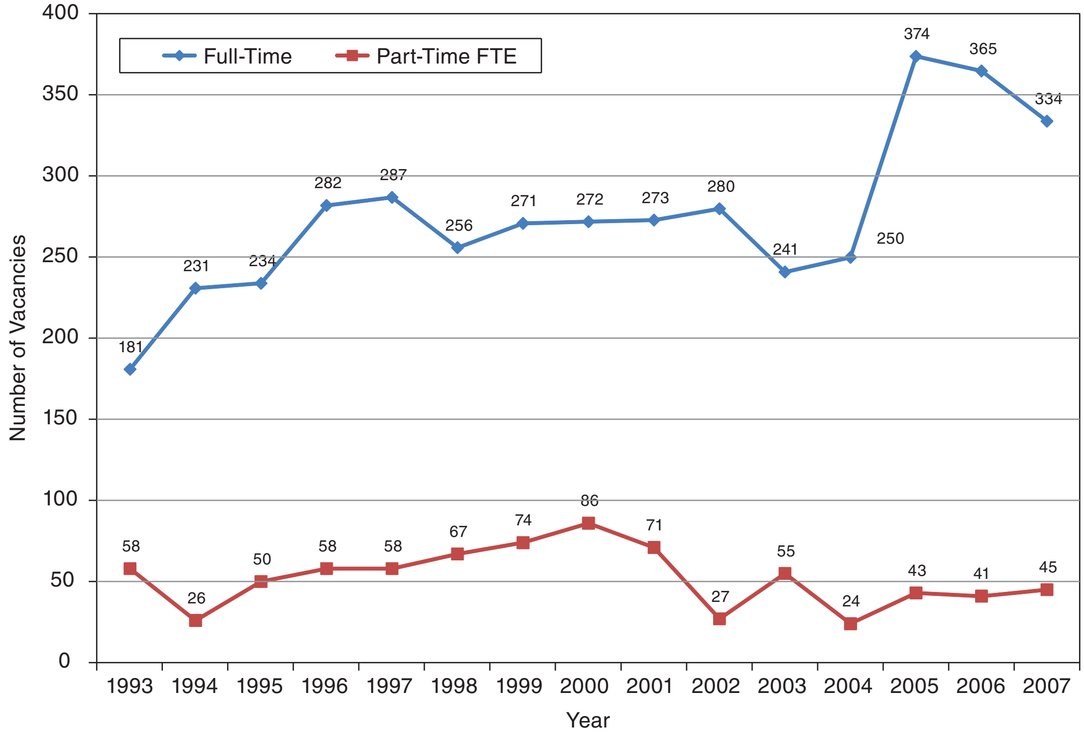

FIGURE 6-7 Number of vacant budgeted faculty positions in U.S. dental schools, 1997-2007.
SOURCE: Data from 1993-2006 from Okwuji, A. S., E. Anderson, R. Valachovic. "Dental School Vacant Budgeted Faculty Positions 2007-08" *Journal of Dental Education*, 2009 73:1415-1422.

TABLE 6-1 Vacant Positions by Primary Area of Appointment

	2006-2007 Vacant Positions			2007-2008 Vacant Positions		
Primary Area of Appointment	Full-time	Part-Time	Total	Full-time	Part-Time	Total
Clinical Sciences	254	38	292	233	41	274
Basic Sciences	24	0	24	18	0	18
Administration	24	0	24	15	1	16
Allied Dental	4	0	4	4	0	4
Research	30	0	30	41	0	41
Behavioral Science	4	0	4	5	1	6
Total Reported	340	38	378	316	43	359

SOURCE: 2006-2007 data from Okwuji, A. S., E. Anderson, R. Valachovic. "Dental School Vacant Budgeted Faculty Positions 2007-08" *Journal of Dental Education,* 2009 73: 1415-1422; Chmar, J., R.G. Weaver, and R. Valachovic. "Dental School Vacant Budgeted Faculty Positions, Academic Years 2005–06 and 2006–07" *Journal of Dental Education* 2008 72:370-385.

at the professorial level (assistant, associate, or full) rose by only 25 to 30 percent (see Figure 6-9).[13,14]

Several factors influence the income of dentists. Dentists in group practices generally have considerably higher income than sole practitioners, and specialists earn considerably more than general dentists. This is potentially important because most dentists pursuing research training beyond dental school, particularly in the form of the Ph.D. degree, have also secured training as specialists in one of the 10 dental specialties. Difference in income as a function of age may also be significant inasmuch as entering either a research career or pursuing research training during the early years after dental school calls into the play the contrast between the income of dental research faculty and the income of early career practitioners, both in terms of the differential in income per se and also as it relates to the long-term impact of compensation

[13] Haden, N.K., R.G. Weaver, amd R.W. Valachovic. 2002. Meeting the demand for future dental school faculty: Trends, challenges, and responses. *Journal of Dental Education* 66(9):1102-1113.

[14] ADA. 2009. 2007 *Survey of Dental Practice: Income from the Private Practice of Dentistry.* Chicago, IL: ADA Survey Center, American Dental Association.

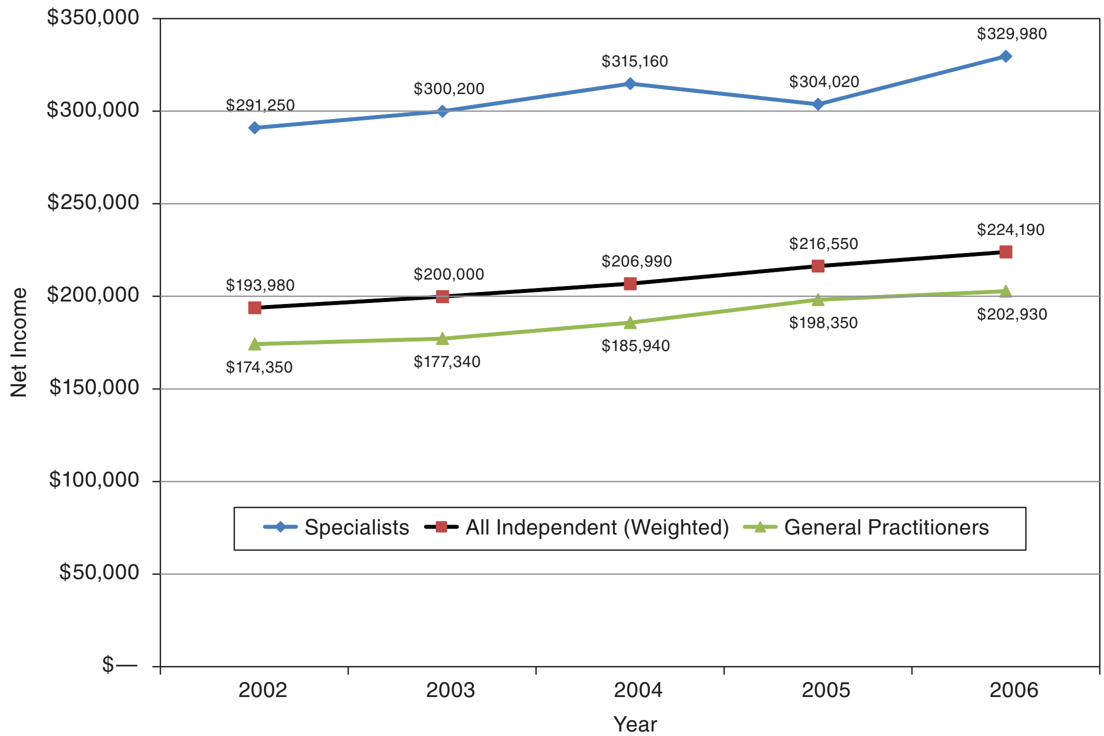

FIGURE 6-8 Net income from private practice of independent dentists, 2002-2006.
SOURCE: Tabulation from the American Dental Association. 2008. *Survey of Dental Practice. Volume 1: Income from Private Practice of Dentistry 2008.* Chicago, IL: ADA.

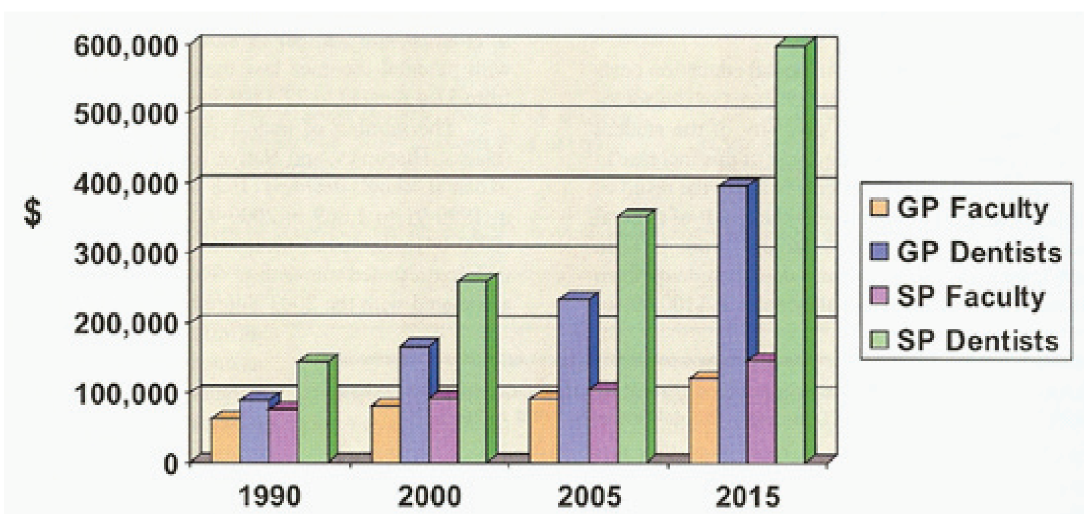

FIGURE 6-9 Net income from private practice dentists and dental faculty, actual and projected, 1990-2015.
SOURCE: Bailit, H.L, T.J. Beazoglou, A.J. Formicola, L.A. Tedesco, L.J. Brown, and R.J. Weaver. U.S. state-supported dental schools: financial projections and implications. 2008. *Journal of Dental Education.* 72(2 Suppl.):98-109 in: New Models of Dental Education, The Macy Foundation Study, Reconsidering Dental Education: Planning for the Future, p. 103.

and benefits that have been foregone (Figure 6-10). Thus, very early career dentists earn about $200,000 per year and are approaching their peak earning capacity in their early forties—about the same age at which biomedical research scientists secure their own first R01 grant.

In 2001, the average age for all dental faculty was 49.6 years, and the average age for full-time faculty was 50.6 years.[15] Furthermore, "Fifty percent of all faculty are

[15] Haden, N.K., R.G. Weaver, and R.W. Valachovic. 2002. Meeting the demand for future dental school faculty: Trends, challenges, and responses. *Journal of Dental Education* 66(9):1102-1113.

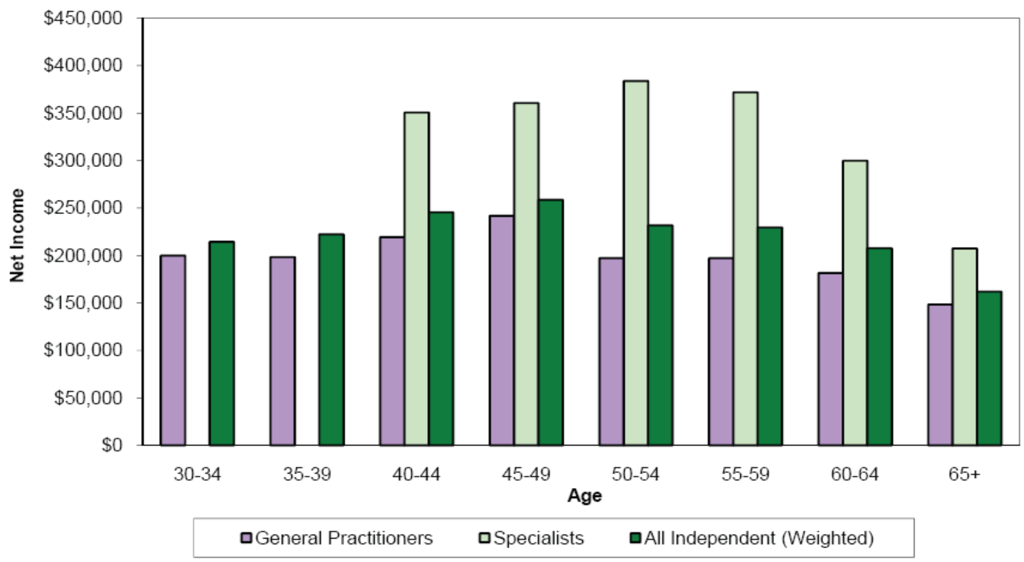

FIGURE 6-10 Net income from the primary private practice of independent dentists by age, 2006.
SOURCE: ADA. 2007. *2007 Survey of Dental Practices*. Chicago, IL: ADA Survey Center, American Dental Association.

50 years old or older, and 20 percent (2,266 individuals) are 60 or older." In a report published in 2008, respondents to a survey indicated that 28 percent were 60 years of age or older, 37 percent were 50 to 59, 20 percent were 40 to 49, and only 15 percent were younger than age 40.[16]

Debt

Total resident and non-resident costs for all four years of dental school from 1998 to 2008 are shown in Figure 6-11. The cumulative debt of dental graduates and its growth is shown in Figure 6-12. Clearly, the debt burden of dental graduates is substantial and offers a strong incentive to seek the higher paying clinical practice option rather than a career in biomedical research.

A Plausible Approach for the Future: Compensation, Debt, and Integrating the NIDCR Plan

Without underestimating the difficulties of building a robust oral health research infrastructure when trends within the dental profession and dental education are moving in the opposite direction, the NIDCR goals of broadening the scope of inquiry, strengthening the research pipeline, fostering novel clinical research avenues, and eliminating oral health disparities are not unrealistic. This is especially true when viewed in the light of important countertrends. For instance, beyond the obvious rationale of gauging the likely number of dentists entering the workforce to meet the nation's dental treatment needs, the population of matriculated students in the nation's dental schools represents the single most likely reservoir of future researchers in the oral health sciences. It is therefore fortunate that the size and quality of the national applicant pool for U.S. dental schools is strong, as evidenced by a nearly 3-to-1 ratio of applicants to available seats. This upward trend in applicants to positions has continued since 2001-2002. Dental education has responded to this demand by increasing the seats in existing dental schools and by opening several new dental schools, which, in aggregate, added up to an overall increase in dental enrollment of more than 500 students for the 10 years between 1998 and 2008. Apart from the implications of this increase for dental care services to the public, this trend enlarges the potential pool from which future researchers might be drawn while simultaneously adding pressure to an already fragile ratio of students to available professors.

Consistent with the increase in dental school enrollment are ADA figures showing that "the overall number of dental school graduates increased by 16.7 percent between 1998 and 2007 (from 4,041 to 4,714)," as can be seen in Figure 6-13.[17]

Of special note is the growing percentage of dental graduates who seek positions as employees. The prospect of an

[16] Haden, N.K., W. Hendricson, R.R. Ranney, A. Vargas, L. Cardenas, W. Rose, R. Ross, and E. Funk. 2008. The quality of dental faculty work-life: Report on the 2007 Dental School Faculty Work Environment Survey. *Journal of Dental Education* 72(5):514-529.

[17] ADA. 2009. *2007-2008 Survey of Dental Education. Volume 1. Academic Programs, Enrollment, and Graduates.* Chicago, IL: ADA, p. 46.

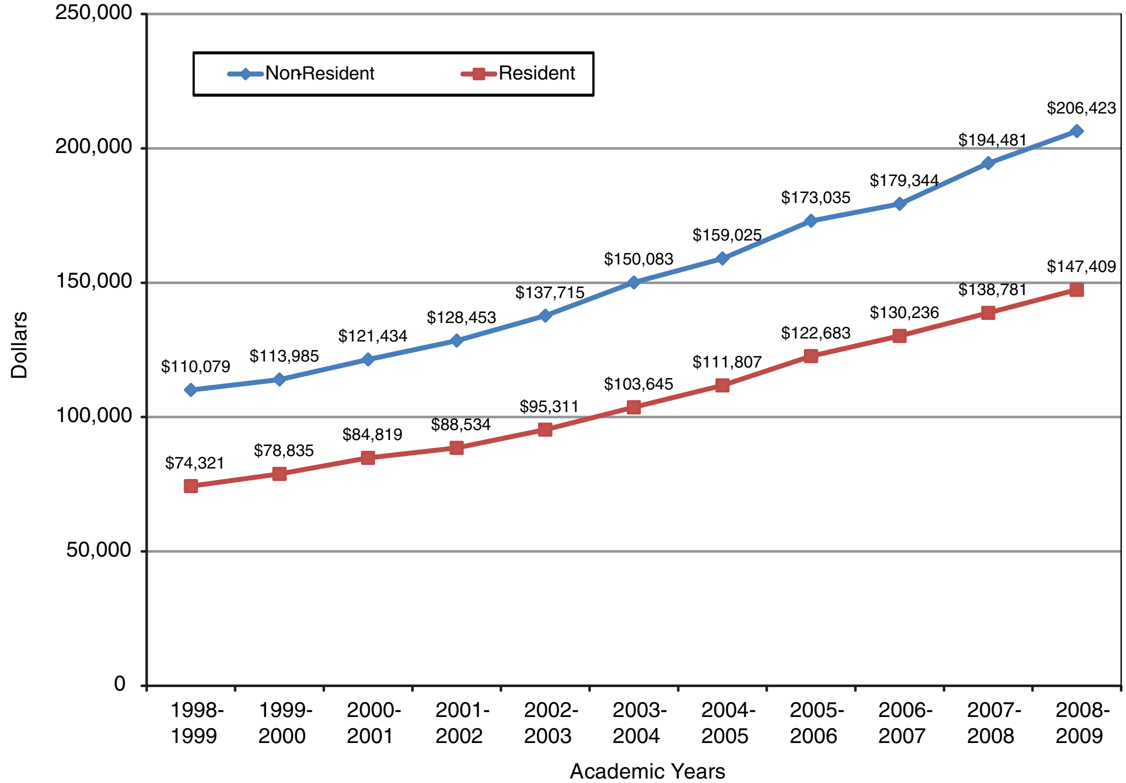

FIGURE 6-11 Average total resident and non-resident cost for all four years, 1998-1999 to 2008-2009.
SOURCE: American Dental Association. 2009 (April). *2007-2008 Survey of Dental Education. Volume 2: Tuition, Admission, and Attrition.* Chicago, IL: ADA.

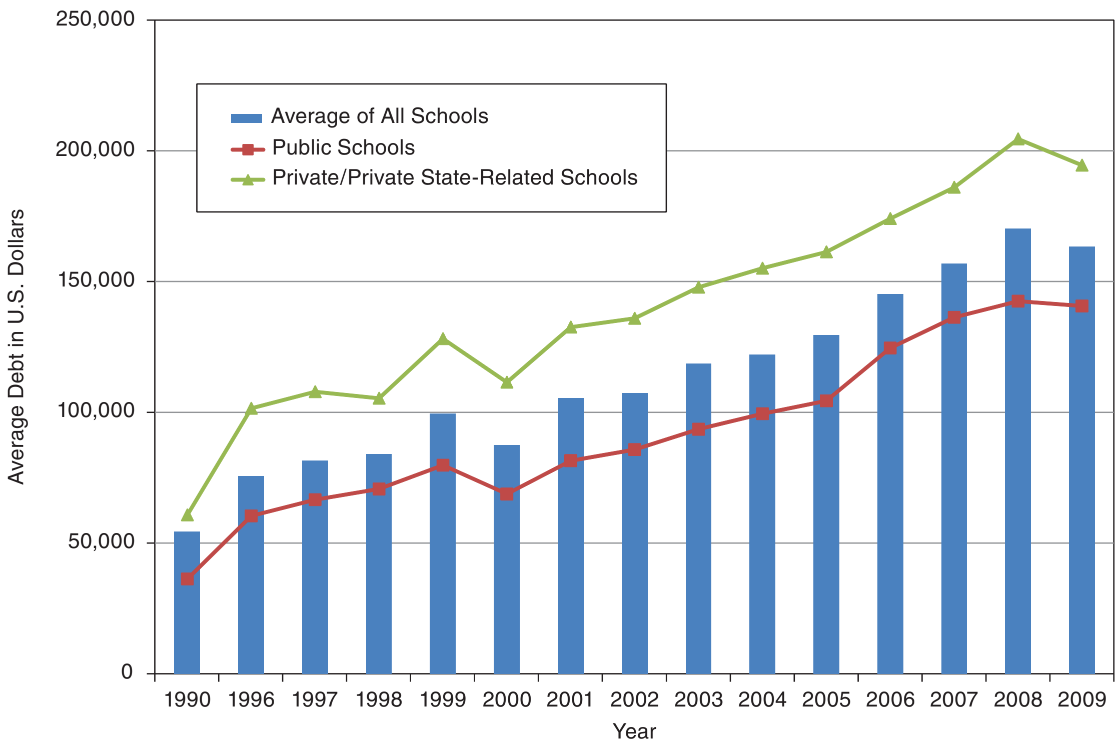

FIGURE 6-12 Average cumulative debt of all dental school graduates, 1990 to 2009.
SOURCE: Data adapted from the American Dental Education Association. 2010. *Journal of Dental Education.* 74(9):1011-1016.

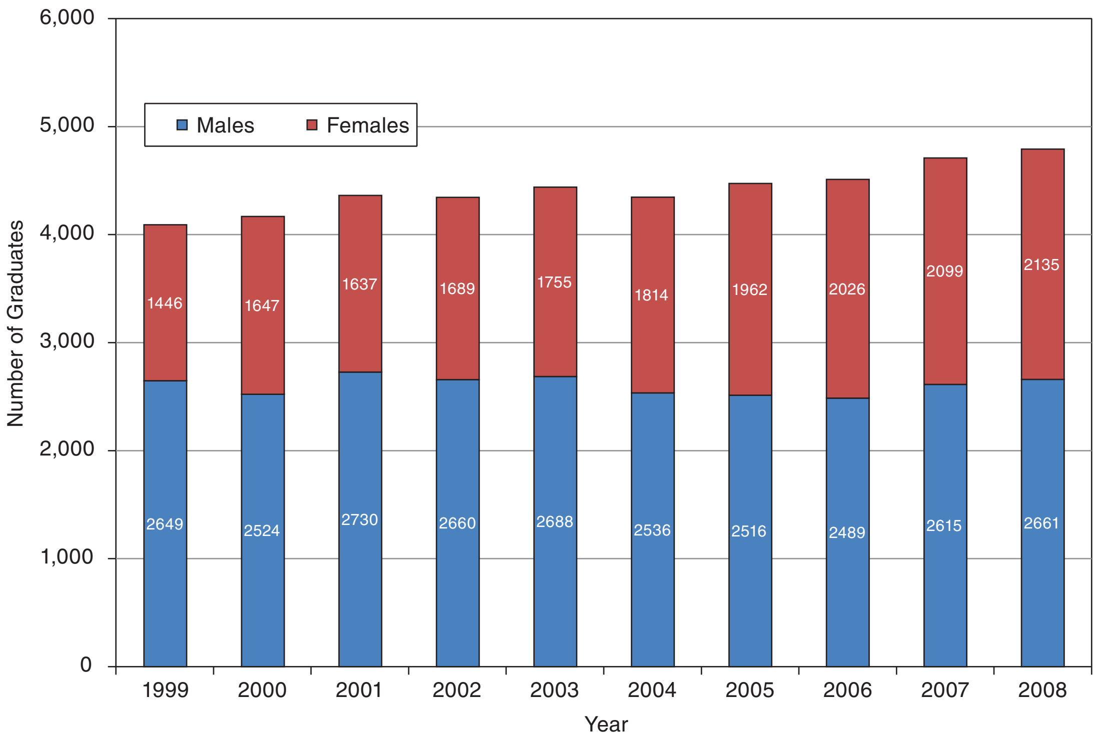

FIGURE 6-13 Dental school graduates, 1998-2007.
NOTE: ADA surveys of the immediate career plans of graduates are particularly significant (see Table 6-2).
SOURCE: Data adapted from ADA. 2009. *2007-2008 Survey of Dental Education. Volume 1: Academic Programs, Enrollment, and Graduates.* Chicago, IL: ADA.

TABLE 6-2 Immediate Plans upon Graduation, by Percentage of Respondents

Immediate Plans	1985	1990	1995	2000	2001	2002	2003	2004	2005	2006
Private Practice										
Solo	9.4	5.8	5.8	5.5	4	4.7	4.4	4.1	3.7	3.8
Partner/group	14.3	12	11.1	9.5	7.7	8.7	7.4	6	6.1	6.6
Associate/employed	34.4	31.3	32.9	36.5	41.1	38.9	38.5	40.3	41.8	42.1
Total Private Practice	58.1	49.1	49.8	51.5	52.8	52.2	50.3	50.4	51.6	52.5
Advanced Education	23.6	33.4	36	34.1	34.4	35.7	37.1	38.6	38.6	37.8
Teaching/research/admin.	0.9	1	1.1	0.5	0.6	0.5	1.9	0.5	0.8	0.5
Government Service	10.3	11.6	8.9	11	10	9.3	7.6	7.5	6.1	5.9
Undecided	7.2	4.9	4.2	2.9	2.3	2.2	3	2.9	3	3.2

SOURCE: Chmar, J.E., A.H. Harlow, R.G. Weaver, and R.W. Valachovic. 2007. Annual ADEA survey of dental school seniors, 2006 graduating class. *Journal of Dental Education* 71(9):1241.

immediate (but more modest) income in a salaried position as an associate in an established dental practice clearly has appeal as a debt-payment strategy in comparison with the need to forgo immediate income while seeking additional financing to build an independent dental practice. This trend may actually represent a potential opportunity for directing an interested subset of dental graduates into comparably paying research positions. Specifically, a more granular approach to understanding the impact of differential compensation and student debt as disincentives to biomedical research careers offers a potentially more effective strategy that has not been tried when eliciting interest in research careers among dental students: Ordinarily, comparisons are made between only two career choices: dentist (or specialist) versus academic (professor or researcher). As Charles Bertolami suggests,

> One way to address the problems stemming from income differential between dental educators and practicing dentists is to argue that these categories actually encompass three,

> rather than two, discrete occupations: dentist (or specialist); professor; and businessperson (understood as owner or proprietor of a practice). Different levels of work, responsibility, and risk distinguish these three jobs.[18]

Assuming that the blend of work, responsibility, and risk determines compensation, it is important for dental graduates to understand that it is the assumption of higher risk—especially financial risk—that correlates with a greater financial return. Therefore, it is the category of owner or proprietor of a dental practice—in effect, a business person—whose compensation is relatively high that skews the average income of practicing dentists to the higher income brackets when viewed in aggregate. These high aggregated income figures are what graduating dentists have in mind when entering clinical practice. However, as mentioned earlier, the percentage of dental graduates whose immediate plans upon graduation are to become employed dentists is both substantial and increasing, up from 34.4 percent in 1985 to 42.1 percent in 2006 (Table 6-2). That an increasing percentage of dentists is accepting of the idea of being an employee (at a lower income than that of an owner or proprietor, while still meeting student debt obligations) may mean that a significant subpopulation of students exists in dental schools for whom the option of employment not in a private practice but as a dental academic or researcher could be attractive, assuming the compensation is about the same.

Critically, then, the question is not how compensation differs between dental professors and researchers versus practicing dentists, but rather how compensation compares between professors and researchers and the category of employed (non-owner) dentists. Furthermore, how the benefits of being an employee (including retirement and health benefits, paid vacation time, portability, and relative freedom from financial risk)—and not just starting salary—translate into prized values over an entire career becomes a central issue. Dental graduates willing to put personal financial assets at significant risk in the building up and running of a business-based dental practice in return for significant economic reward associated with these risks will find an academic research career relatively unattractive. This may not be the case, however, for the employed dentist who is unable or unwilling to place personal assets at risk. For the person contemplating a career in dental academics, Nash and Brown pose the crucial question: "Are the monetary benefits from dental training large enough to repay all costs of training and yield a positive net return to the dental school faculty member?"[19] The comparisons in Figures 6-14 and 6-15 show that a "good part of the differential between faculty compensation and owner/private practitioners can be explained as the premium that the latter receive for accepting the business risk of owning a practice. These risks include capital investment and management risk." However (and most significant in this discussion), among those dentists choosing to be employees, the lifetime differential in income between faculty members and practitioners is small. It is only when comparisons are made with owners and proprietors of dental businesses that the large differentials in income emerge. "Owning and equipping a dental office is expensive and not risk free. . . . Illness or accident can end a career before accrued debt is paid off . . . [and] both the capital risks and management risks must be compensated. . . . In addition, such owner/proprietors very likely initiate their businesses by first going out to secure a business loan. In contrast, neither employed dentists nor dental school faculty members are asked to make equity investments that require them to begin their careers by assuming yet more debt." Distinguishing between employee/dentists and owner/proprietor dentists, as suggested by Nash and Brown, may be very useful in communicating research career opportunities to dental students. Although dental faculty positions can never be expected to offer salaries competitive with dentists who are proprietors of a business, the difference is not great between research and faculty dentists and the growing segment of employed dentists. Even in 2006, before the impact of a major economic downturn on the economics of dental practice had materialized, employed dentists earned almost 40 percent less than owner/proprietors. In light of this finding, and to the extent that financial comparisons are made between faculty positions and practice positions, they should be made only among the category of employed dentists: "This is the premium such individuals pay for the kinds of freedoms employees typically enjoy—including paid vacation time, possibly sick time, a lack of assets at risk, and relative ease of moving from job to job or place to place."

The practical significance of the Nash and Brown analysis is that it might be advantageous not to view the dental student population as homogeneous and undifferentiated. Rather, research careers in the oral health sciences can be credibly marketed to a significant and identifiable subpopulation of dental students: specifically, those with an inclination to accept a long-term position as an employee rather than as an owner/proprietor. Bringing this choice to the awareness of dental students early in their education could have an impact on the appeal of research careers for some students.

Our predecessor report made several observations that are as true today as they were when the report was issued in 2005, including:

- If education in biomedical research is to be offered to dentists, it needs either to be a part of professional school study or provided as a postgraduate experience.

[18] Bertolami, C.N. 2007. Creating the dental school faculty of the future: A guide for the perplexed. *Journal of Dental Education,* 71(10):1267-1280. American Dental Education Association.

[19] Nash, K.D., and L.J. Brown. 2004. Rate of return from a career as dental school faculty. In L.J. Brown and L.H. Meskin, eds. *The Economics of Dental Education*. Chicago: American Dental Association, Health Policy Resources Center, pp. 41-79.

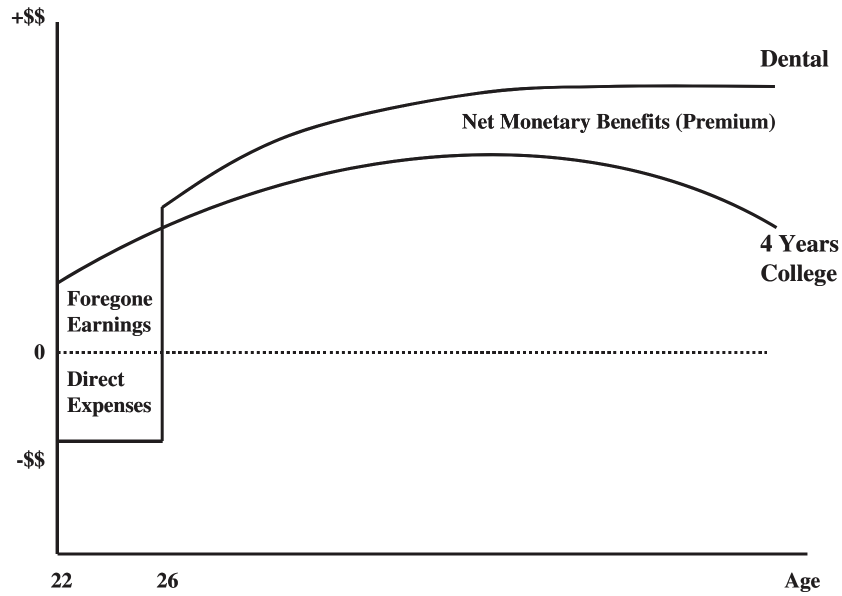

FIGURE 6-14 Model of estimating the rate of return to an investment in a dental education.
SOURCE: Nash, K.D., and L.J. Brown. 2004. Rate of return from a career as dental school faculty. In L.J. Brown and L.H. Meskin, eds. *The Economics of Dental Education.* Chicago, IL: ADA, Health Policy Resources Center.

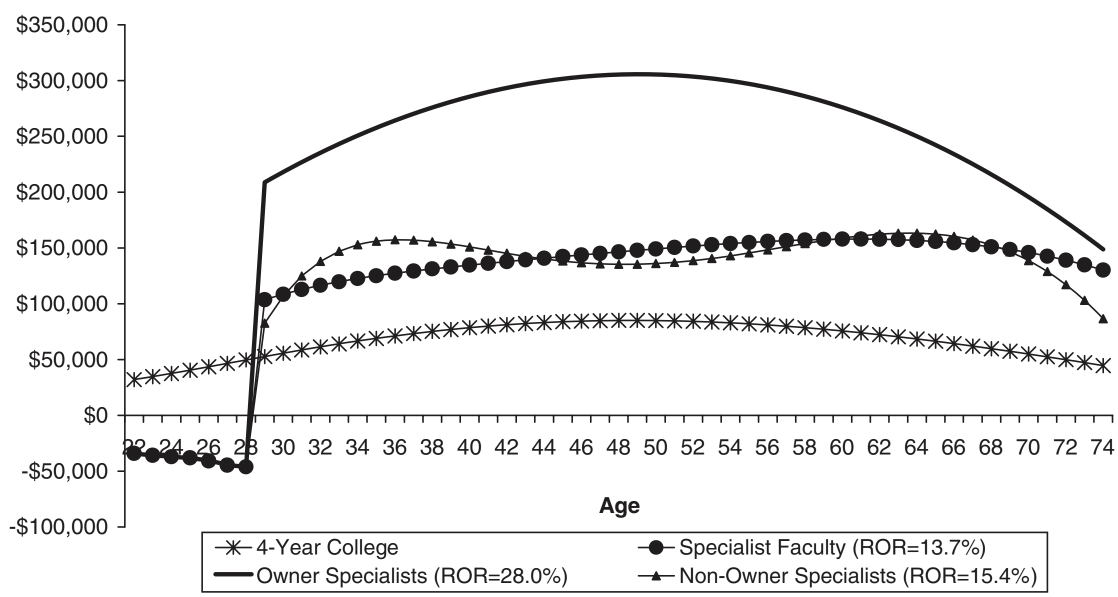

FIGURE 6-15 Average earnings of dental specialists in various careers and average earnings of four-year college graduates, by age, 2000.
SOURCE: Nash, K.D., and L.J. Brown. 2004. Rate of return from a career as dental school faculty. In L.J. Brown and L.H. Meskin, eds. *The Economics of Dental Education.* Chicago, IL: ADA, Health Policy Resources Center.

- Individuals at the high end of the academic distribution are not being attracted to careers in biomedical research.
- The percentage of dental graduates interested in teaching, research, or administration is small and declining. Few students entering dental school are aware of a career path that includes oral health research, and even fewer consider this option as they complete their training.
- The reasons for this low interest include the prospects of a high income in dental practice; accumulated high student debt; and a culture in many dental schools, especially among the clinical faculty, that values the technical aspects of dentistry and often marginalizes research.

The 2005 report lamented the fact that competition is great for the highest academic performers graduating from dental school and that the occupational activities most effective at siphoning off the best graduates academically are the various clinical specialties in dentistry. These training programs require anywhere from 2 to 7 years of additional study after dental school. Accordingly, the appeal of studying several more years for a Ph.D. degree to enter a field guaranteed to offer a lower level of compensation does not enter the consciousness of most graduates of dental programs. Although the current situation relative to the research personnel needs in the oral health sciences is about the same as described in the 2005 report, and though a new and disturbing trend has emerged that seems to de-emphasize research in dental schools, the goals of the new NIDCR strategic plan are well suited to addressing the key problems.

Assuming the current university-based model of both educating and employing research scientists in dentistry remains the operative paradigm, a key question is: What will it take to make both teaching and the research integral to a university-based teaching model appealing to the kinds of individuals required by the biomedical research enterprise in the oral health sciences? Implicit in the previous discussion have been the significant impediments to careers in education and research that materialize as a consequence of dental graduate debt and the need to balance salary and working environment.

What dental educators are really doing when they ask dental students to consider a research career is inducing them to make a dramatic break with their settled career aspiration of becoming a dentist. The available population of potential candidates is not only relatively small—fewer than 5,000 nationally—but also prejudicially filtered: All dental students have gone to college where they encountered research scientists. "They know what academic life is all about and understand what it means to be a professor," Nash and Brown explain. "In deciding to go to dental school, they have consciously rejected the notion of an academic career. The fixity of this idea in a student's mind—that they are going to be a dentist not a professor—generates a relatively high gradient against which dental educators have to prevail if such students are to be attracted to an academic career in spite of an explicit and antecedent decision against it."

RECOMMENDATIONS

Clearly, the best science needs to continue to be brought to bear on problems in oral, dental, and craniofacial health. At the same time, however, a critical mass of investigators who possess a special and long-term commitment to research in the oral health sciences must be maintained. With these goals in mind, the committee believes that the following recommendations are consistent with the 2009 NIDCR strategic plan and that they offer a path forward for achieving that plan's goals, namely, to increase the biomedical research workforce in the oral health sciences in order to bring the best science to bear on problems in oral, dental, and craniofacial health.

Recommendation 6–1: Working through appropriate organizations such as the American Association for Dental Research, the American Dental Education Association, and research-intensive dental schools, the National Institute of Dental and Craniofacial Research must increase efforts to achieve closer integration between schools of dentistry and the broader research, practice, and education communities with the goal of generating new and vibrant research pathways and partnerships for students and faculty.

Recommendation 6–2: Because individual research fellowships have proven more effective in terms of generating long-term research career commitments than institutionally based programs, greater opportunities for independent NIH research fellowship support is encouraged, including K awards, programs to support postdoctoral research for dentists, Ph.D. programs for non-dentists in subject areas relevant to oral health, and programs for internationally trained non-U.S.-citizen dentists seeking Ph.D. and postdoctoral fellowships. Partnerships with other components of the academic health system need to be developed and maintained based on recognition of the value added by the oral health sciences through systems-oriented approaches as already embodied in programs such as the Clinical and Translational Science Award programs and practice-based research networks. All such NIH-sponsored initiatives should explicitly identify a collaborative role for oral health research.

Recommendation 6–3: Ideally, programs need to be developed that offer tuition waivers or supplements, or loan forgiveness, or both, for the dental school component

of combined D.D.S./D.M.D./Ph.D. programs. This would allow most or all of the burden of the D.D.S./D.M.D. tuition to be covered for students who commit to long-term careers in dental research. Enhanced stipends for graduate students should be provided if fiscally feasible without causing students to lose eligibility for low-interest student loans. In conjoined D.D.S./D.M.D.-Ph.D. programs, when the clinical degree is awarded prior to the Ph.D., the NIH needs to be encouraged to permit post-doctoral stipend levels to apply during the post-D.D.S. phase (as opposed to the lower, predoctoral stipend levels). The feasibility of adaptations of the existing Medical Science Training Program (M.D./Ph.D.) model to dental education—including full funding for eight or so years—should be explored.

7

Nursing Research

Research training in nursing prepares investigators to create new scientific knowledge to guide nursing practice, assess the health care environment, improve patient, family, and community outcomes, and influence health policy.

The science of nursing is focused on the development of knowledge to: (1) build the scientific base for clinical practice; (2) prevent disease and disability; (3) manage and eliminate symptoms caused by illness; and (4) enhance end-of-life and palliative care.[1] As described by Donaldson and Crowley, such research is characterized by three themes of inquiry that relate to human well-being: (1) principles and laws that govern life processes and offer maximum optimum function during illness and health; (2) patterns of human behavior in interaction with the environment in critical life situations; and (3) processes by which positive changes in health status are affected.[2] Thus, nursing studies serve to integrate the full range of biobehavioral responses of human beings.

As in many health care disciplines, much of nursing practice is not currently based on high-quality evidence. The major objective of modern nursing science is to develop the knowledge base on which to plan the most effective health care. Such research may range from fundamental basic laboratory research to community-based and translational research to improve care of groups highly susceptible to a range of different diseases.

The prevention of disease or disability is a major focus of nursing research along with a strong focus on health promotion and risk reduction across a wide spectrum of individuals and disease conditions. This approach is well exemplified by the following example of a school-based program adopted by most North Carolina schools. It is a health promotion program in exercise and diet for young children at risk for cardiovascular disease. The research results from this prevention-based program are impressive; the young people's total cholesterol levels and measurements of body fat were significantly reduced following the education and exercise interventions, and their fitness levels, physical activity, and knowledge about cardiovascular disease risk factors improved.[3]

Preventing the complications of chronic disease is also a major area for research in nursing. Some of this work develops ways to help individuals and families cope with long-term chronic disease. For example, a program targeting better self-management of Type 1 diabetes examined the effectiveness of specific coping skills; the results of the study showed both improved metabolic control and higher quality of life in adolescents who used the skills. The program has been adopted in more than 100 clinical programs.[4]

Nursing care and research have traditionally addressed strategies for the management of symptoms associated with illnesses or their treatment. For example, in a study that focused on developing a longer-acting pain medication, investigators found that gender is a major factor in whether drugs are effective. Women responded well to seldom-used kappa-opioid drugs, but men had little benefit from those drugs.[5]

Influencing, redesigning, and shaping the environment for patients, families, and communities is another major area of study in nursing. Many studies have shown the influence of nursing surveillance and presence on positive patient outcomes. A shortage of nurses, a critical factor in the current health care environment, has been demonstrated to increase patient mortality and morbidity. Other studies show the benefit of home visits by advanced practice nurses in improving the health and quality of life of elders being discharged from the hospital.[6]

Research in nursing is often referred to as "nursing science" or "nursing research," which has led some to confuse it with the nursing profession. This terminology exists at the National

[1] NINR. 2006. *NINR Strategic Plan,* Pub No. 06-4832. Online at http://www.ninr.nih.gov/AboutNINR/NINRMissionandStrategicPlan/.

[2] Donaldson, S.K., and D.M. Crowley. 1978. The discipline of nursing. *Nursing Outlook* 26(Feb):113-120.

[3] NINR Strategic Plan, 2006, p. 26.

[4] NINR Strategic Plan, 2006, p. 27.

[5] NINR Strategic Plan, 2006, p. 28.

[6] NINR Strategic Plan, 2006, p. 28.

Institutes of Health (NIH) in the name of the National Institute for Nursing Research (NINR); however, the funding from NINR supports scientific research relevant to the science of nursing, and the investigators may be nurses or non-nurses.

The conditions needed for training in nursing research described in the 2005 NRC report hold true today:

> Research training for nurses, as for other biomedical and behavioral researchers, needs to occur within strong research-intensive environments that typically will be in universities and schools of nursing. Important characteristics of these training environments include an interdisciplinary cadre of researchers and a strong group of nursing research colleagues who are senior scientists with consistent extramural review and funding of their investigative programs and obvious productivity in terms of publications and presentations. These elements are essential to the environment required for excellence in research training. (NRC, 2005, p. 73)

To encourage the development of research training in nursing, NINR devotes at least 7 percent of its funds to research training—about double what is found in other Institutes. The committee supports this priority as critical to the future of nursing research.

CHANGING THE CAREER TRAJECTORY FOR NURSE-SCIENTISTS

Changing the career trajectory for nurse-researchers involves three major efforts: (1) enhancing sustained productivity for nurse-scientists to promote an earlier and more rapid progression through the educational programs to doctoral and postdoctoral study; (2) responding to the shortage of nurse-investigators by increasing the number of individuals seeking doctoral education and faculty roles; and (3) emphasizing research-intensive training environments, including increased postdoctoral and career development opportunities.

ENHANCING SUSTAINED PRODUCTITY FOR NURSE-SCIENTISTS

Nurse-scientists play a critical role in the conduct of research and the generation of new knowledge that can serve as the evidence base for practice and the improvement of patient health outcomes. However, nurses enter Ph.D. programs mostly at a substantially later age than in any other biomedical or clinical science, limiting their years of potential scientific productivity. Faculty in many scientific fields starting their careers in their mid-30s may well have a research career of 30 to 40 years (to age 65-75). The average age of doctorally prepared nurse faculty, however, is 55.6 years [AACN data online][7], and the average age of retirement is 62.5 years—clearly limiting the productive years for nursing science and health practice in general. Nurse-investigators tend to have a shorter career span, thus limiting the development of nursing science and its application to nursing practice. Clearly a major driver in the short career span is the late stage at which nurse-scientists receive the Ph.D.

The fact that Ph.D. training for nurse-scientists occurs at such an advanced age (current assistant professors in nursing schools received the Ph.D. when they were 42.9 years) is a direct consequence of the traditional model for nurse-scientist training. The current path from the R.N. to the Ph.D. can be remarkably tortuous. After receiving the B.S.N. degree, nurses are encouraged to work in clinical practice, and indeed a subsequent application for admission to an M.S.N. program often requires several years of work experience. Again, after receipt of the M.S.N. degree, a period of additional clinical exposure is customary before entering a Ph.D. program. In addition, 65 percent of such doctoral students are unfunded (or only partly funded), and it is likely that these students work to cover their expenses. As a result, graduate students in nursing spend 8.3 to 15.9 years earning their doctorate after entering a master's program,[8] and the committee sees no sign that this trend is being reversed.

One way to help address this problem is to reduce the number of interruptions that nursing doctoral students experience. Once students enter undergraduate programs in nursing, students with interests in science should be identified early and encouraged to consider doctoral education and research. They should also have a chance to interact with nurse-scientists early in their undergraduate years. Several such programs have already been created.

In order to move undergraduates directly into doctoral education, nursing programs need to dispel the myth that students need clinical practice before entering graduate school. In fact, students interested in a research career may be best served by not earning a master's degree first, as is the case in many scientific fields. In addition, certification requirements for advanced practice may add two years to master's programs, further postponing entry into doctoral education. Funding that supports concurrent clinical and research training (similar to the MSTP) may facilitate movement into and through doctoral education.

The origins of the current educational structure in nursing and the hurdles it creates are summarized in the 2005 report:

> Nursing developed both its Ph.D. and its D.N.Sc.[9] programs to build on the master's degree in nursing as well as to accommodate breaks between degrees for clinical practice. Early

[7] AACN. Special Survey of Vacant Faculty Positions for Academic Year 2009-2020. Available at http://www/aacn.nche.edu/ids/pdf/vacancy09.pdf.

[8] National Opinion Research Center. 2001. Survey of Earned Doctorates. Unpublished special reports generated for the American Association of Colleges of Nursing. Chicago, IL: AACN.

[9] McEwen, M., and G. Bechtel. 2000. Characteristics of nursing doctoral programs in the United States. *Journal of Professional Nursing*. 16:282-292.

> reliance on the master's degree is understandable in that it was nursing's highest degree for many years before the establishment of a significant number of research doctoral programs. As doctoral programs were developed, they built on the master's content, which at the time was predominantly research and theory focused. Over time the master's programs have changed to become primarily preparation for advanced clinical practice, yet nursing continues to require the master's degree for entry into doctoral study in most programs. Currently, very few doctoral programs in nursing admit baccalaureate graduates directly into the program, and for those that do, the master's degree is usually required as a progression step. This requirement for entry into the Ph.D. program makes the group of advanced nurse-practitioners, rather than baccalaureate students, the major pool from which applicants are recruited into research. This is problematic in that this practitioner pool has the same demographic characteristics as the profession and thus is older in average age and more limited in diversity compared to applicants for science Ph.D. programs in general. Incorporation of the clinical/professional content from the master's degree as foundational to the Ph.D. in nursing also encourages faculty to recruit and teach only nurses. Currently there are only a few doctorate programs in nursing that admit non-nurses.
>
> Even though there are other fields that require a master's degree as a requirement for earning the professional research doctorate, such as the M.P.H. for the Dr.P.H., the master's degree has a completely different meaning relative to the science Ph.D. degree. The master's degree is usually awarded as a "consolation prize" for students who are unable to complete the requirements for the science Ph.D. By making the master's degree a requirement for its Ph.D. program, nursing has created confusion as to the meaning of the degree outside the nursing profession. (NRC, 2005, p. 74)

Nursing is both a practice profession that requires practitioners with clinical expertise and an academic discipline and science that requires independent researchers and scientists to build the body of knowledge. Each has a separate set of educational needs and goals. To improve the productivity and research focus of the Ph.D. in nursing, doctoral programs need to be structured to admit students directly from baccalaureate programs, to admit non-nurses, to decrease the number of years from high school to Ph.D. graduation, and to expand the interdisciplinary scope of their programs and research topics.

As outlined above, there is no consistent research career trajectory evident among practicing scientists in nursing today. The common thread is that they entered their doctoral programs later than most other scientists, and the majority have not benefited from postdoctoral education. As such, they bring with them rich clinical experiences that may help shape the focus of their inquiry. In addition, when nurses complete their doctoral education, most move directly into an academic career. There they frequently encounter a setting in which the demands for teaching and lack of pervasive research programs, socialization, and further mentoring make continuing progress as a scientist difficult.

RESPONDING TO THE SHORTAGE OF NURSE-INVESTIGATORS

It has been well established that not only is there both a current shortage but also there is a projected continued shortage of nursing faculty, especially those who are scientists and researchers. At this time, approximately 50 percent of the faculty teaching in nursing baccalaureate programs are doctorally prepared [AACN].[10] This represents a marked increase from the 15 percent in the late 1970s. This 50 percent level was reached by 1999, but it has not increased since then despite a large increase in the number of doctoral degree programs available to nurses during the same time period. This is a reflection of two factors: (1) other than a modest increase in the number of doctoral degrees earned in 2007 and 2008, the yield of Ph.D. degrees has been largely static (even though the number of programs has increased, as shown in Table 7-1), and (2) the older age of graduates. The combination of these two factors suggests that an increasing number of doctorally prepared faculty will retire in the next few years, but there will not be an adequate number of new Ph.D.s to replace them. Nursing programs will be left with too few faculty members to conduct research and educate the next generation of scientists.

A 2009-2010 Special Survey of Vacant Faculty Positions conducted by the American Association of Colleges of Nursing (AACN) indicated that 90.6 percent of the vacancies require an earned doctoral degree [AACN],[11] yet graduation rates from nursing doctoral programs are relatively flat. If there is any hope of filling a significant number of these faculty positions, both the NIH and nursing schools will need to provide incentives to increase the number of nurses who select a research career, and to do so early in their professional development.

CHARACTERISTICS OF NURSING PROGRAM FROM THE RESEARCH-DOCTORATE STUDY

The data in this section come from the NRC Research-Doctorate Study. The data from the study are valuable, because they provide unique information on program, faculty, and student characteristics. Although not time series data, they do provide a snapshot of nursing programs in 2006. Data were collected from 55 of the 85 programs that awarded Ph.D.s in nursing in 2006. Not all Ph.D.-granting institutions agreed to participate in the study, and only programs that averaged one Ph.D. or more per year submitted data. But these 55 programs educate a large proportion of the Ph.D.s in nursing, and their characteristics are generally representative of nursing programs. The data support the

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[10] AACN. 2009. American Association of Colleges of Nursing. 2008-2009 Enrollment and Graduations in Baccalaureate and Graduate Programs in Nursing. Washington, DC: AACN. Pub. no. 08-09-1.

[11] AACN. Special Survey of Vacant Faculty Positions for Academic Year 2009-2020. Available at http://www/aacn.nche.edu/ids/pdf/vacancy09.pdf.

TABLE 7-1 Nursing Doctorates from U.S. Institutions, 1997-2008

	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
Number of Doctorates	420	399	353	414	363	437	413	394	422	415	483	505
Number of Males	13	17	14	15	24	23	35	18	35	33	35	43
Number of Females	406	380	337	399	335	414	378	376	387	382	448	462
Minorities	24	22	29	21	31	30	38	42	35	42	43	51
Citizenship												
U.S. Citizen	356	336	296	344	290	350	337	316	320	339	392	412
Permanent Resident	11	11	8	9	10	7	7	11	9	11	11	14
Temporary Resident	40	33	36	45	48	49	50	51	55	52	53	49
Unknown Status	13	19	13	16	13	2	5	5	10	4	6	6
Postdoctoral Plans												
Postdoctoral Fellow	12	12	7	20	23	29	21	23	21	37	22	33
Postdoctoral Research	2	3	3	5	8	9	8	6	8	6	5	8
Postdoctoral Trainee	0	0	0	1	0	1	2	0	2	1	2	2
Other Study	0	3	6	4	5	5	2	4	2	9	2	2
Employment	242	211	195	218	189	225	203	193	199	212	255	251
Other Plans	5	11	4	8	5	10	5	4	2	8	3	7
Unknown Plans	39	45	24	19	26	46	28	21	24	26	30	30

SOURCE: NSF. 2008. *Survey of Earned Doctorates, 2008.* Washington, DC: NSF.

finding elsewhere in this chapter concerning the aging of the faculty, the late age at which students receive a doctorate, and the need for additional training support at the doctoral and postdoctoral levels.

The Faculty

There are 1,471 faculty members in these 55 programs and the average size is 26, varying from a minimum of 8 to a maximum of 110. As is true of the profession in general, the faculty members are primarily female (7 percent male), and 14 of the programs have an all female faculty. Only 10 of the faculty with known citizenship were temporary residents. Most of the nursing faculty (88 percent) had an appointment in the nursing department or school, and only 12 percent were neither tenured nor on the tenure track (see Table 7-2). The percentage of assistant professors in other sciences ranges from 15 percent to 21 percent, and in nursing 31 percent of the tenure-track faculty are in that rank. This would suggest that either assistant professors in nursing are staying longer in this rank than in other sciences, or they tend to move out of the assistant professor faculty role into clinical positions at a significant rate, to be replaced by new Ph.D.s. A final possibility is that in 2006 the number of assistant professors of nursing increased rapidly by absorbing many of the newly minted Ph.D.s, although viewed historically this seems unlikely.

The average age of the faculty is 54, and 26 percent of the faculty are 60 years old or older. The age at time of degree for new assistant professors is 42.9 years, and for associate professors it is 39.9 years. The professors who received their degree even earlier were on average 35.9 years old when they completed their doctorate. Again this is consistent with the trend noted earlier in this chapter. Of the faculty who provided information about postdoctoral training, 30.1 percent had at least one postdoctoral appointment and 7.4 percent had more than one appointment. As would be expected, faculty members with more recent doctorates were more likely to have

TABLE 7-2 Tenure and Rank Status of Nursing Faculty

Rank	Non-Tenured Non-Tenure Track	Non-Tenured Tenure Track	Tenured	Total
Assistant Professor	84	310	8	402
Associate Professor	40	49	343	432
Professor	40	4	535	579
Emeritus	2		15	17
Other	14	1	3	18
Total	180	364	904	1448

SOURCE: Dataset for the NRC Research-Doctorate Study.

postdoctoral training with 31 percent receiving their degree in the period 1997 to 2006. This also is likely contributing to the increasing age of assistant professors on nursing faculties.

A majority, 64 percent or 801 of the nursing faculty, have extramural funding, and these grants support 810 students either totally or partially. The average number of publications per faculty per year during the period 2000 to 2006 was about 0.5 in nursing, which is much lower than seen in other fields in the biomedical sciences, where the range is between 1.3 and 1.9.

The Trainees

In the fall of 2005, 2,176 students were enrolled in 55 doctoral programs, and the first-year enrollment was 442 students. As is the case with the profession, 94 percent of the doctoral students were female. In addition 12 percent were underrepresented minorities, and 10 percent were temporary residents. The enrollment status of the students is very different from other fields, with 1,294 (59 percent) full-time and 882 part-time. For full time-students the time to degree was 3.8 years. One of the 55 programs had an M.D./Ph.D. program with an enrollment of 3 students.

The level of full financial support for nursing students in 2006 was only 35 percent, and 27 percent of the students received no support. Presumably many of these graduate students worked to offset all, or part, of the cost of their education. A total of 37 of the 55 programs had externally funded training grants, and 17 percent of the students were supported on these grants. A small percentage, 9 percent and 7 percent, respectively, were supported on research assistantships and teaching assistantships. In addition to predoctoral training activities, 24 of the 55 nursing programs in the fall of 2005 supported 99 postdoctoral trainees.

Emphasizing Research Intensive Training Environments

Typically funded by the NINR, research training for nurse scientists has uses a variety of National Research Service Awards (NRSAs) and Career Development K awards. Individual predoctoral awards (F31) have been slowly increasing, but there are very limited numbers of individual postdoctoral awards (F32). In contrast, the institutional NRSAs (T32) initially grew considerably over time, but since 2003 there have been no steady increases in the number of slots supported (see Figure 7-1). There were 245 trainees supported in 2009 (156 predoctorates and 62 postdoctorates), which represents a decline from 2003.

The institutional and individual research training awards under the NRSA program both serve an extremely valuable purpose in nursing research and should continue to be funded. Individual awards build scientific capability, and T32 institutional awards build a cadre of strong senior researchers. The individual predoctoral awards (F31), if allocated for up to 5 years per award, will support full-time, consistent progression for research training.

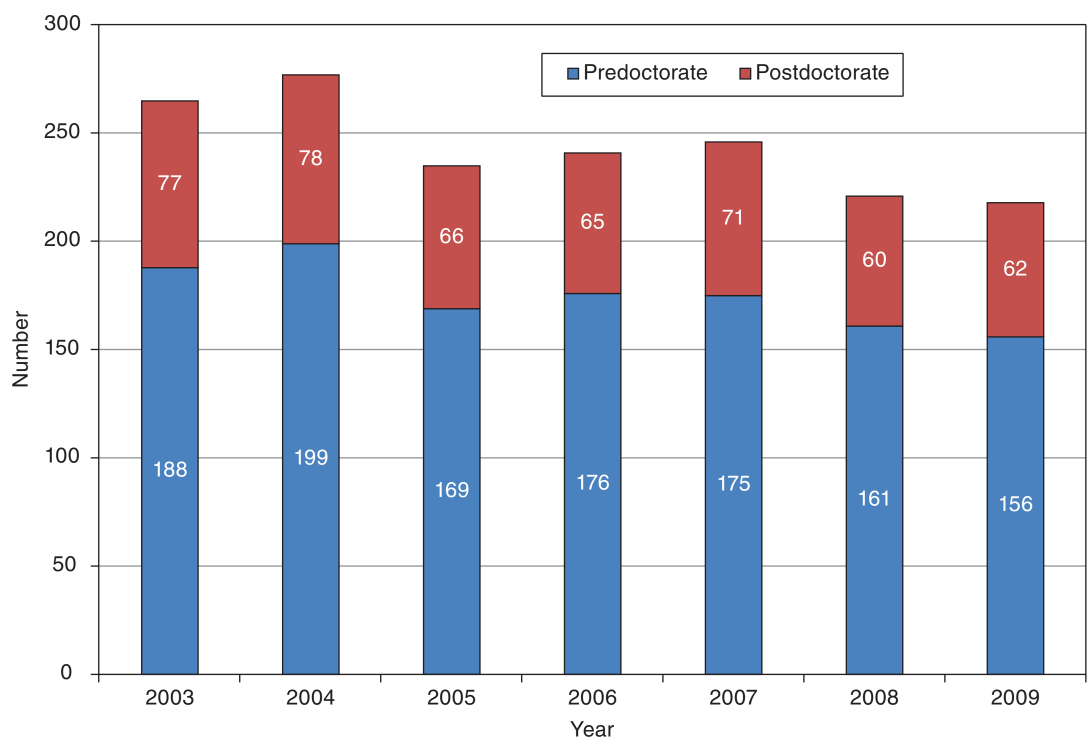

FIGURE 7-1 Training positions at the postdoctoral and predoctoral levels.
SOURCE: National Institutes of Health.

As outlined in the 2005 report, several changes to the T32 awards would strengthen them:

- T32 awards should be placed only in research-intensive universities with strong interdisciplinary opportunities and research funding, and interdisciplinary activities should be a critical aspect of the initial NRSA application and annual reports.
- T32 awards should be allocated only to schools with research-intensive environments including a cadre of senior investigators with extramurally funded research and research infrastructures that support research and research training.
- The application process for T32 positions as predoctoral trainees or postdoctoral fellows should be more formalized, with specific proposals submitted in relationship to their research and the match with faculty at the institution made explicit.
- Criteria for selection of T32 fellows and trainees should be based on a consistent, full-time plan for research training and long-term potential for contribution to science and nursing.
- The monitoring and tracking of trainees and fellows should be formalized with changes in research plans or mentor(s) filed as part of the annual report.

A growing number of nurse-investigators are receiving K awards from NINR through the following mechanisms: K01 Mentored Research Scientist Development Award; Minority K01, Mentored Research Scientist Development Award for Minority Investigators; K22, Career Transition Award and K23, Mentored Patient Oriented-Research Career Development Award; and K24, Mid-Career Investigator Award in Patient Oriented Research. In addition, other NIH institutes and centers support nursing research through the K mechanisms, because elements of nursing research are intrinsic to other fields.

Recently, NINR staff have been advising potential K awardees to apply instead for small R-series awards. To compete in an era of limited research dollars, the availability of these early and mid-career awards needs to be increased and encouraged. There is little systematic information on the outcomes of these awards, e.g., successful research grants and publications by awardees. Based on the success in other fields, however, and the need for strongly research-prepared faculty to concentrate on the science necessary for practice, the committee believes that expanding such awards would benefit the field.

RECOMMENDATIONS

In addition to the recommendations which cross disciplines, the committee recognizes that the graying of the professoriate and need for nurse-scientists is particularly acute in nursing.

Recommendation 7–1: T32 programs in nursing should emphasize the rapid progression into research careers. Criteria should include identification of predoctoral trainees who are within 8 years of high school graduation, streamlining the master's degree in passing to the Ph.D., and postdoctoral training within 2 years of completion of the Ph.D.

Recommendation 7–2: T32 awards should focus on programs where students and fellows have the opportunity to work with senior scientists, and applications to slots should require applicants a specific research and mentoring plan.

Recommendation 7–3: NINR should increase the number of mid- and senior career awards to enhance the number of scientists capable of sustaining programs of research and should increase the length of support for K awards to 5 years to be consistent with other institutes and centers.

Recommendation 7–4: Given the size of the NINR budget and the acute need for nursing faculty, the NIH should consider an infusion of support to allow NINR to more closely meet the needs.

Recommendation 7–5: To enhance the rapid progression for clinical scientist training, NINR should develop and pilot-test an MSTP-like program to support clinical training at the M.S.N. or D.N.P. level for those wishing to be clinician-scientists.

8

Health Services Research

Health services research (HSR) provides the information needed to understand the effectiveness and efficiency of our health care delivery system and its impact on the health and well-being of individuals and populations.[1] Health services research documents deficiencies in patient and population health and in the provision of health services and seeks to identify contributing factors. There are many examples: being uninsured in America reduces access to health care and contributes to poorer health outcomes (Institute of Medicine [IOM] reports on uninsured); medical errors too frequently occur in hospitals and many patients suffer injury or death (IOM, 1999); and in the community, only half of the time are individuals receiving preventive and chronic disease care consistent with scientific evidence (McGlynn, 2003).

Health services researchers seek solutions to these and other problems that adversely affect access to care, quality, safety, and cost of care. Health services research evaluates the impact of government and private-sector health policies, designs and evaluates innovations in health care organization and financing, and examines the effects of new technologies or new uses of existing technologies. Assessing the impact of health services on population health requires health services researchers to go beyond disease outcomes to examine health status and health-related quality of life outcomes, assess delivery system quality and efficiency, as well as focus attention on prevention and health promotion services.

The contributions of health services research to policy, management, and clinical care have been diverse. Planners and policy makers, for example, are frustrated by the inability to generalize and use findings from efficacy studies: persons recruited to randomized control trials testing new treatments typically are not representative of the larger population expected to benefit from the treatment. Thus, it is up health services research to fill this information gap by assessing the impact of diagnostic and treatment technologies on patient outcomes and costs across real-world practice settings and diverse populations.

Translational research has emerged as an important dimension of health services research design and analysis; translational research provides the knowledge base to move scientific discoveries from laboratory, clinical, or population studies into clinical applications at the National Cancer Institute. Yet translation alone is generally not sufficient to ensure these services are available across America. Implementation research is needed to effectively adapt new clinical applications to diverse real-world practice settings in which programs, tools, and guidelines will be utilized and need to be integrated into the existing hospitals and community practice settings (Rubenstein and Pugh, 2006). Together translation and implementation research are gaining greater visibility as we have come to recognize that many Americans are failing to receive consistent high-quality health care based on the latest scientific knowledge. Meeting the challenges of translation and implementation research requires additional disciplinary breadth, drawing on areas of organizational and operations research, psychology, marketing, education, and adult learning. Also expanded applications of health information technology are needed in support of consumer-patient decision making and real-time decision support for health care providers. The rapid growth and continuing change in scientific health information will result in the translation and implementation processes being continual and not one-time or infrequent events. The capacity to achieve this goal may require fundamental re-thinking of information flow and how it supports all aspects of health services.

Central to advances in all scientific fields are measurement tools, and for health services research measurement tools span payment and financing, appropriateness of utilization (overuse, underuse, and misuse; IOM, 2001), quality of care, and patient outcomes of care. Health services research

[1] Many definitions of this multidisciplinary field are available in the literature, including those developed by previous NRC committees on personnel needs in the biomedical and behavioral sciences; see, for example, NAS 1977, 1983, 1989 and 1994. Other authors include the Institute of Medicine 1995. A recent definition circulated within the community was developed by K.N. Lohr and D.M. Steinwachs (2002).

has provided the measurement tools being used in payment for inpatient hospital services, outpatient services, and nursing home care, as well as capitation payment methods for persons enrolled in health plans. Improved payment methods are making it possible to adjust payment for quality of care and to better reward efficiency. These measurement tools, and others to be developed, will be needed to monitor and evaluate the impact of the 2010 Health Reform legislation and how well it achieves its goals. Examples of quality-of-care measures that will require further development include: assessing the timeliness of health care, measuring coordination of patient care when multiple providers are involved in diagnosis and treatment, providing patient-centeredness of care, and equity of health care. Although these are not new, there are few if any accepted measurement tools to assess deficiencies and progress toward the goals of health reform. The training and support of researchers who focus on measurement is a continuing and growing need in health services research.

Since 2003 Congress has provided support to the Agency for Healthcare Research and Quality (AHRQ) to develop and fund comparative effectiveness research (CER). In 2009, the American Recovery and Reinvestment Act (ARRA) augmented CER support with $1.1 billion for research and training through AHRQ, the National Institutes of Health, and the Office of the Secretary of Health and Human Services (HHS). CER as defined by HHS combines key elements of health services and clinical research:

> Comparative effectiveness research is the conduct and synthesis of research comparing the benefits and harms of different interventions and strategies to prevent, diagnose, treat and monitor health conditions in "real world" settings. The purpose of this research is to improve health outcomes by developing and disseminating evidence-based information to patients, clinicians, and other decision-makers, responding to their expressed needs, about which interventions are most effective for which patients under specific circumstances.
>
> - To provide this information, comparative effectiveness research must assess a comprehensive array of health-related outcomes for diverse patient populations and sub-groups.
> - Defined interventions compared may include medications, procedures, medical and assistive devices and technologies, diagnostic testing, behavioral change, and delivery system strategies.
> - This research necessitates the development, expansion, and use of a variety of data sources and methods to assess comparative effectiveness and actively disseminate the results.

The expectation is that CER will provide new information that is not currently available about what treatments and services work best for individuals across America's diverse populations, taking into consideration the person's circumstances and the timing of services. The new CER mandate complements the initiatives discussed above in translation and implementation research, intensifying the focus on research driving health system transformation to achieve better health outcomes for all Americans and greater efficiency.

FEDERAL SUPPORT OF HEALTH SERVICES RESEARCH

In 1968, Congress recognized the emerging role of health services research for improving health care delivery in the United States and created the National Center for Health Services Research and Development (NCHSRD) in the Department of Health, Education, and Welfare (DHEW). During the years 1968-1989, NCHSRD sought to develop research on issues of access, cost, and quality, and to develop data systems to support research on utilization and cost of care.[2] However, over time the budget for NCHSRD declined and the future of the NCHSRD became uncertain. Private foundations played a critical role in sustaining the health services research field during these years.[3]

In 1989, health services research once again found strong support in Congress and a new vision for health services research was created in the authorization of the Agency for Health Care Policy and Research (AHCPR). Congress directed the Agency—subsequently renamed the Agency for Healthcare Quality and Research—to undertake research on patient outcomes, develop practice guidelines, and disseminate the research to change the practice of medicine.[4] The agency placed greater emphasis than previously on the examination of clinical practice, decision making, and comparative effectiveness of alternative approaches to diagnosis and treatment. The funding for AHRQ has grown over the years from $128 million in fiscal year 1993 to $397 million in fiscal year 2010, plus $300 million in CER funding from the ARRA appropriation.

While the National Research Service Awards (NRSA) program included support for health services research from its inception (see, for example, NRC, 1977), Congress specified in 1989 that one-half of 1 percent of the NRSA budget for training be allocated for training health services researchers through AHRQ, subsequently expanding that

[2] The center initiated large-scale demonstrations, including the Experimental Medical Care Review Organization (EMCRO) to develop tools for quality measurement and their evaluation. The EMCRO demonstration provided the Medicare program with the methodologies it needed in the Professional Standards Review Organization (PSRO) to evaluate hospital use. The NCHSRD also competitively funded health services research centers in academic institutions and Kaiser Permanente.

[3] It should be noted that health services research in focused areas like mental health services, alcohol and drug abuse treatment services, and veterans' health care continued throughout this time. Health services research funding also comes from the Centers for Medicare and Medicaid Services (CMS), Centers for Disease Control and Prevention (CDC), Department of Defense (DoD), and several NIH institutes.

[4] In 2001, the reauthorization of AHCPR led to a name change to the Agency for Healthcare Research and Quality (AHRQ). The word policy was dropped from the title and quality was added to reinforce the quality-of-care research mission of the agency.

allocation to 1 percent of NRSA funding in 1999, which has remained unchanged.

It should be noted that in the early 1990s Congress authorized a 15 percent set-aside for both research and NRSA training in service-related research supported by the National Institute of Mental Health (NIMH), the National Institute of Drug Abuse (NIDA), and the National Institute of Alcohol Abuse and Alcoholism (NIAAA) as part of the reorganization of the former Alcohol, Drug Abuse and Mental Health Administration into the National Institutes of Health. Even with this congressionally mandated set-aside for these NIH institutes, AHRQ remained the lead agency for health services research. NIH funding has been directed at HSR focused on questions related to the delivery of health care for specific diseases/disorders. AHRQ and NIH fund complementary research and in many instances have co-funded major health services research studies.

HEALTH SERVICES RESEARCH WORKFORCE

No national statistical system reports on the size and composition of the health services research workforce (Moore and McGinnis, 2009; Pittman and Holve, 2009). Obtaining information on the workforce in this field is a challenge. Identifying scientists who primarily do health services research is complicated by the interdisciplinary nature of the field. Health services research is an applied field, and so most health services researchers have another unique discipline or profession that they bring to health services research. Workforce data usually classify health services researchers by their primary discipline or profession and often are unable to identify the field of scientific inquiry as health services research. As NIH moves more toward trans-disciplinary research, the problem of not having multiple classifications incorporating both discipline and field of application may be an issue faced by many basic sciences and clinical researchers, as well as health services research.

In addition, anecdotal evidence suggests that some investigators involved in health services research studies do not identify themselves as health services researchers, nor do they necessarily belong to the only national professional association in this area, namely AcademyHealth. This partial or part-time involvement of many scientists in health services research only further complicates efforts to estimate the size and composition of the health services research workforce.

McGinnis and Moore addressed this issue in their study on the current status of the health services research workforce. In a conservative estimate of the field, counting HSRProj investigators (since 2004), speakers from AcademyHealth's Annual Research Meeting in 2007, and AcademyHealth members whose membership has lapsed or joined in 2000 or later, Moore and McGinnis found that the field has more than doubled in size since the IOM's estimate in 1995, growing from approximately 5,000 health services researchers to more than 13,000 researchers in 2007. Using a more expansive definition of the field by including researchers in disciplinary associations with subgroups that sometimes do health services research, such as the American Public Health Association, the American Society of Health Economists, the American Statistical Association, and the American Sociological Association, there could be an additional 6,000 intermitted members of the field (Moore and McGinnis, 2009).

The best data available on the composition of health services research workforce[5] likely comes from the most recent AcademyHealth membership survey in 2008 (AcademyHealth, 2008). AcademyHealth draws its members from both health services research and health policy, and includes student memberships. Although this database more than likely underestimates the total size of the workforce, it does provide some insights into its composition.

As of 2008, 51 percent of AcademyHealth's 3,500 individual members report having a Ph.D., Sc.D., or other doctoral-level training in science. There are another 12 percent reporting an M.D. Table 8-1 shows the distribution of health services researchers by employment sector.

AcademyHealth membership has greater female representation (60.7 percent) than male (39.3 percent). This representation has changed slightly from AcademyHealth's survey of members in 2002, when 55 percent of the respondents were women and 45 percent were men. Of note is that the youngest members were twice as likely to be female as to be male, while the oldest respondents were twice as likely to be male as to be female. The ethnic mix of members is 21 percent from minority ethnic backgrounds, including Asian/Pacific Islanders (10.6 percent), African Americans (5.2 percent), and Hispanics/Latinos (2.6 percent), plus 79 percent Caucasian and 2.5 percent other. Representation of all minorities has increased since 2002—to 21 percent from 12.8 percent.

Table 8-2 shows the primary field of interest by the members of AcademyHealth, and the largest share of the members classify their primary discipline as public health (21.5 percent). Only 13.3 percent of members identify their primary discipline as health services research.

In a study on the demand for health services researchers, Thornton and Brown (2009) found that the demand from both universities and non-academic employers is expected to increase. Based on their work one can anticipate there will be a growing demand for "people who can analyze the effectiveness of health service systems from disease management firms; investment firms with a large stake in the health care sector; state and local government; hospitals and providers that will be implementing quality reporting systems and pay-for-performance systems;" and the health

[5] Jeanne Moore and Sandra McGinnis's analysis in 2007 uses data from AcademyHealth membership as well as participants from AcademyHealth meetings and principal investigators listed in HSRProj. AcademyHealth's data solely represent its membership as of 2008.

TABLE 8-1 Setting of Primary Employment, 2008

Sector	Percent
College/University	48.8
Government	10
Health Care Delivery Organization	9.3
Research Organization	7.4
Other (please specify)	4.5
Association	4.3
Consulting Firm	4.3
Foundation	3.5
Health Policy Center	2.5
Insurance	2
Pharmaceutical or Biotechnology	1.5
Quality Improvement	1.2
Professional Society	0.8

SOURCE: AcademyHealth Member Survey, 2008.

TABLE 8-2 Primary Field of AcademyHealth Members, 2008

Sector	Percent
Public Health	21.5
Public Policy	16.7
Other (please specify)	15
Health Services Research	13.3
Medicine	10.9
Nursing	7.1
Sociology	4
Economics	3.8
Psychology	2.3
Public Administration	1.6
Political Science	1.1
Operations Research	1
Law	0.7
Business Administration	0.6
Anthropology	0.4

SOURCE: AcademyHealth Member Survey, 2008.

industry including equipment manufacturers, pharmaceutical firms, and insurers.

Graduate Programs in Health Services Research

Graduate programs in health services research are not separately accredited, and because many graduates could come from doctoral programs with a different specialty than health services research, there is no accurate tally of doctoral students earning degrees in health services research (Ricketts, 2009). However, in its 2009 online directory of master's and doctoral programs in HSR, AcademyHealth reports that there are now 41 schools providing HSR doctoral programs and 22 schools with postdoctoral training programs. Doctoral programs are mainly Ph.D. programs, including both disciplinary (e.g., health economics, medical sociology) and general training in health services research. An example of additional training opportunities is illustrated by Veterans Administration's description of a new fellowship program:

> VA Advanced Fellowship Program in Health Services Research and Development (HSR&D): This includes 16 training sites for Ph.D. associated health professionals, 8 training sites for post-residency physician associated health professionals, and 3 sites for post-doctoral physician associated health professionals. HSR&D also participates in the VA Advanced Fellowship Program in Medical Informatics which includes 7 training sites for post-doctoral and physician health professionals in medical informatics.

The NRSA program provides support for training in health services research. As discussed above, the AHRQ has received funding equal to one percent of all NRSA funds for NIH. AHRQ supplements NRSA funding with $500,000 annually. As shown in Table 8-3, both NIH and AHRQ are funding HSR training at predoctoral and postdoctoral levels. Taken together, there were 107 predoctoral training positions in 2008, 68 percent of them funded by AHRQ. There were also a total of 85 postdoctoral positions, of which 49 percent were funded by AHRQ. The agency accepts new and renewal training grant applications every 5 years. In general, the agency has been able to fund only two-thirds of the requested training positions, and this is very similar to the rate for all NIH training awards. In addition, several NIH institutes provide NRSA awards in health services research, including NIMH, NIAAA, and NIDA. Overall, the total number of trainees is likely less than 2 percent of all NRSA training positions. No data are available on graduates of doctoral programs who are not funded by the NRSA program but who plan to pursue health services research careers. It would be expected that these numbers far exceed NRSA recipients, as they do in other health research fields.

Although there is incomplete information on the characteristics and careers of all individuals with training in health services research, there is some information of NRSA trainees supported by AHRQ. In particular, AHRQ commissioned an outcome study in 1999 of NRSA trainees between 1986 and 1997, which used information from the curricula vitae (CV) of the traimees. The results of this study were reported in the last assessment of the NRSA program. These data were updated in 2005 when data on trainees from 1998 to 2003 were added and data on the earlier trainees were made current to 2003. From 1986 to August 2003, AHRQ supported more than 1,000 individuals through different funding mechanisms. The NRSA program T32 institutional awards supported 346 predoctoral and 435 postdoctoral trainees through 27 university-based or university-affiliated training sites. Another 81 AHRQ F32 individual NRSA postdoctoral fellowships and 5 predoctoral fellowships were awarded. Some individuals had multiple awards under different mechanisms. A total of 854 individuals had support.

TABLE 8-3 Health Services Research Training Positions Funded by AHRQ and the NIH

Positions	1990	1995	2000	2005	2006	2007	2008
NIH Predoctoral Trainees	11	6	0	20	27	28	28
NIH Predoctoral Fellows	1	4	8	14	7	8	8
AHRQ Predoctoral Trainees	22	19	3	71	67	76	71
AHRQ Predoctoral Fellows	0	0	0	1	2	1	2
Predoctoral Subtotal	34	29	11	105	101	112	107
NIH Postdoctoral Trainees	31	16	0	31	39	29	40
NIH Postdoctoral Fellows	2	1	1	4	3	3	5
AHRQ Postdoctoral Trainees	5	1	3	40	35	37	40
AHRQ Postdoctoral Fellows	3	0	0	2	2	3	2
Postdoctoral Subtotal	38	18	4	75	77	69	85

SOURCE: NIH database, 2008.

In 2000, AHRQ launched its career development (K) award program and by August 2003 had made 48 awards. The majority of AHRQ-supported NRSA trainees and fellows between 1986 and 2003 were female (502 of 854, or 59 percent), a difference especially evident among T32 predoctoral trainees (229 of 346, or 66 percent) and F32 fellows (45 of 76, or 58 percent). There were almost even numbers of males (203) and females (225) with T32 postdoctoral trainees during this period.

The CVs of 709 trainees provided information on career progression and research productivity. CVs were received from 850: 346 had T32 predoctoral support, 428 had T32 postdoctoral support, and 76 had F32 fellowships. Of those who earned a doctorate by 2003, about 75 percent or 244 of the doctorates with a known degree field earned their doctorate in a health science field, including: health services research (81); related multidisciplinary health fields such as health policy, health administration, or public health (118); or one of the other health sciences (45). Over 90 percent of the T32 predoctoral trainees earned their baccalaureate degrees in one of the sciences, with 42 percent in the social sciences, 15 percent in the health sciences, and 19 percent in other scientific fields, including the physical and mathematical sciences. The degrees of those with baccalaureate degrees in non-sciences were either in education, humanities, or professional fields. Length of time in training for T32 and F31 predoctoral students averaged about 20 months, but 36 percent were only in training for 12 months. There was some difference in length of training by gender, with 81 percent of females in training for 24 months or less and 75 percent of males for this period. At the postdoctoral level, 84 percent of F32 fellows were in training for 24 months or less, and 86 percent of the T32 awardees were in training for this period. For both the T32 and F32 trainees, about half were in training for 24 months.

Half of the AHRQ NRSA T32 postdoctoral trainees with research doctorates earned them in the social sciences (sociology, economics, or the other social sciences); the remainder earned them in a variety of health or other fields. The other half of the AHRQ NRSA T32 postdoctoral trainees had clinical doctorates, and about half of these were earned in internal medicine; another 20 percent were earned in pediatrics and another 6 percent were earned in family practice, with the remainder earned in a wide variety of other clinical specialties. About 20 percent, or 59, of the 241 clinical doctorates with CV information earned a joint M.D./Ph.D. Just over half of the AHRQ NRSA F32 fellows held clinical doctorates, and more were in internal medicine.

The study also showed that the AHRQ NRSA trainees and fellows actively pursue research careers through a variety of employment paths. Most AHRQ NRSA T32 predoctoral trainees who completed their doctorates by 2003 did not pursue formal postdoctoral research training. First employment data were available for 555 of the predoctoral and postdoctoral trainees, and a large majority of both groups where employed in academic institutions. For the postdoctorates, 71 percent of 382 trainees were in academe, 23 percent were in for-profit or non-profit organizations, and 5 percent were in government. Of those in academic positions, 76 percent were Ph.D.s and 72 percent had clinical degrees. Most of the clinical doctorates that complete training began their academic career as an instructor. The percentage for the 165 predoctoral trainees formed a similar pattern, but only 57 percent had an academic position and 29 percent were in for-profit or non-profit organizations. The current employment of postdoctoral trainees at the end of 2003 closely resembles their first employment with 79 percent in academic positions and 13 percent in health-related employment. The remaining 8 percent were in for-profit or other organizations. For T32 predoctoral trainees, academic employment was almost as high at 67 percent, with 21 percent in health-related employment and the remaining 11 percent in for-profit or other organizations.

Of the employed NRSA T32 predoctoral trainees, about half (48 percent) reported having received post-training research support, and about 77 percent reported at least one post-training scientific journal publication. For NRSA T32 postdoctoral trainees with research doctorates, 72 percent reported having received post-training research support, and 85 percent listed at least one scientific journal publication following training. About 60 percent of the employed NRSA T32 postdoctoral trainees with clinical doctorates reported having received post-training research support, and about 78 percent had at least one scientific journal publication following training. Two-thirds of the employed former AHRQ NRSA F fellows reported having received grant support. In general, 90 percent of all trainees had at least one post-training scientific journal publication.

FEDERAL HEALTH SERVICES RESEARCH FUNDING

The broad relevance of health services research has contributed to federal funding through multiple agencies, unlike the funding of most other areas of health research. AHRQ's research is expected to address cross-cutting issues such as access, quality and cost issues that are faced by the entire American health care system. Other funding sources seek to fund health services research in support of their organizational missions. The VA and DoD focus on their delivery systems, CMS on financing Medicare and Medicaid, CDC on prevention, and the NIH on delivery of services for specific diseases. These funding sources are complemented by private sources, including major foundations (e.g., Robert Wood Johnson Foundation, Commonwealth Fund, MacArthur Foundation, Kellogg Foundation, Kaiser Family Foundation, and a number of state-based foundations) and private corporations. The following discussion will be limited to federal funding of health services research.

In 2001 the Coalition for Health Services Research (CHSR), the advocacy affiliate of AcademyHealth, began an initiative to document health services research funding levels across the federal government. The first report was completed in 2003 and now there are annual updates. As of FY 2009, the Coalition estimates that a total of $1.48 billion was expended for health services research and related activities by the federal government in as shown below:

- Agency for Healthcare Research and Quality (AHRQ)—$372 million;
- Centers for Disease Control and Prevention (CDC):
  - — National Center for Health Statistics (NCHS)—$125 million;
  - — Extramural Prevention Research Program—$31 million;
  - — Prevention Research Centers—$31 million;
- Centers for Medicare and Medicaid Services (CMS)—$39 million;[6]
- Health Resources and Services Administration (HRSA)—$9 million;
- National Institutes of Health (NIH) (All Institutes)—$779 million;
- Veterans Health Administration (VHA)—$75 million; and
- The Department of Defense (DoD)—$17 million.

Despite repeated calls from the Coalition for Health Services Research that federal agencies use a standard definition or uniform categories to report their expenditures, the data presented above are measured by these agencies using their own unique definition for what constitutes health services research. Only with a uniform definition and standard categories, would it be possible to assess how the current funding meets emerging needs.

Comparing the health services research funding of $1.5 billion to total federal health research funding of $35 billion in 2005 (Global Forum for Health Research, 2005) shows that approximately 4 percent of total funding is being devoted to health services research, based on classifications used within each agency and institute.

NIH institutes report funding health services research as shown in Table 8-4. NIMH, NIDA, and NCI have the largest programmatic commitment, ranging from 17 to 23 percent of budget. Other institutes report smaller commitments of budget to health services research.

In summary, AHRQ provides 25 percent of all health services research funding as reported by federal agencies. Other federal agencies support more focused program-specific and disease-specific health services research. Private funding of health services research is substantial but no comprehensive source of information is available on non-federal sources.

CAREERS IN HEALTH SERVICES RESEARCH

The employment opportunities and careers in health services research are widely varied. Academic careers may be in schools of medicine, nursing, public health, and other health professional schools, as well as engineering and traditional arts and sciences departments, along with business and public policy schools. To effectively manage interdisciplinary research, academic institutions usually have organizational structures such as centers or institutes for health services research that cross school and departmental boundaries. At some institutions there are multiple centers reflecting different areas of specialization and the availability of funding for specialized centers from federal and private sources.

Private-sector health services research careers are available in many areas. Federal contract work evaluating major public policy initiatives are primarily done by private research firms. These organizations include RAND, Mathematica, Abt Associates, Westat, and others. These organizations are organized to do short-term large-scale studies that are not as easily organized and managed in most academic settings.

[6] Most of the funding in CMS's research budget actually represents Congressional earmarks for activities that are only remotely related to CMS's research and demonstration interests.

TABLE 8-4 NIH Institute Health Services Research Budgets Health Services Research FY 2008 Estimate (Dollars in Thousands)

	Total Health Services Research Budget	Proportion of Total Institute Budget That Is Health Services Research	Proportion of NIH's Total Health Services Research Budget
NIMH	$94,273	6.67%	12.68%
NIDA	$61,207	6.08%	8.23%
NCI	$207,363	4.29%	27.89%
NIA	$47,696	4.53%	6.42%
NIDDK	$28,944	1.55%	3.89%
NIAAA	$22,410	5.10%	3.01%
NHLBI	$55,968	1.90%	7.53%
NINR	$21,227	15.38%	2.86%
Other NIH HSR	$204,298	1.28%	27.48%
Total	$743,388		

SOURCE: Coalition for Health Services Research (2008). Analysis was completed using data from NIH's Research Portfolion Online Reporting Tools (RePORT).

Other private-sector health services research careers are in research organizations sponsored by HMOs and health plans, hospital systems, pharmaceutical firms, insurers, and other major stakeholders in health care. Health services research positions may involve directing research, translating research into practice and products, and managing and evaluating health care operations.

Associations for professional groups, manufacturers, and advocacy groups recruit people trained in health services research to strengthen their capacity to use information coming from health services research to advance their advocacy objectives and meet the needs of their members. As efforts to translate science into practice accelerate, the demand for individuals skilled in health services research and communication to users is likely to grow.

Government agencies recruit substantial numbers of health services research professionals to lead and manage research programs, to support policy analysis and development, and to work with managers and providers in the VA and DoD health care delivery systems.

New career paths for health services research professionals may emerge as research into effective translation of knowledge into practice grows. The 2003 Medicare prescription drug legislation mandated in Section 1013 that comparative effectiveness studies of health care services including prescription drugs increased the need for health services researchers trained in pharmaco-economics. The ARRA provided a substantial increase in CER funding for both research and investment in research infrastructure including methods and data. The development of tools and techniques to support translation is likely to become an industry that will require research skills in the design, evaluation, and testing of new technologies. Translation of knowledge for clinicians may be the initial priority, but priorities will likely expand to include managers, patients, and the public. The passage of the 2010 Affordable Health Care Act for America brings new and increased demands to monitor the success of health reform and identify unintended consequences. To achieve goals of greater efficiency in American health care and better quality, additional investments in health services research and translation and implementation in practice will be needed. The future demand for well-trained health services researchers is currently strong and growing.

RECOMMENDATIONS

Recommendation 8–1: Health services research training should be expanded and strengthened within each NIH institute and center.

Biomedical research has created a growing gap between research advances in biomedical science and the ability to apply them effectively to improve the health of the public. Thus there is a need for more effective health care delivery practices to ensure effective and evidence-based care, and to reduce waste and unnecessary risk to patients.

Recommendation 8–2: AHRQ training programs should be expanded, at a minimum commensurate with the growth in total federal spending on health services research, including comparative effectiveness research.

Recognition of the rising costs of care, with concerns about quality and consistency, have driven increases in services research. Health services research has established an important evidence base to enable patients and health care organizations to evaluate benefits and risks of diagnostic and therapeutic intervention and to compare relative values of older and newer approaches as choices proliferate. This field can also evaluate different approaches to health care delivery and financing, which will allow the nation to get more benefit from the dramatic advances in biomedical science. Ideally, the total numbers of persons being trained in HSR should grow at the same rate as national health care expenditures. The NRSA program provides funding for a fraction of all trainees, which is divided among NIH institutes and AHRQ. Since NRSA funding is expected to ensure an adequate supply of research personnel for health research, it is reasonable to expect the proportion of NRSA funding for HSR trainees to approximate the proportion of the federal health research that is HSR. This guideline suggests the need to roughly double NRSA funding of HSR training, from the current level of approximately 2 percent of NRSA funds to 4 percent.

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Appendixes

Appendix A

Committee Biographies

Roger Chalkley, D. Phil., is senior associate dean of biomedical research education and training at the Vanderbilt School of Medicine. Dr. Chalkley is responsible for the overview of the activities of the Office of Biomedical Research Education and Training, including oversight of the Indisciplinary Graduate Program in the Biological Sciences, the M.D./Ph.D. program, postdoctoral affairs, and graduate student affairs as well as minority activities and supporting training grant applications. Dr. Chalkley was educated at Pembroke College, Oxford, in chemistry and did his postdoctoral research in gene regulation and chromatin structure in the laboratory of James Bonner at Caltech. After almost 20 years in the biochemistry department at the University of Iowa-School of Medicine, he moved to Vanderbilt in 1986. He has published almost 200 papers in chromatin research. Dr. Chalkley has had an active interest in graduate education for many years and was involved in the establishment of the IGP where he served as director for the past eight years. He has been a hardcore runner for 40 years and is a (self-described) competent rock climber.

William T. Greenough, Ph.D. (*Vice Chair*) (NAS), is Swanlund Chair and Center for Advanced Study Professor of Psychology at the University of Illinois in Urbana-Champaign. His research focuses on neural mechanisms of learning and memory; neurobiology of long-term potentiation and epilepsy; mechanisms of the brain–behavioral development; neurobiology of the aging process; and plasticity of metabolic support components of the brain. Dr. Greenough's awards and honors include AAAS fellow (1985), NIMH MERIT award (1989), member of the National Academy of Sciences (1992), Fragile X Foundation William Rosen Award for Outstanding Research (1998), University of Illinois Oakley-Kunde Award for Undergraduate Teaching (1998), and American Psychological Society William James Fellow Research Award (1998). He obtained his Ph.D. from the University of California at Los Angeles in 1969. He brings to the committee his knowledge of neuropsychology and learning processes, which is an important area of NIH research. He also has a broad knowledge of training and research issues through his research support from the National Institute of Aging, National Institute of Mental Health, and National Institute on Alcohol Abuse and Alcoholism.

David Korn, M.D. (*Vice Chair*) (IOM), is presently the vice provost for research at Harvard University, a position he assumed in November 2008. Prior to that he served as chief scientific officer of the Association of American Medical Colleges (AAMC) in Washington, D.C., from January 2008 to November 2008 and as AAMC's senior vice president for biomedical and health sciences research from September 1997 to January 2008. Before joining AAMC, Dr. Korn served as Carl and Elizabeth Naumann Professor and dean of the Stanford University School of Medicine from October 1984 to April 1995, and as vice president of Stanford University from January 1986 to April 1995. Before that he served as professor and chairman of the Department of Pathology at Stanford, and chief of the pathology service at the Stanford University Hospital since June 1968. Dr. Korn received his doctorate from Harvard University. He has been chairman of the Stanford University Committee on Research; president of the American Association of Pathologists (now the American Society for Investigative Pathology), from which he received the Gold-Headed Cane Award for lifetime achievement in 2004; president of the Association of Pathology Chairman; a member of the board of directors and the executive committee of the Federation of American Societies for Experimental Biology; and a member of the board of directors of the Association of Academic Health Centers. Dr. Korn was a founder and chairman of the board of directors of the California Transplant Donor Network, one of the nation's largest organ procurement organizations. More recently, he was a founder of the Association for the Accreditation of Human Research Protection Programs, a nonprofit corporation created to enhance and standardize the protection of human participants in medical research. He is a member of the Institute of Medicine of the National Academy of Sciences and has served on various National Academies committees, including the Clinical Research Roundtable. In the past decade his writings and lectures have focused on issues of academic values and health and science policy.

Charles Bertolami, D.D.S., D. Med. Sc., is dean of the College of Dentistry at New York University. A leader in the dental research, education, and clinical communities, he was named the 14th dean of the 142-year-old New York University College of Dentistry in 2007. Dr. Bertolami was formerly the dean of the University of California-San Francisco (UCSF) School of Dentistry; during the 12 years he served in that post, the UCSF School of Dentistry led the nation in overall NIH funding for dental schools. In addition to expanding the school's research capacity, he also enhanced the school's clinical and teaching programs, including renovating clinics and laboratories; implemented a new curriculum reinforcing integration of basic and clinical sciences in dental education; established and expanded joint degree programs; and established a year-long post-baccalaureate program for students from economically or educationally disadvantaged groups. Dr. Bertolami is the president-elect of the American Dental Education Association and is a former president of the American Association for Dental Research.

Thomas O. Daniel, M.D., is the president of Celgene Research. Dr. Daniel has more than two decades of medical and pharmaceutical research experience, having most recently served as the chief scientific officer at Ambryx, Inc., a biotechnology company focused on discovering and developing protein-based therapeutics. Prior to that, Dr. Daniel was vice president of research at Amgen Inc., where he served as research site head for Amgen Seattle, as inflammation therapeutic area head, and on research and development portfolio review boards. Prior to Amgen's acquisition of Immunex, Dr. Daniel was senior vice president of discovery research at Immunex, where he consolidated and built programs in oncology and vascular biology. As president of Celgene Global Research, he is responsible for leading the discovery, preclinical, and early-stage clinical programs for Celgene worldwide. Prior to his industrial positions he was the K. M. Hakim Professor of Medicine and Cell Biology at Vanderbilt University, and director of the Vanderbilt Center for Vascular Biology. Dr. Daniel obtained his M.D. degree from University of Texas Southwestern, trained in internal medicine at Massachusetts General Hospital, completed postdoctoral work in molecular genetics at University of Texas Southwestern, was a Howard Hughes Medical Institute associate at UCSF, and an NIH-funded investigator for 20 years at Vanderbilt. His laboratory research programs focused on cellular and receptor mechanisms regulating endothelial growth and neovascularization.

Margaret Grey, Dr.Ph.P.H., R.N., F.A.A.N. (IOM), is the dean and Annie Goodrich Professor at the Yale School of Nursing. She has been at Yale since January of 1993. Prior to assuming the deanship on September 1, 2005, she served as associate dean for scholarly affairs. She is also director of the NIH-funded Center for Self and Family Management and a related pre- and postdoctoral training program. She was the founding director of the school's doctoral program. Previously she held progressive academic and administrative appointments at the University of Pennsylvania and Columbia University. She holds a bachelor's degree from the University of Pittsburgh, an M.S.N. in pediatric nursing from Yale University, and a doctorate in public health and social psychology from Columbia University.

James Jackson, Ph.D. (IOM), is Daniel Katz Distinguished University Professor of Psychology at the University of Michigan at Ann Arbor and director of the Institute for Social Research (ISR). Dr. Jackson's research efforts include carrying out a number of national surveys and one international survey of black populations focusing on issues of racial and ethnic influences on life course development; attitude change; reciprocity; social support; and coping and health. He obtained his Ph.D. in social psychology from Wayne State University. Dr. Jackson is a recognized authority on African American life, and currently has a major grant from the National Institute of Mental Health to assess the physical, emotional, mental, and economic health of a nationally representative sample of more than 4,000 Black American adults. His knowledge and understanding of issues related to the underrepresentation of minority groups in biomedical, behavioral, and clinical research will be very helpful to the committee in addressing personnel needs in these populations.

Keith Micoli, Ph.D., is the manager of the postdoctoral program and ethics program coordinator at New York University's (NYU's) School of Medicine. He earned his B.A. from New College of Florida in 1993 and his Ph.D. from the University of Alabama at Birmingham (UAB) in 2001, and, before moving to NYU in August 2008, was a postdoctoral fellow and instructor at UAB. He also held an appointment as adjunct assistant professor at Samford University, teaching microbiology. Keith served on the board of directors of the National Postdoctoral Association from 2003 to 2007 and was board chairman from 2005 to 2007.

John C. Wooley, Ph.D., is associate vice chancellor for research at the University of California San Diego (UCSD), an adjunct professor in pharmacology and in chemistry and biochemistry, and a strategic advisor and senior fellow of the San Diego Supercomputer Center. He received his Ph.D. degree in 1975 at the University of Chicago, working with Al Crewe and Robert Uretz in biological physics. Prior to his appointment at UCSD he was at the Department of Energy, where he served as deputy associate director in the Office of Science. In that capacity, he was responsible for biological and environmental sciences and oversaw human and microbial genomics, biotechnology, molecular and cell biology, health effects of radiation and energy production, computational and structural biology, and climate change research. Prior to going to the Department of Energy, he was the director of the Division of Infrastructure and Resources for the Biological Sciences Directorate at the National Science Foundation (NSF). For his role in advocating, establishing, and leading the Biological Instrumentation Facilities and the Biological Research Centers, Dr. Wooley received NSF's top performance award, "NSF Superior Accomplishment." He also held positions as a visiting scientist at G.D. Searle and Company in England, as an assistant professor of biochemical sciences at Princeton, and research associate professor of biophysics at Johns Hopkins Medical School. Dr. Wooley created the first programs within the U.S. federal government for funding research in bioinformatics and in computational biology, and has been involved in strengthening the interface between computing and biology for more than a decade. For the new UCSD California Institute for Telecommunication and Information Technology [Cal-(IT)2], Dr. Wooley directs the biology and biomedical layer or applications component, termed Digitally-enabled Genomic Medicine (DeGeM), a step in delivering personalized medicine in a wireless clinical setting. His current research involves bioinformatics and structural genomics, while his principal objective at UCSD is to stimulate new research initiatives for large-scale, multidisciplinary challenges. He also collaborates in developing scientific applications of information technology and high performance computing; creating industry–university collaborations; expanding applied life science opportunities, notably around drug discovery; and establishing a biotechnology and pharmacology science park on UCSD's health sciences campus zone.

Susan Fiske, Ph.D., is the Eugene Higgins Professor of Psychology at Princeton University. Dr. Fiske received her Ph.D. from Harvard University and has an honorary doctorate from Université Catholique de Louvain-la-Neuve, Belgium. Dr. Fiske's research addresses how stereotyping, prejudice, and discrimination are encouraged or discouraged by social relationships, such as cooperation, competition, and power. She has just finished a third edition of *Social Cognition* (1984, 1991, 2008, each with Taylor) on how people make sense of each other. She has written more than nearly 200 articles and chapters and edited many books and journal special issues. Notably, she edits the *Annual Review of Psychology* (with Schacter and Sternberg) and the *Handbook of Social Psychology* (with Gilbert and Lindzey). She also wrote a recent upper-level text, *Social Beings: A Core Motives Approach to Social Psychology* (2004). She is a member of the American Academy of Arts and Sciences, past president of the Association for Psychological Sciences, and 2008 winner of the William James Fellow Award.

Joan M. Lakoski, Ph.D., is the associate vice chancellor for academic career development and the founding and executive director of the Office of Academic Career Development at the University of Pittsburgh Health Sciences, associate dean for postdoctoral education, and professor of pharmacology at the University of Pittsburgh School of Medicine. Dr. Lakoski received her doctoral degree from the University of Iowa, completed postdoctoral training in the Department of Psychiatry at the Yale University School of Medicine, and has held faculty positions at the University of Texas Medical Branch in Galveston and the Pennsylvania State University College of Medicine, including interim chair of the Department of Pharmacology at Penn State. She maintains an active research program investigating the neuropharmacology of aging and impacts of mentoring, is a member of the graduate faculty at the University of Pittsburgh, and participates as a reviewer for NIH Center for Scientific Review study section panels. She has been the recipient of an NIH Research Career Development Award, an Independent Investigator Award from the National Alliance of Research on Schizophrenia, an administrative fellowship at the Pennsylvania State University, and a Committee on Institutional Cooperation Academic Leadership Program Fellow. Currently, she serves as chair of the Ethics Advisory Committee of the Endocrine Society, as a member of the AAMC Group on Faculty Affairs Program Planning and Transition Committee, as a member of the Board Development Committee for the National Postdoctoral Association, as a member of the Postdoctorate Committee for the AAMC Graduate Research and Education Training Group, as chair of the Committing on Teaching for the International Union of Pharmacology, as a AAMC women's liaison officer for the University of Pittsburgh School of Medicine, and serves as co-director of the KL2 Clinical Research Scholars Program and director of mentoring and faculty development for the Clinical Translational Service Award at the University of Pittsburgh Schools of the Health Sciences. Her administrative responsibilities encompass oversight and development of comprehensive career development services, including mentoring programs for professional students, postdoctoral fellows, residents, clinical fellows, and faculty across the health schools at the University of Pittsburgh. She remains committed to creating and shaping the future of the biomedical research community.

Mark Pauly, Ph.D. (IOM), received a Ph.D. in economics from the University of Virginia. Dr. Pauly is a former commissioner on the Physician Payment Review Commission and an active member of the Institute of Medicine. One of the nation's leading health economists, Dr. Pauly has made significant contributions to the fields of medical economics and health insurance. His classic study on the economics of moral hazard was the first to point out how health insurance coverage may affect patients' use of medical services. Subsequent work, both theoretical and empirical, has explored the impact of conventional insurance coverage on preventive care, on outpatient care, and on prescription drug use in managed care. He is currently studying the effect of poor health on worker productivity. In addition, he has explored the influences that determine whether insurance coverage is available and, through several cost-effectiveness studies, the influence of medical care and health practices on health outcomes and cost. His interests in health policy deal with ways to reduce the number of uninsured people through tax credits for public and private insurance, and appropriate design for Medicare in a budget-constrained environment. Dr. Pauly is a co-editor-in-chief of the *International Journal of Health Care Finance and Economics* and an associate editor of the *Journal of Risk and Uncertainty*. He has served on Institute of Medicine panels on public accountability for health insurers under Medicare and on improving the supply of vaccines.

Larry J. Shapiro, M.D. (IOM), is the executive vice chancellor for medical affairs at Washington University in St. Louis and dean of the school of medicine. Prior to his current position he was the W.H. and Marie Wattis Distinguished Professor and chair of the Department of Pediatrics at the University of California, San Francisco (UCSF), School of Medicine and has been the chief of pediatric services at UCSF Children's Hospital since 1991. Dr. Shapiro is a member of the Institute of Medicine and the American Academy of Arts and Sciences. He is a fellow of the American Association for the Advancement of Science. Dr. Shapiro is a member of many professional societies and organizations and has served as the president of the American Society of Human Genetics, the American Board of Medical Genetics, the Society for Inherited Metabolic Diseases, the Western Society for Pediatric Research, the Society for Pediatric Research, and the American Pediatric Society. He is currently the chairman of the board of the Association of Academic Health Centers. Dr. Shapiro earned both undergraduate and medical degrees from Washington University in St. Louis. After completing his residency at St. Louis Children's Hospital in 1973, he became a research associate at the National Institute of Arthritis, Metabolism and Digestive Diseases, Section on Human Biochemical Genetics. In 1975, he joined the faculty at the University of California, Los Angeles (UCLA) School of Medicine as an assistant professor of pediatrics and director of the Harbor-UCLA Genetic Metabolic Laboratory. Eight years later, Dr. Shapiro was named professor of pediatrics and biological chemistry, and in 1986 he became chief of the Division of Medical Genetics. While at UCLA, he was a Howard Hughes Medical Institute investigator.

Edward H. Shortliffe is president and chief executive officer of the American Medical Informatics Association. He is also professor in the School of Biomedical Informatics at the University of Texas Health Science Center in Houston, Texas. Previously he was professor of biomedical informatics at Arizona State University and professor of basic medical sciences and professor of medicine at the University of Arizona College of Medicine. Until May 2008 he served as the founding dean of the Phoenix campus of the University of Arizona's College of Medicine. Before that he was the Rolf A. Scholdager Professor and chair of the Department of Biomedical Informatics at Columbia College of Physicians and Surgeons in New York City (2000-2007) and professor of medicine and of computer science at Stanford University (1979-2000). After receiving an A.B. in applied mathematics from Harvard College in 1970, he moved to Stanford University where he was awarded a Ph.D. in medical information sciences in 1975 and an M.D. in 1976. During the early 1970s, he was principal developer of the medical expert system known as MYCIN. After a pause for internal medicine house-staff training at Massachusetts General Hospital and Stanford Hospital between 1976 and 1979, he joined the Stanford internal medicine faculty where he served as chief of general internal medicine, associate chair of medicine for primary care, and director of an active research program in clinical information systems and decision support. He spearheaded the formation of a Stanford graduate degree program in biomedical informatics and divided his time between clinical medicine and biomedical informatics research. He continues to be closely involved with medical education and biomedical informatics graduate training. His research interests include the broad range of issues related to integrated decision-support systems, their effective implementation, and the role of the Internet in health care. Dr. Shortliffe is a member of the Institute of Medicine, the American Society for Clinical Investigation, the Association of American Physicians, and the American Clinical and Climatological Association. He has also been elected to fellowship in the American College of Medical Informatics and the American Association for Artificial Intelligence. He is a master of the American College of Physicians and was a member of that organization's board of regents from 1996-2002. He is editor-in-chief of the *Journal of Biomedical Informatics* and serves on the editorial boards for several other biomedical informatics publications. He has served on the Computer Science and Telecommunications Board (National Research Council) and the Biomedical Library Review Committee (National Library of Medicine) and was the recipient of a research career development award from the latter agency. In addition, he received the Grace Murray Hopper Award of the Association for Computing Machinery in 1976 and the Morris F. Collen Award of the American College of Medical Informatics in 2006 and has been a Henry J. Kaiser Family Foundation Faculty Scholar in general internal medicine.

Donald Steinwachs, Ph.D. (IOM), is professor in the Health Policy and Management Department at Johns Hopkins University. He is also the director of the Health Services Research and Development Center there. Dr. Steinwachs received his Ph.D. in 1973 from Johns Hopkins University. Dr. Steinwach's current research seeks to identify opportunities to improve quality of health care and patient outcomes and when feasible, evaluate promising quality improvement interventions. Previous research includes studies of medical effectiveness and patient outcomes for individuals with specific medical (e.g., asthma), surgical (e.g., cataract surgery), and psychiatric (e.g., schizophrenia) conditions. A current study is evaluating an intervention with schizophrenia patients using a Web-based tool for patients to compare their care to evidence-based standards and empower them to discuss quality with their therapist.

Valerie Petit Wilson is associate dean of the graduate school for recruitment and professional development (since 2005) and clinical professor of community health at Brown University. She is also executive director of the Leadership Alliance, a consortium of 33 leading teaching and research institutions dedicated to preparing underrepresented students for careers in academia, government, and private sectors through research and clinical doctoral training. In these roles Dr. Wilson is the principal investigator of numerous federal and private grants that enhance and support the development of undergraduate research scholars and promotes the development of a network of more than 2,000 Leadership Alliance alumni and doctoral scholars, She is also co-principal investigator for projects related to Brown's participation in the Ph.D. Completion Project. Prior to beginning these appointments at Brown University, she was deputy director of the Center for Bioenvironmental Research and clinical professor of Environmental Health at Tulane University from 1998-2003. She previously directed the Division of Health Sciences Policy of the Institute of Medicine, National Academy of Sciences from 1993-1997. From 1981 to 1993 she held increasingly responsible positions at the National Institutes of Health and the Department of Health and Human Services, spanning biomedical research, research program administration, policy analysis, and policy development. Dr. Wilson's expertise is in policy analysis, biomedical and environmental ethics, university administration, and workforce development. Dr. Wilson holds a B.S. degree in chemistry/pre-med from Xavier University of Louisiana and a Ph.D. in molecular biology from Johns Hopkins University, where she was supported by an NIH training grant and subsequently a Ford Foundation predoctoral fellow.

Allan Yates, M.D., Ph.D., is an emeritus professor in the Department of Pathology and a previous director of the Medical Scientist Program at Ohio State University. Dr. Yates was also the previous vice-chair for research and graduate education in the Department of Pathology. The Medical Scientist Program at Ohio State, which leads to both the M.D. and Ph.D. degrees, has a unique, integrated curriculum that draws on the nationally recognized educational and scientific strengths of Ohio State University. Dr. Yates' research involves investigating the role of glycolipids in the biology of human brain tumors. This includes glycolipid analyses, transfection of genes encoding enzymes that synthesize glycolipids, and examining the biological effects of altered glycolipid compositions of brain tumors both in cell culture and animal models. Dr. Yates was a fellow of the American College of Pathologists in 1991 and AAAS fellow in 2003. (Deceased August 2010)

Appendix B

Ruth L. Kirschstein National Research Service Award Training Grants and Fellowship

The National Institutes of Health, Agency for Health Care Policy and Research, and Health Resources and Services Administration provide predoctoral and postdoctoral research training support through a number of National Research Service Award programs. At each level the programs are distinguished by whether they are made directly to individuals, who use the support at an institution of their choice, or to institutions, which in turn make awards to individuals in their programs. The following is a list of programs encompassed by the National Research Service Awards:

INDIVIDUAL AWARDS

National Research Service Award Individual Predoctoral Fellowships (F30)—The National Institute of Mental Health (NIMH), the National Institute on Drug Abuse (NIDA), the National Institute on Alcohol Abuse and Alcoholism (NIAAA), and the National Institute of Environmental Health Sciences (NIEHS) provide National Research Service Awards (NRSAs) predoctoral training to individuals working towards the combined M.D./Ph.D. degree. This fellowship program is designed to help ensure that highly trained physician-scientists will be available in adequate numbers and in the appropriate research areas and fields to meet the nation's mental health, drug abuse and addiction, alcohol abuse and alcoholism and environmental health sciences research needs. In addition, this mechanism has the potential to train clinical investigators who wish to focus their research endeavors on patient-oriented studies.

National Research Service Awards Individual Predoctoral Fellowships (F31)—This fellowship program is directed at different groups.

The National Research Service Award Predoctoral Fellowship for Minority Students will provide up to five years of support for research training leading to the Ph.D. or equivalent research degree; the combined M.D./Ph.D. degree; or other combined professional degree and research doctoral degree in the biomedical, behavioral sciences, or health services research. These fellowships are designed to enhance the racial and ethnic diversity of the biomedical, behavioral, and health services research labor force in the United States. Accordingly, academic institutions are encouraged to identify and recruit students from underrepresented racial and ethnic groups who can apply for this fellowship. Support is NOT available for individuals enrolled in medical or other professional schools UNLESS they are also enrolled in a combined professional doctorate/Ph.D. degree program in biomedical, behavioral, or health services research.

The NRSA Predoctoral Fellowship for Students with Disabilities will provide up to five years of support for research training leading to the Ph.D. (or equivalent research degree), or the combined M.D./Ph.D. degree (or other combined professional research doctoral degrees) in the biomedical or behavioral sciences. The intent of this Predoctoral Fellowship Program is to encourage students with disabilities to seek graduate degrees and thus further the goal of increasing the number of scientists with disabilities who are prepared to pursue careers in biomedical and behavioral research.

The NRSA Individual Predoctoral Fellows are provided by the National Institute on Alcohol Abuse and Alcoholism (NIAAA), the National Institute on Deafness and Other Communication Disorders (NIDCD), the National Institute on Drug Abuse (NIDA), the National Institute of Mental Health (NIMH), and the National Institute of Neurological Disorders and Stroke (NINDS). These Institutes award NRSA individual predoctoral fellowships (F31) to promising applicants with the potential to become productive, independent investigators in the scientific mission areas of these Institutes. This program will provide predoctoral training support for doctoral candidates that have successfully completed their comprehensive examinations or the equivalent by the time of award and will be performing dissertation research and training.

National Research Service Award Individual Postdoctoral Fellowship (F32)—This fellowship is designed to provide individuals who have received a Ph.D., M.D., D.O., D.C., D.D.S., D.V.M., O.D., D.P.M., Sc.D., Eng.D., Dr. P.H., D.N.S., N.D., Pharm.D., D.S.W., Psy.D., or equivalent degree with postdoctoral training that broaden their scientific background and provide them with the potential to become productive, independent investigators in fields related to the mission of the NIH constituent institutes and centers. Research is to be conducted at a sponsoring institution and under the direction of an individual who will serve as a mentor and will supervise the training and research experience. Individuals may receive up to 3 years of aggregate NRSA support at the postdoctoral level, including any combination of support from institutional training grants and individual fellowship awards.

National Research Service Award Senior Postdoctoral Fellowship (F33)—The NIH awards NRSA senior fellowships (F33) to experienced scientists who wish to make major changes in the direction of their research careers or who wish to broaden their scientific background by acquiring new research capabilities. These awards will enable individuals with at least seven years of research experience beyond the doctorate, and who have progressed to the stage of independent investigator, to take time from regular professional responsibilities for the purpose of receiving training to increase their scientific capabilities. In most cases, this award is used to support sabbatical experiences for established independent scientists. This program is not designed for postdoctoral-level investigators seeking to prove their research potential prior to independence. Senior fellowship support may be requested for a period of up to 2 years. However, no individual may receive more than 3 years of aggregate NRSA support at the postdoctoral level, including any combination of support from institutional and individual awards.

Minority Access to Research Careers Faculty Fellowships (F34)—For advanced research training of selected faculty members at eligible institutions in which student enrollments are drawn substantially from minority groups.

Intramural National Research Service Award Postdoctoral FellowshiR (F35)—To allow physicians, dentists, and veterinarians with limited research experience an opportunity to prepare for careers in biomedical or behavioral laboratory research through training on the NIH campus.

INSTITUTIONAL AWARDS

National Research Service Award Institutional Training Grants (T32)—The institutional research training grants provide support to training programs at institutions of higher education, and are designed to allow the director of the program to select the trainees and to develop a curriculum of study and research experiences necessary to provide high-quality research training. The grant offsets the cost of stipends and tuition support for the appointed trainees. The following types of training can be supported by this grant:

Predoctoral Training. Predoctoral research training leads to the Ph.D. degree or a comparable research doctoral degree. Students enrolled in health-professional training programs that wish to postpone their professional studies in order to engage in full-time research training may also be appointed to an Institutional Research Training Grant. Predoctoral research training emphasizes fundamental training in areas of biomedical and behavioral sciences. Awards may not be used to support studies leading to the M.D., D.O., D.D.S., or a similar professional degree, unless the trainee is enrolled in a combined-degree (e.g., M.D./Ph.D.) program. In addition, they may not be used to support residencies or other nonresearch clinical training.

Postdoctoral Training. Postdoctoral research training is for individuals who have received a Ph.D., D.V.M, D.D.S., M.D., or a comparable doctoral degree from an accredited domestic or foreign institution. Research training at the postdoctoral level must emphasize specialized training to meet national research priorities in the biomedical, behavioral, or clinical sciences. Research training grants are a mechanism for the postdoctoral training of physicians and other health professionals who may have extensive clinical training but limited research experience. For such individuals, the training may be a part of a research degree program. In all cases, postdoctoral trainees should agree to engage in at least 2 years of research, research training, or comparable activities beginning at the time of appointment. It has been shown that the duration of training has been shown to be strongly correlated with retention in post-training research activity.

Short-Term Research Training for Health-Professional Students. Applications for Institutional Research Training Grants may include a request for short-term predoctoral positions reserved specifically to provide full-time, health-related research training experiences during the summer or other “off-quarter” periods. Such positions are limited to medical students, dental students, students in other health-professional programs, and graduate students in the physical or quantitative sciences. Short-term appointments are intended to provide such students with opportunities to participate in biomedical and/or behavioral research in an effort to attract them into health-related research careers. Short-term positions should be requested in the application and approved at the time of award. Normally, short-term positions are not to be used for individuals who have already earned a doctoral degree. Short-term research training positions should last at least 8 but no more than 12 weeks. Individual health-professional students or students in the quantitative sciences selected for appointment should be encouraged to obtain multiple periods of short-term, health-related research training during the years leading to their degree. Such appointments may be consecutive or may be reserved for summers or other "off-quarter" periods. It should be noted that not all NIH Institutes and Centers permit short-term positions. Applicants interested in such positions should contact the awarding institute or center prior to completing their application.

Short-term appointments on regular NRSA Institutional Research Training Grants (T32) should not be confused with NRSA Short-Term Institutional Research Training Grants (T35), which are exclusively reserved for short-term research training appointments.

Minority Access to Research Careers (MARC) Undergraduate Institutional Grants (T34)—The Minority Access to Research Careers (MARC) Branch of the Division of Minority Opportunity in Research (MORE) of the National Institute of General Medical Sciences (NIGMS) provide awards for biomedical research to selected institutions to support the undergraduate education of minority students who can compete successfully for entry into graduate programs leading to a Ph.D. degree in the biomedical or behavioral sciences. Biomedical research includes such areas as cell biology, biochemistry, physiology, pharmacology, genetics, etc., and behavioral research as well as the more quantitative areas such as mathematics, physics, chemistry and computer sciences, necessary to analyze biological phenomena. The MARC Undergraduate Student Training in Academic Research (U-STAR) program supports institutional training grants for underrepresented minority junior and senior honors students in any of the above cited science areas to improve their preparation for graduate training in the biomedical/behavioral sciences. In addition, MARC U-STAR grants provide an allowable cost support to improve the research training environment for MARC trainees and pre-MARC students (freshmen and sophomores) and science faculty development at MARC-supported institutions. Currently, progress in many sub-disciplines in the biological sciences (e.g., structural biology, bioinformatics, modeling of complex systems, population genetics, and evolution) is dependent on the use of information and methodologies from diverse disciplines of science such as mathematics, biophysics, computer science, and engineering. Thus, the MARC U- STAR program specifically encourages the development of pedagogical tools for incorporating quantitative concepts, computational skills, and principles of modeling complex biological phenomena in pre-MARC and MARC student science curricula. To this end, the MARC U-STAR program will also provide funds for the development of needed course materials for the curricular changes proposed, as well as for faculty training required for introducing the use of such materials in the different science courses.

Short-Term Training Awards (T35)—National Research Service Awards (NRSA) Short-Term Institutional Research Training Grants (T35) are made to eligible institutions to develop or enhance research training opportunities for individuals interested in careers in biomedical and behavioral research. Many of the NIH Institutes and Centers use this grant mechanism exclusively to support intensive, short-term research training experiences for students in health professional schools during the summer. In addition, the Short-Term Institutional Research Training Grant can be used to support other types of predoctoral and postdoctoral training in focused, often emerging, scientific areas relevant to the mission of the funding NIH institute or center. The proposed training must be in either basic or clinical aspects of the health-related sciences. The training should be of sufficient depth to enable the trainees, upon completion of the program, to have a thorough exposure to the principles underlying the conduct of research.

Appendix C

Classification of Ph.D. Fields

CLASSIFICATION OF PH.D. FIELDS IN THE BASIC BIOMEDICAL SCIENCES

Anatomy
Bacteriology
Biochemistry
Bioinformatics
Biological Immunology
Biological Sciences, General
Biological Sciences, Other
Biomedical Engineering
Biomedical Sciences
Biophysics
Biotechnology Research
Cell Biology
Developmental Biology/Embryology
Endocrinology
Genetics, Human and Animal
Medicinal/Pharmaceutical Chemistry
Microbiology
Molecular Biology
Neuroscience
Nutritional Sciences
Parasitology
Pathology, Human and Animal
Pharmacology, Human and Animal
Physiology
Toxicology
Veterinary Medicine
Zoology

CLASSIFICATION OF PH.D. FIELDS IN THE BEHAVIORAL AND SOCIAL SCIENCES

Anthropology
Audiology and Speech Pathology
Demography/Population Studies
Sociology

Psychology

Clinical
Cognitive and Psycholinguistics
Comparative
Developmental and Child
Educational
Experimental
Industrial and Organizational
Personality
Psychology, General
Psychology, Other
Psychometrics
Physiological/Psychobiology
Quantitative
Social

CLASSIFICATION OF PH.D. FIELDS IN THE CLINICAL SCIENCES

Biometrics and Biostatistics
Environmental Health
Epidemiology
Exercise Physiology/Science
Health Sciences, General
Health Sciences, Other
Health Systems/Services Administration
Nursing
Pharmacy
Public Health
Rehabilitation/Therapeutic Services
Physicians in Academic Departments of Schools of Medicine

Appendix D

Demographic Projections of the Research Workforce in the Biomedical, Clinical, and Behavioral Sciences, 2006-2016

Projecting the research workforce is particularly difficult at this time. Available survey data on the workforce predate the economic crisis and subsequent stimulus, and no previous experience is available to indicate how the size and composition of the workforce have been affected and will change as a result in the future. Projections are reported here that rely on the statistical record, and because of these circumstances they probably carry a larger than usual, although unquantifiable, margin of error.

We consider first what the record says about the research workforce in three large fields: the basic biomedical, clinical, and behavioral and social (or simply behavioral) sciences. The disciplines that these three major fields cover are specified in the preceding appendix. By the workforce we understand all those residing in the United States who are qualified to do research by reason of the appropriate degree, as long as they are not retired. Although some without the degree may make important contributions, their numbers are probably small in comparison and in any case are not documented.

We first describe the workforce itself, then the graduates and immigrants who regularly add themselves to it, then the process of leaving the workforce through retirement and death as well as other changes in status, such as from employment to unemployment. These descriptive sections give fairly clear indications of the directions in which the workforce could be headed—absent the perturbations related to the great recession. We then describe the assumptions made in the projections and present projections of the workforce up to 2016.

THE SCIENTIFIC WORKFORCE

The scientific workforce has three major segments: Ph.D.s with U.S. doctorates, immigrant Ph.D.s with foreign doctorates, and M.D.s who do not also have Ph.D.s but have research interests. Because the NIH did not release data on M.D. researchers, we focus entirely on Ph.D.s, especially on the U.S.-trained, about whom there are the most data.[1]

U.S.-Trained Ph.D.s

The latest survey, in 2006, put the number of research scientists with U.S. Ph.D.s at 126,000 in the biomedical field, 24,000 in the clinical field, and 120,000 in the behavioral field (Table D-1). Five years earlier, behavioral and biomedical scientists were virtually equal at 113,000-114,000 each, but since then behavioral scientists have increased at a rate of only 1.1 percent annually, in contrast to an increase of 2.1 percent annually for biomedical scientists. Clinical scientists, by far the smallest group, grew much faster, at 4.7 percent annually.

The recent increases in U.S.-trained Ph.D.s are roughly in line with long-term trends, which suggest slowing growth in the behavioral field, slightly accelerating growth in the biomedical field, and greater acceleration in the clinical field (Figure D-1). Over the past two decades, however, growth rates have moderated in each field. Rates were higher from 1995 to 2001, at 2.5 percent annually for U.S.-trained behavioral scientists, 3.7 percent for biomedical scientists, and 5.5 percent for clinical scientists. From 2001 to 2006, the annual increments in the workforce were around 1,300 behavioral scientists, twice that number of biomedical scientists, and about 1,000 clinical scientists. Given estimates of retirements and deaths (to be considered below), this implies that, in 2001-2006, close to 25 percent of biomedical and behavioral Ph.D. graduates annually and about 15 percent of clinical graduates were not being immediately absorbed into the workforce. Exactly where they were or what they were doing instead is not evident.

[1] For completeness, we note other small groups that are not covered: those without Ph.D.s who still do independent scientific work and those with Ph.D.s in other fields, such as informatics, materials science, and physics, who have been recruited into the ranks of health researchers.

TABLE D-1 Workforce of U.S.-Trained Ph.D.s in Three Major Fields, by Sex and Employment Status, 2006

	Biomedical		Clinical		Behavioral	
Status	Males	Females	Males	Females	Males	Females
Total	80,268	45,828	9,451	14,706	57,593	62,758
Employed in Science	68,236	36,340	7,817	11,924	46,399	49,261
Postdoctorate	7,442	6,526	340	549	945	1,455
Other	*60,794*	*29,814*	*7,477*	*11,375*	*45,454*	*47,806*
Employed Out of Science	10,772	6,604	1,600	2,172	10,668	10,715
Unemployed	464	582	N/A	124	224	449
Not in the Labor Force (but not retired)	796	2,302	34	486	302	2,333

SOURCE: Data extracted from National Science Foundation Survey of Doctorate Recipients.

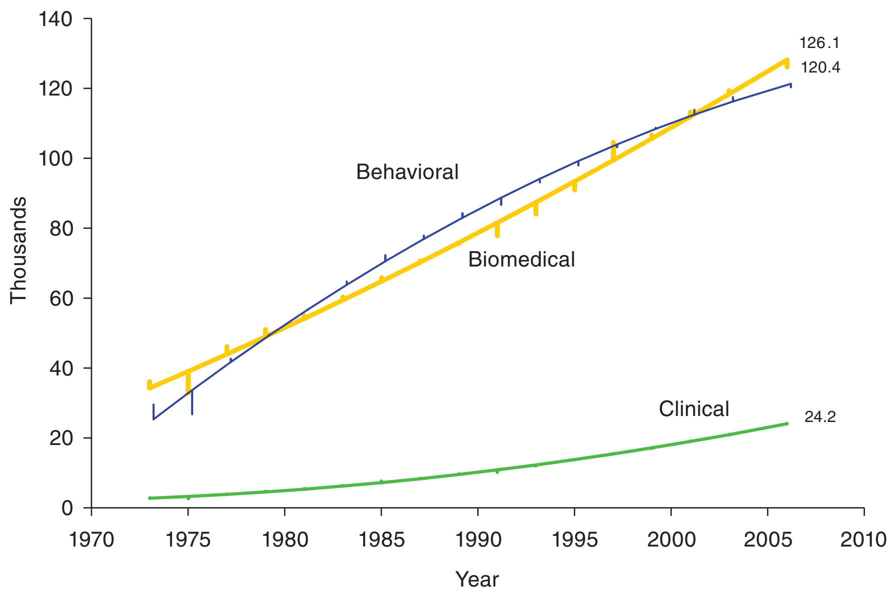

FIGURE D-1 U.S.-trained Ph.D. workforce, in thousands, in three major fields, 1973-2006: quadratic trend and annual variations.
SOURCE: Data extracted from National Science Foundation Survey of Doctorate Recipients, 1973-2006 and NRC analysis.

These estimates of the workforce cover not only those employed in jobs related to science (which includes those on postdoctorates) but also those in nonscience jobs, as well as the unemployed and those not looking for work—often women taking a break from employment (Figure D-2). The estimates exclude the retired. In 2006, those actually employed in science were 80-83 percent of the total workforce. This is a lower proportion than the historical average up to 2001, which is around 90 percent in each field. What has taken the place of jobs in science is non-science employment. In the Ph.D. surveys from 1973 to 2001, the proportion of the workforce employed in non-science jobs did not exceed 10 percent in any field, except once, just barely, among behavioral scientists in 1995. In the two surveys since 2001, in contrast, this proportion has been between 13 and 18 percent in each field.

Postdoctorates have been an important category of science employment, particularly for younger scientists. Across all fields, those on postdoctorates were 17,000 in 2006, or 7.8 percent of all those in science employment. For scientists under 35, postdoctorates made up 42 percent of science employment. The 2006 figures represented increases from 2001 and particularly 2003, when absolute numbers on postdoctorates actually declined. Although 17,000 was the highest figure recorded in the biennial surveys, in percentage terms it represented no more than a return to the levels of the late 1990s.

Another change in the U.S.-trained workforce, but one that has been largely gradual, is the increasing proportion of women (Figure D-3). Shortly after 2003, behavioral scientists reached a turning point, with the sex ratio falling to 100, or equal numbers of men and women. Among clinical scientists, this turning point was reached in 1994, and the sex ratio was down by 2006 to 64 men per 100 women and still falling. Among biomedical scientists, the sex ratio was still elevated at 175 in 2006, although extrapolation of current trends suggests that equality could be reached around 2020.

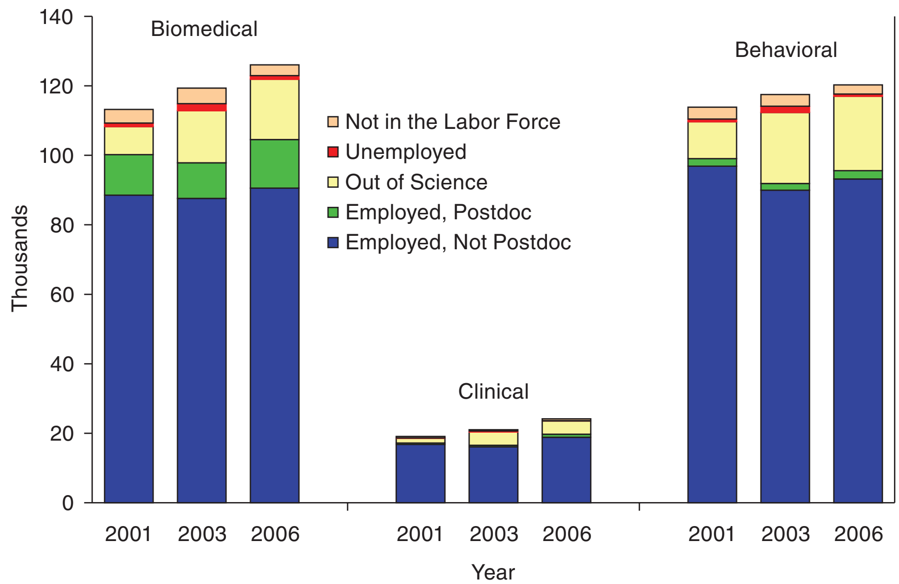

FIGURE D-2 U.S.-trained Ph.D.s by employment status and major field, 2001, 2003, and 2006 (thousands).
SOURCE: Data extracted from National Science Foundation Survey of Doctorate Recipients 2001, 2003, and 2006.

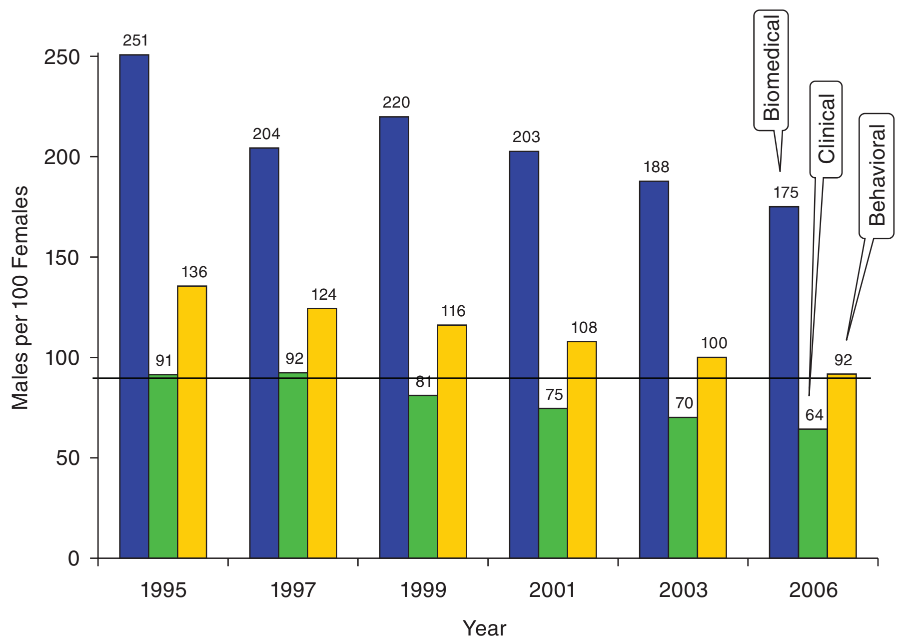

FIGURE D-3 Sex ratio in the U.S.-trained workforce by major field and survey year, 1995-2006.
SOURCE: Data extracted from National Science Foundation Survey of Doctorate Recipients, 1995-2006.

As the sex ratio fell, female scientists apparently became more likely to find scientific employment. In the biomedical field, 85 percent of male scientists were employed in science in 2006, but only 79 percent of female scientists were so employed. In the other two fields, employment in science was almost equally likely for each gender, which was not true in the past (Figure D-4). Female scientists are more likely than males, however, to be out of the labor force. (Those out of the labor force but not retired are counted, for current purposes, as being in the workforce, because one assumes, for projection purposes, that they could readily return to employment.) The numbers are small—about 5,000 in the three fields combined—but the proportion among women in 2006 was five to nine times the proportion among men.

The age of the labor force has also been changing gradually. The median age in 2006 was considerably lower among biomedical scientists, at 46.9 years, than in the other two

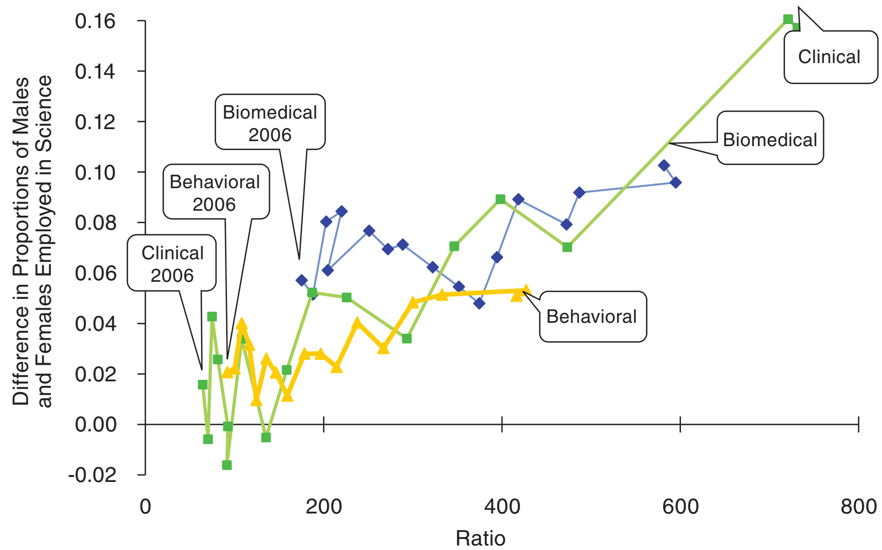

FIGURE D-4 Differences in male and female employment in science relative to the sex ratio in the U.S.-trained workforce between 1973 and 2006.
SOURCE: Data extracted from National Science Foundation Survey of Doctorate Recipients, 1973 and 2006.

fields. Among clinical scientists the median was 51.1 years, among behavioral scientists 52.3 years. These medians represent increases, since 1995, of 1.3 years in the biomedical field, 3.9 years in the clinical field, and 4.5 years in the behavioral field. Those 55 years and older have been a growing proportion of the workforce, but their gains have not been coming at the expense of the youngest scientists. The proportion of those under 35 has also shown some growth; though relatively slight (Figure D-5).

Foreign-Trained Ph.D.s

Foreign-trained Ph.D.s provide a substantial addition to the research workforce. They are not the only immigrants in the workforce. U.S.-trained Ph.D.s include many noncitizens, both permanent residents and temporary residents, the latter having risen to a quarter of Ph.D. graduates. These noncitizens have been incorporated into the preceding tabulations, and this section adds only those who received their Ph.D.s outside the United States.

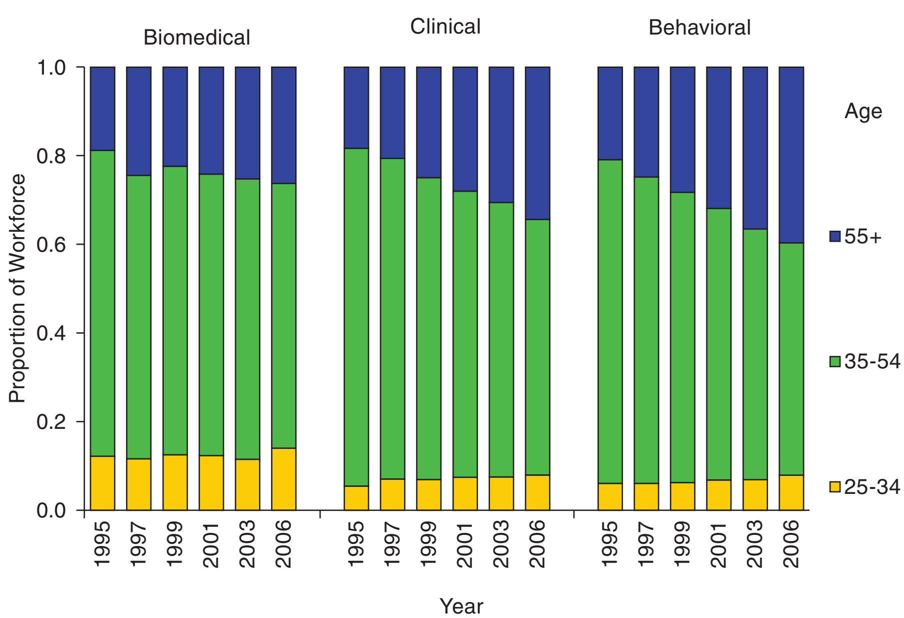

FIGURE D-5 Proportional age distribution of U.S.-trained workforce by major field, 1995-2006.
SOURCE: Data extracted from National Science Foundation Survey of Doctorate Recipients, 1995-2006.

The foreign-trained were not all included in surveys. They were counted in 2003 and 2006 (although not in 2001), but in both cases, the sample frame was based on the decennial census. Any Ph.D.s who entered the country after the census were therefore not counted. Estimates were generated of these additional migrants through a complicated process involving estimating the preceding inflows and extrapolating forward. The specific procedures are described below. They produced upward adjustments to the survey figures of 20-40 percent (varying by field) for 2003 and 40-90 percent for 2006.

Before adjustment, the foreign-trained were equivalent to a fourth of the U.S.-trained in the biomedical field in 2006. After adjustment, they were equivalent to about a third. In the clinical field, the adjustment increases the numbers of the foreign-trained from almost half to two-thirds of the U.S.-trained. The behavioral field is a stark contrast, where the foreign-trained are much fewer, and the adjustment increases their numbers from 3 to 5 percent of the U.S.-trained (Figure D-6). Taking into account the foreign-trained, the workforce in biomedical sciences, instead of being only slightly larger than the workforce in behavioral sciences, was actually 50 percent larger in 2006.

The proportions employed in science among the foreign-trained were generally similar to those among the U.S.-trained, with no consistent variation across fields. For instance, in 2006 in the biomedical field, the foreign-trained were slightly more likely to be employed in science and slightly less likely to be employed out of science, but the reverse was true in the behavioral field. Similarly, gender composition was largely similar, except that, in the biomedical field, the sex ratio was slightly higher among the foreign-trained than the U.S.-trained. One important way in which the foreign-trained differed from the U.S.-trained was in age distribution. Their median ages were five to eight years lower, the difference mainly having to do with fewer foreign-trained scientists 55 years or older and more under 35 years. As a result, whereas foreign-trained biomedical and clinical scientists made up 21 percent of those 55 years and older in 2006, of those under 35 years, they made up 45 percent in the biomedical field and 56 percent in the clinical field (Figure D-7).

WORKFORCE ENTRANTS

The three main groups of entrants who regularly augment the workforce correspond to its three major segments, and as with these three segments, most of the data available cover Ph.D. graduates of U.S. universities. This section focuses mainly on them but adds estimates of foreign-trained Ph.D. migrants.

To summarize the main characteristics of these entrants, we note that, from 2000 to 2007 (the last year for which data are available), the numbers of Ph.D. graduates in the three major fields have mostly been rising, but the trends have been somewhat erratic. NIH funding appears to play an outsize role in producing these graduates. Their demographic characteristics indicate why the workforce is changing. As a group, they have become increasingly female and, in a reversal of previous trends, are now slightly younger on average than earlier.

Trends

From 2000 to 2007, annual Ph.D. graduates in the biomedical field increased 23 percent and in the clinical field 33

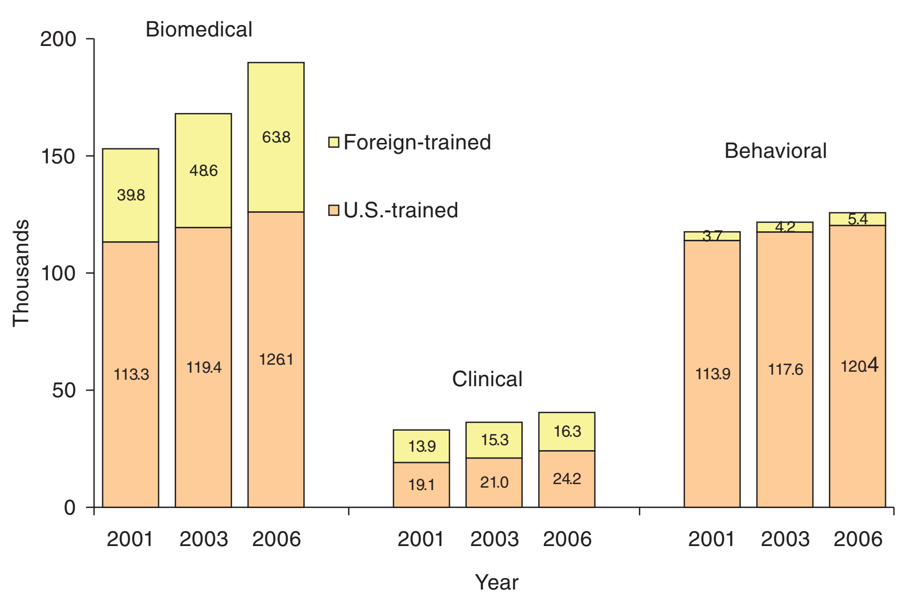

FIGURE D-6 U.S.-trained and foreign-trained Ph.D. workforce, by major field and year (thousands).
SOURCE: Data extracted from National Science Foundation Survey of Doctorate Recipients and National Survey of College Graduates, 2001-2006.

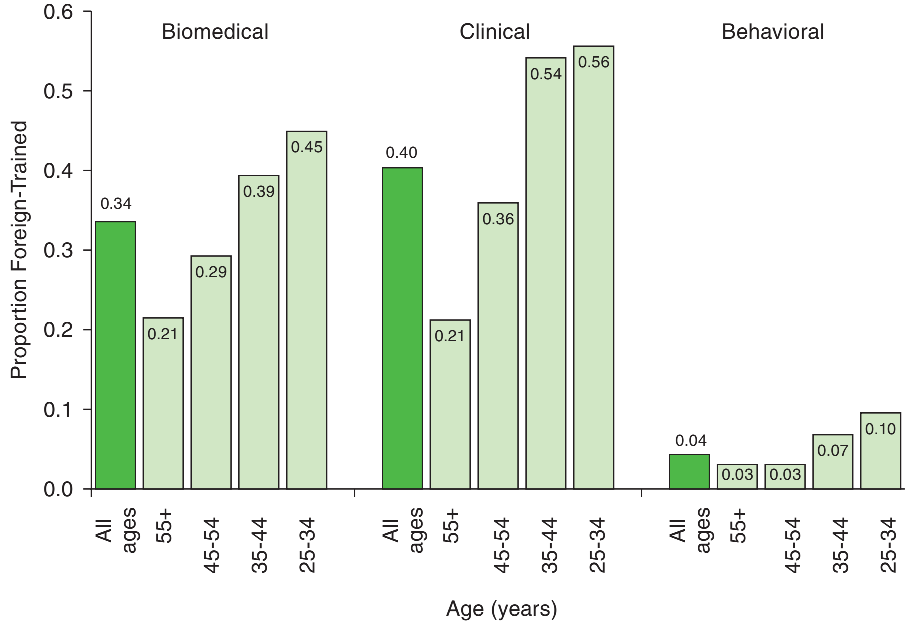

FIGURE D-7 Proportion foreign-trained in the workforce by age group and major field, 2006.
SOURCE: Data extracted from National Science Foundation National Survey of College Graduates, 2006.

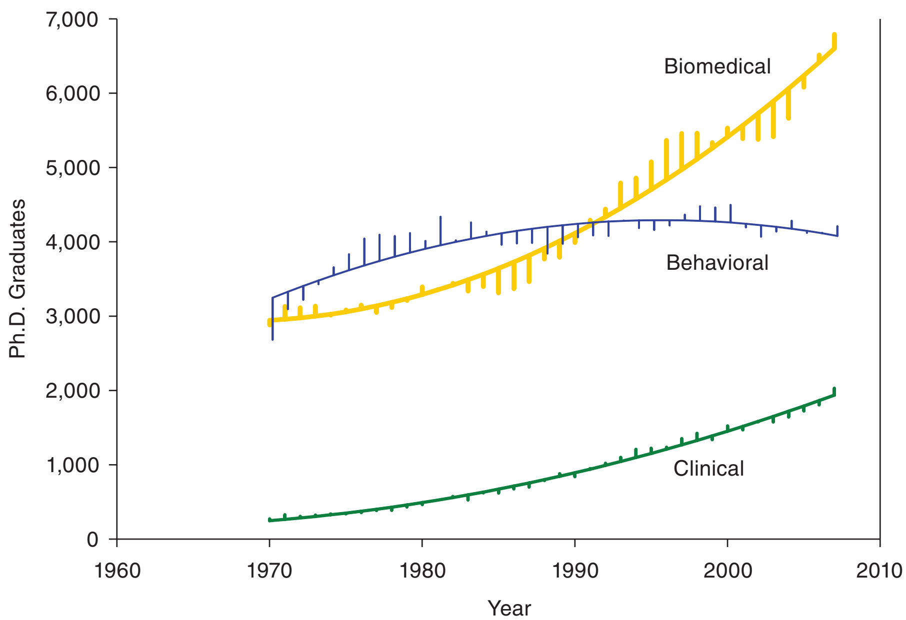

FIGURE D-8 Ph.D. graduates from U.S. universities by major field, 1970-2007: quadratic trend and annual variations.
SOURCE: Data extracted from National Science Foundation Survey of Earned Doctorates, 2007.

percent. In the behavioral field, however, they fell 6 percent, although the trend since 2005 has been positive. These trends have generally been in line with earlier trends (Figure D-8). Roughly around 2001-2002, however, each field experienced a drop in Ph.D. graduates that was deeper, at least in the biomedical and behavioral fields, than previous declines dating to the 1970s. Figure D-9 shows growth rates over 15 years for graduates in each field. (Since annual rates are quite erratic, we show five-year moving averages.) A dip in growth around 2000 or shortly after is evident, but since then growth has rebounded, although by 2007 it had not reached the levels of the early 1990s.

Ph.D. graduates include a number on temporary U.S. visas. In 2007, they were 30 percent of biomedical graduates, 23 percent of clinical graduates, and 10 percent of behavioral graduates. Their numbers appear to rise when the numbers

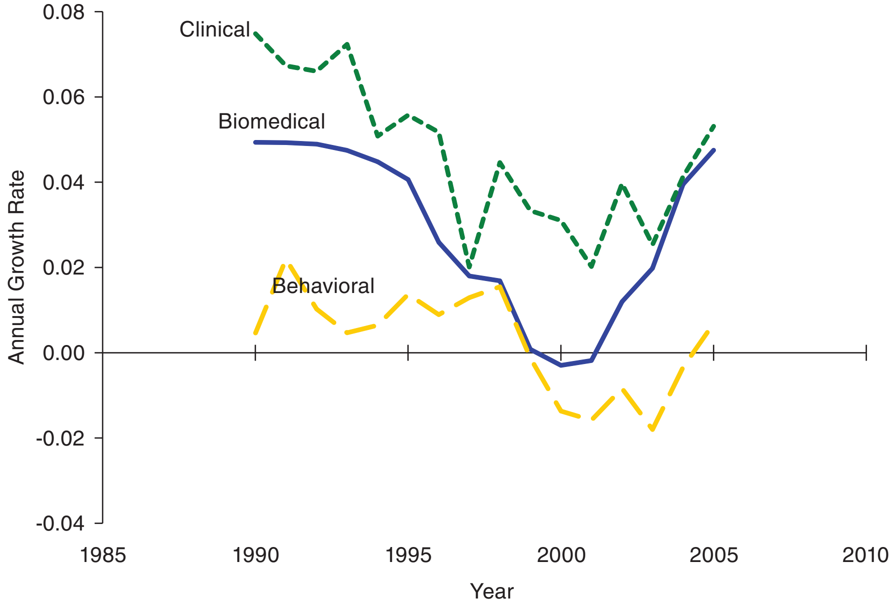

FIGURE D-9 Annual growth rates for Ph.D. graduates by major field (five-year moving averages).
SOURCE: Data extracted from National Science Foundation Survey of Earned Doctorates, 2007.

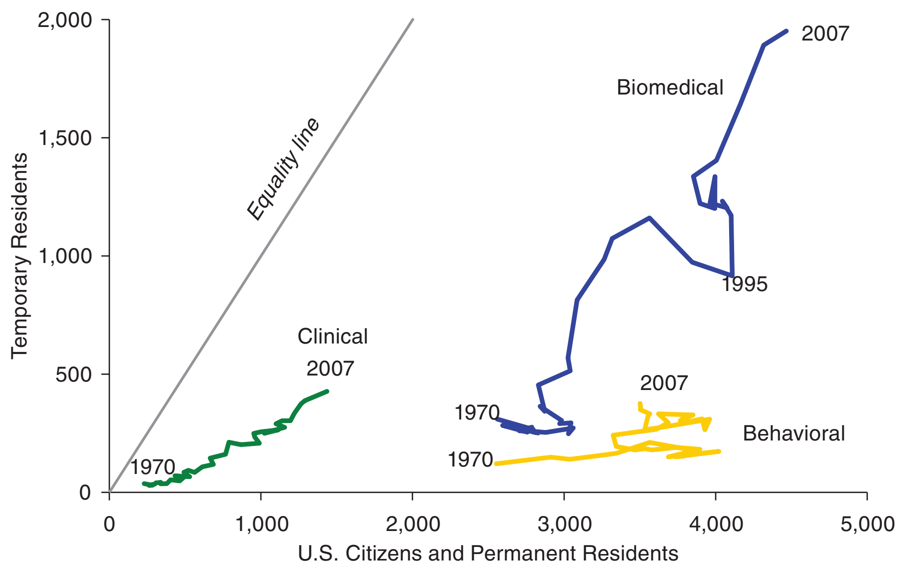

FIGURE D-10 Ph.D. graduates who are U.S. citizens or permanent residents versus temporary residents, by major field, 1970-2007.
SOURCE: Data extracted from National Science Foundation Survey of Earned Doctorates, 2007.

of those who are U.S. citizens or permanent residents rise, although not necessarily as fast (Figure D-10). The correlations between the sizes of the two groups over time are 0.94 among biomedical graduates, 0.99 among clinical graduates, and smaller although still positive at 0.32 among behavioral graduates. This suggests that temporary resident students do not mainly fill in for citizens but instead respond to similar changing incentives and disincentives to enroll (or at least to graduate), although they may respond more or less strongly than citizens and permanent residents. The rising numbers of temporary residents among graduates show no apparent lasting impact, at least so far, from any recent changes in immigration regulations.

Most U.S. citizens and permanent residents intend to stay and work in the United States immediately after graduation. Only 3-4 percent of those who express an intention say they would work elsewhere. The percentages do not vary by sex or major field and have not changed much over the years, although recently they may have become marginally more similar recently across fields.

For temporary residents, intentions to stay in the United States after graduation vary across fields, being generally lowest among behavioral graduates and female clinical graduates, intermediate among male clinical graduates, and highest among biomedical graduates. Overall, intentions to stay have been rising, generally as the proportion who are temporary residents has also been rising (Figure D-11). The combination of rising proportions of temporary residents and rising proportions of them intending to stay in the United States implies that, among those newly minted Ph.D.s entering the U.S. workforce, temporary residents are increasingly prominent (Figure D-12). Among biomedical graduates, they

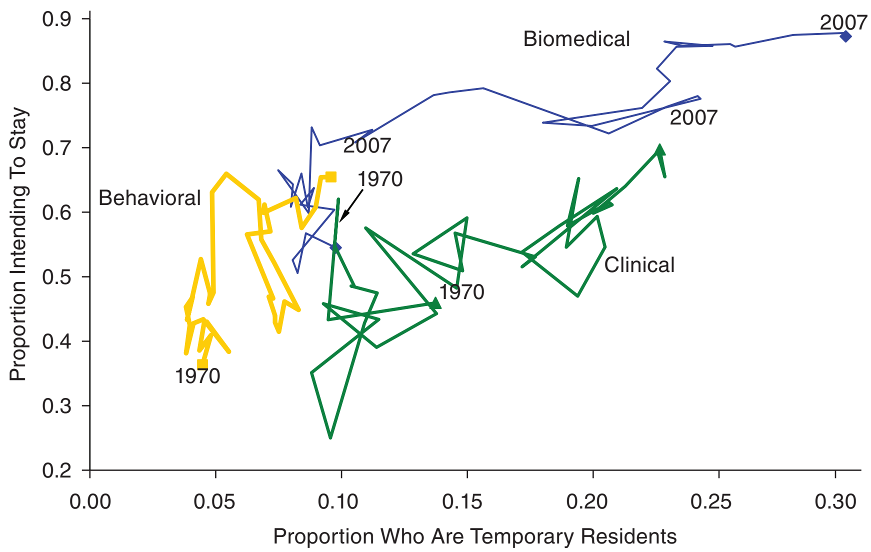

FIGURE D-11 Temporary-resident Ph.D. graduates and their proportion intending to stay in the United States, by major field, 1970-2007.
SOURCE: Data extracted from National Science Foundation Survey of Earned Doctorates, 2007.

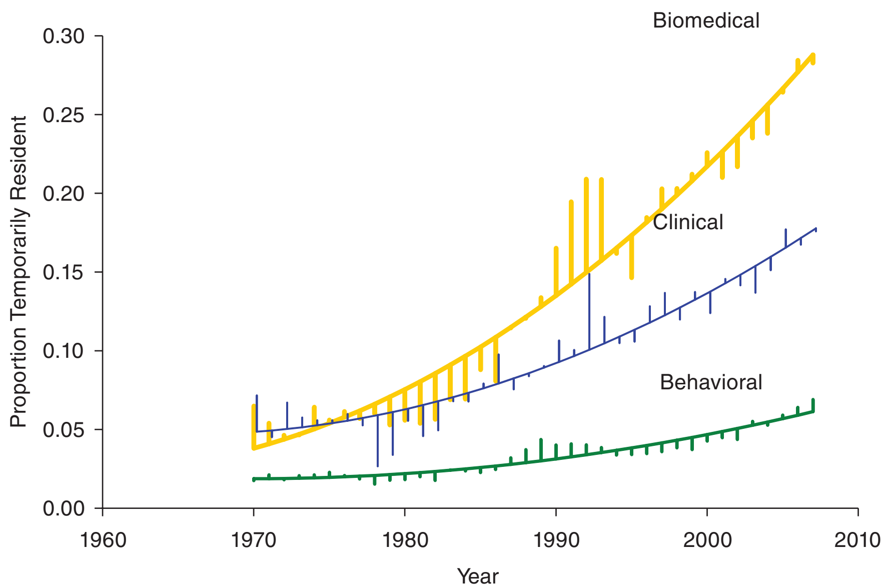

FIGURE D-12 Temporary residents as a proportion of those Ph.D. graduates intending to stay in the United States, by major field, 1970-2007: quadratic trend and annual.
SOURCE: Data extracted from National Science Foundation Survey of Earned Doctorates, 2007.

were 17 percent in 1990 and 28 percent by 2007. Even among behavioral graduates they showed an increase in this period, from 4 to 7 percent.

Sex and Age

The proportion of graduates who are female is rising in each field. Women have been the majority among clinical graduates since 1983, just over a decade before they became a majority in the clinical workforce. Among behavioral graduates women have been the majority since 1986, and it took 17 more years before they became a majority in the workforce. By 2007 in these two fields, female graduates outnumbered male graduates by two to one, and the female-male gap has continued to grow. Women are still a minority, but not by much, in the biomedical field, in which the sex ratio (the ratio of males per 100 females) was down to 109 by 2007, from 163 in 1990. The sex ratio has been falling faster among biomedical graduates than in the other two fields. All the graduate sex ratios are well below those in the research workforce as a whole.

The clinical and behavioral fields differ in one important respect. Figure D-13 shows the trend in numbers of female clinical graduates plotted against male graduates over time, with the trend for each decade shown separately, and the parallel trend among behavioral graduates. In the 1970s and through the early 1980s, numbers of male and female clinical graduates were mostly uncorrelated. In the late 1980s, however, both numbers tended to increase in parallel, a tendency clearly continuing in the 1990s and 2000s. Factors that increase the number of female graduates also appear to increase the number of males, although not quite as strongly, leading the sex ratio to drift further from equality. Trends among biomedical graduates (not shown) resemble those for clinical graduates. The behavioral field shows a contrasting pattern. In the early 1970s, male and female graduates increased in parallel, but since then, increases in female graduates have gone with decreases in male graduates. The sex ratio is dropping among behavioral graduates as females replace males.

Since roughly 1995, Ph.D. graduates have been getting younger. This is true in each field even when male and female graduates are examined separately (Figure D-14). The change has been relatively gradual and by 2007 still fell short of reversing the rising trends in the median age over the preceding 15 years. By 2007, median age among biomedical graduates was 31.3 years, down from the high of 32.2 in 1995 and the lowest since 1984. Among behavioral graduates, the median age of 33.6 years was two years younger than the peak in 1990 and the lowest since 1983. In both these fields, the median age for female graduates was lower than that for males by half a year to a year, a divergence that started mainly in the 1990s. Among clinical graduates, median age has also declined, but from considerably higher levels, as high as 36.5 among males (in 1994) and 42.6 among females (in 1997). The 2007 medians of 35.0 and 38.1 thus represent substantial declines. As these estimates indicate, female clinical graduates have been substantially older than males, unlike in the other two fields.

The declines in age have involved mainly reductions in older graduates, those in their late thirties or older. Graduates have become somewhat more concentrated at relatively younger ages. The tendency has been for younger average ages and a greater concentration of graduates at modal ages to go

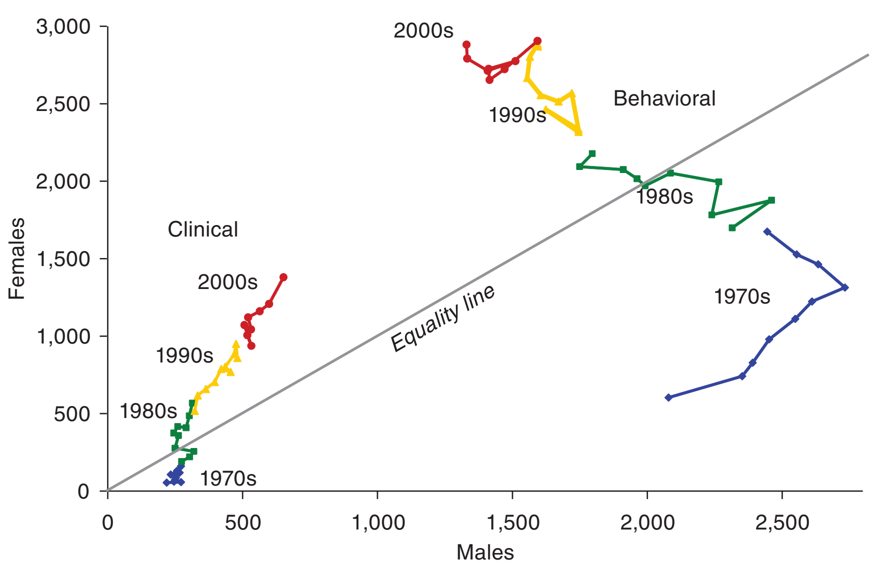

FIGURE D-13 Numbers of male and female clinical and behavioral graduates, 1970-2007.
SOURCE: Data extracted from National Science Foundation Survey of Earned Doctorates, 2007.

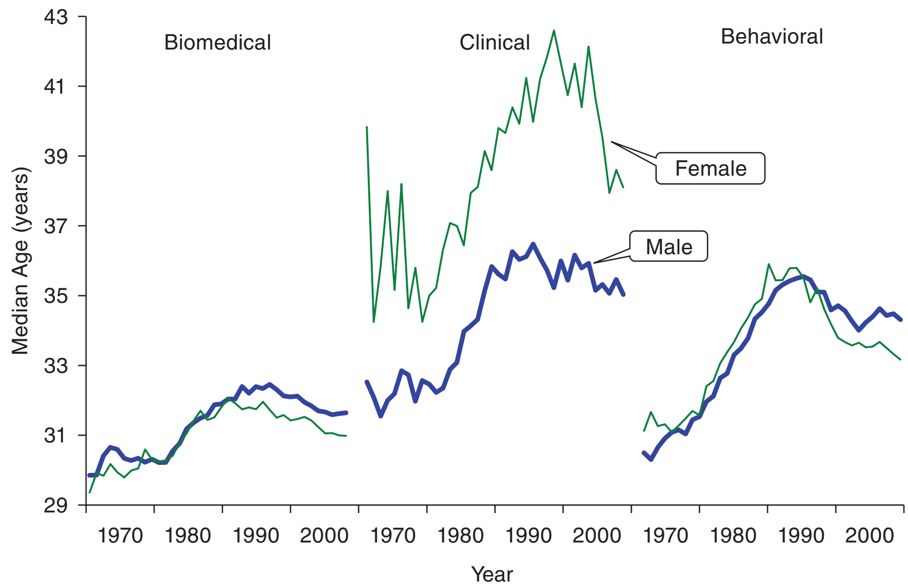

FIGURE D-14 Median age among Ph.D. graduates by major field and sex, 1970-2007.
SOURCE: Data extracted from National Science Foundation Survey of Earned Doctorates, 2007.

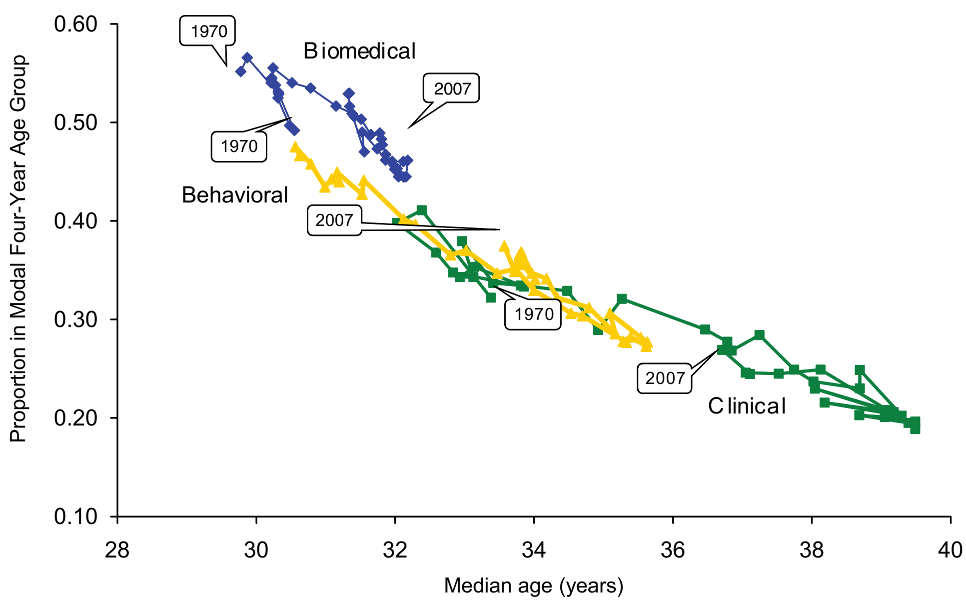

FIGURE D-15 Proportion of graduates in the modal four-year age group, by median age and major field, 1970-2007.
SOURCE: Data extracted from National Science Foundation Survey of Earned Doctorates, 2007.

together. In the biomedical field, which has a lower median age than the other two fields, 53 percent of 2007 graduates were in the modal age range of 27-31 years. In the clinical field, with the highest median age, only 27 percent were in the modal age range of 30-33 years. Across fields and over time, the pattern is unmistakable (Figure D-15). As median ages rose in each field, the modal age covered fewer graduates, but then the trend reversed, leaving median ages and modal concentrations in 2007 at intermediate levels in each field.

The declines in median age do not imply that training is becoming more efficient or even shorter. Offsetting slightly earlier graduation is increasing resort to postdoctoral work. In 1995, 30 percent of behavioral graduates planned on a postdoctoral fellowship. By 2007, this proportion had risen to 46 percent. Clinical graduates showed a smaller increase, from 21 to 28 percent. Although biomedical graduates did not show an increase in this period, they were already at a very high level: 82 percent by 2007.

NIH Support

Graduates in the biomedical field passed 5,000 in 1995, about the same time that the number of NIH predoctoral biomedical awards (National Research Science Awards [NRSAs], for trainees and fellows combined) also passed 5,000. Graduates passed 6,000 in 2005, and predoctoral awards passed 6,000 two years later (Figure D-16). In the 1980s and early 1990s, the ratio of biomedical Ph.D. graduates to NRSA-supported doctoral students was close to 0.8:1, rising to around 1.1:1 after 2000. This suggests that the clear majority of Ph.D.s in these fields were NRSA awardees. If three out of four awardees completed the Ph.D., then slightly more than that proportion of graduates were awardees after 2000.

In the clinical field, NRSAs have fluctuated somewhat in number between 500 and 900. The ratio of graduates to current NRSAs was around 1.6:1 in the 1980s and 1990s and settled to 2:1 in the 2000s. Assuming all the awardees graduate, close to half of graduates would have received an award. In the behavioral field, NRSAs since 1990 have fallen short of the number in the clinical field and are proportionally much less important. The ratio of graduates to current awardees is between 5:1 and 7:1, suggesting that a minority of graduates—around 15 percent—receive such awards.

Foreign-Trained Ph.D.s

No counts or sample estimates are available for the flow of foreign-trained Ph.D.s into the U.S. workforce. From the stock information in the 2003 survey, considered above, we estimated the probable annual inflow from the 1990s, making assumptions about retirements and deaths.

Tabulating the 2003 stock by date of entry into the United States, we reverse-survived each immigrant cohort to date of entry to determine its initial size. We used retirement rates and mortality rates by age for the workforce as a whole, described below. These calculations were done separately for men and women in each field. The results suggested a rising trend among foreign-trained biomedical scientists and considerable variability but no convincing trend among foreign clinical and behavioral scientists, who were considerably fewer.

Figure D-17 shows the estimated inflows of these foreign-trained Ph.D.s, compared with the trends in the other entrants into the workforce: the U.S.-trained Ph.D. graduates (citizens and temporary residents) who choose to stay in the United States. Annual immigrant numbers are relatively volatile. In the biomedical field in 2000, they were 50 percent of the entrants into the workforce, up from only 15 percent in 1990. (Estimates were also made for the years 1980-1984 combined and 1985-1989 combined, when inflows were even smaller.) Because U.S.-trained temporary-resident graduates were an additional 10 percent of the total in 2000, immigrants made up the majority of new workforce entrants in that year, and could have been an even larger proportion, because permanent residents are lumped with citizens. In the clinical field, foreign-trained immigrants outnumbered graduates in some years in the early 1990s, and in the late 1990s were 20-40 percent of the total. In the behavioral field they were much less consequential, averaging only 7 percent of the entrants over the decade.

These immigrant flow figures are in a sense underestimates, because those who may have returned to their countries of origin or emigrated elsewhere were not counted

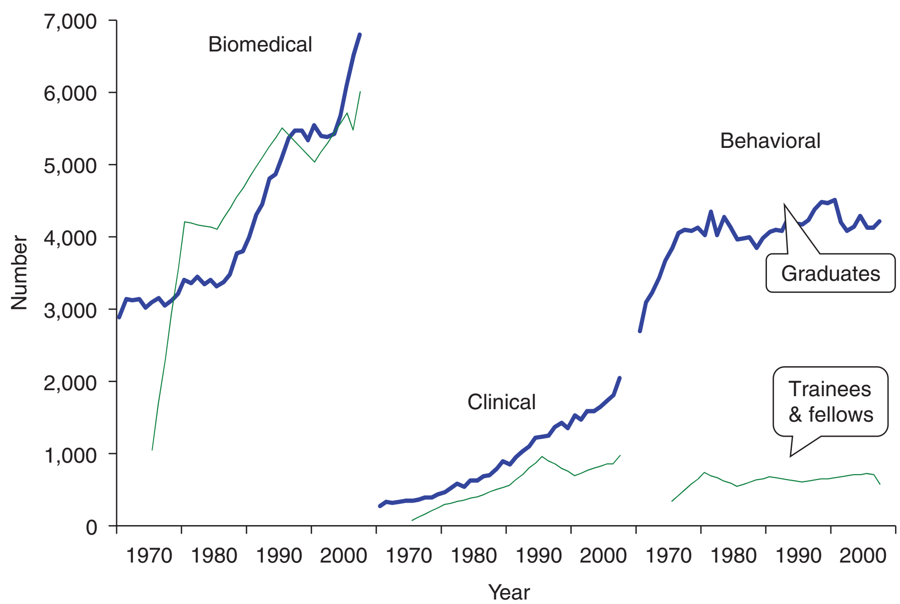

FIGURE D-16 Ph.D. graduates and NRSA predoctoral trainees and fellows by major field, 1970-2007.
SOURCE: Data extracted from National Science Foundation Survey of Earned Doctorates, 2007, and NIH IMPACII Database.

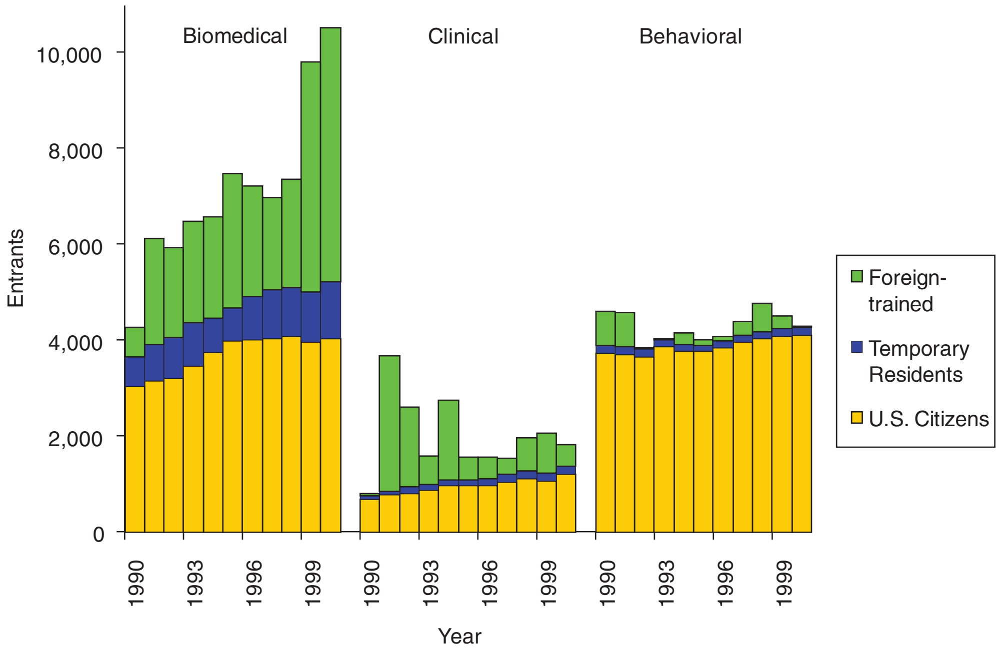

FIGURE D-17 Estimated workforce entrants: foreign-trained Ph.D.s and U.S.-trained citizens and temporary residents, by major field, 1990-2000.
SOURCE: NRC analysis.

in 2003 and were not added to the inflow. The figures represent only immigrant Ph.D.s who stay in the United States for some variable period of time. (Roughly half of those surveyed in 2003 had already stayed in the United States at least 10 years.) These figures for immigrant flow were used to adjust the foreign-trained stock numbers for 2003 and 2006, and also provided estimates of stock in 2001, as described below.

WORKFORCE TRANSITIONS

Leaving the Workforce

Individuals leave the workforce through death, emigration, or retirement. TIAA-CREF mortality tables provide some indication of mortality patterns: 79 percent of male scientists and 87 percent of female scientists should live at least up to age 75.

Data on emigration are largely lacking. Initial tabulations suggest very few U.S.-trained Ph.D.s abroad, although the completeness of these data is uncertain. Some graduates do not intend to stay in the United States, and these intentions, as described above, may be taken into account. But subsequent emigration, after initially entering the U.S. workforce, is assumed, in the absence of adequate data, to be inconsequential. Where foreign-trained Ph.D.s are concerned, emigration data are also lacking. However, we estimated the immigration flow only of those who stayed in the United States for some period, so many of those who subsequently enter and then emigrate are probably not counted as entrants.

Retirement produces more departures from the workforce than death or emigration. From retirement rates estimated between pairs of surveys since the 1990s, the proportions that have retired by age 66 have ranged from 5 up to 50 percent (Figure D-18). These are period estimates, i.e., they assume that a cohort of individuals moves through its career following the retirement rates estimated in a given period for individuals of different ages. No trend over time is evident in the proportions having retired by age 66 except possibly for the period 2003-2006, when lower retirement rates are shown. Because this period between surveys is three years rather than two (as is the case for all other successive surveys), these rates are adjusted, but even without adjustment some decline in the likelihood of retirement appears in each group.

This is illustrated in Figure D-19, which covers only male biomedical scientists. The proportion retired at each age was lower using 2003-2006 rates than using rates for biennial surveys from 1993 to 2001. Adjusting for the fact that the 2003 and 2006 surveys were three years apart makes the difference larger. Rates for 2001-2003, however, provide a less clear contrast with 1993-2001 rates. The contrasts are generally similar in other fields.

Moving Within the Workforce

Although the great majority of Ph.D.s are in science-related occupations, some are not. Some movement does occur among employment categories, particularly between science-related and nonscience-related jobs (Figure D-20).

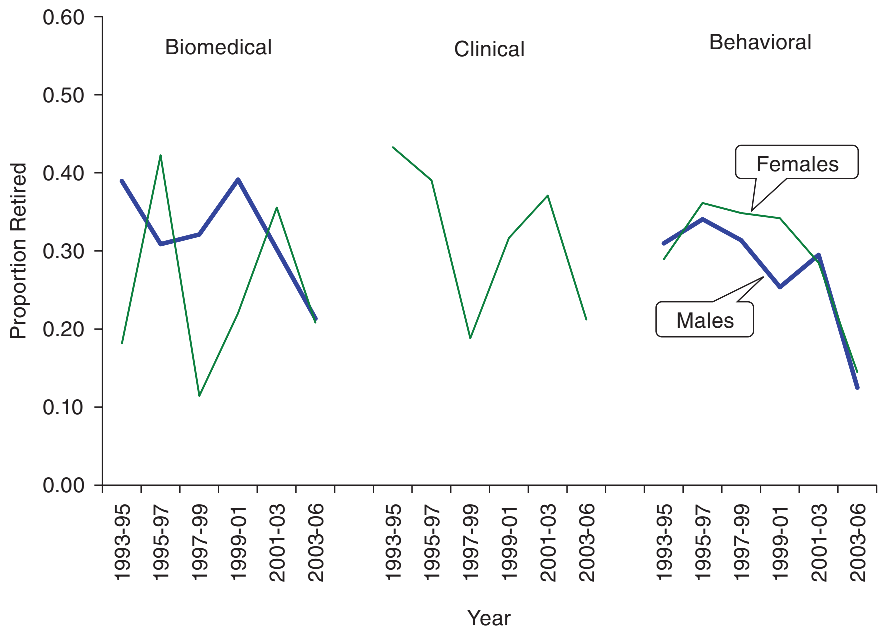

FIGURE D-18 Proportion that would have retired by age 66, from retirement rates in specified periods, by major field and sex.
SOURCE: Data extracted from National Science Foundation Survey of Doctorate Recipients, 1993-2006.

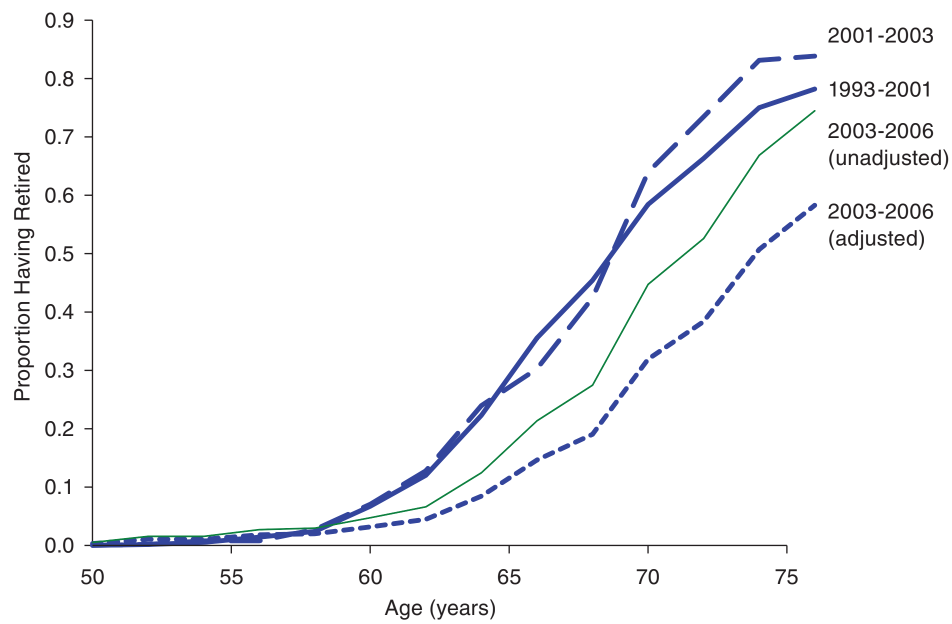

FIGURE D-19 Proportion that would have retired by each age, from retirement rates in specified periods: male biomedical Ph.D.s.
SOURCE: NRC analysis.

Across the three major fields, patterns of such movement do not vary greatly. Between males and females, the main difference involves those not working. There are more of them among women, and among women more in this group do not return to work within two years—60 percent, in contrast to 40 percent among men.

Over time, the main change in these movements has involved non-science jobs (Figure D-21). Those in such jobs may have increased in the early 2000s mainly because fewer of them have been returning to science jobs. This appears to be true for males and females in each field.

PROJECTION APPROACH

In projecting the research workforce, our concern is with its likely size and growth between 2006, the date of the latest

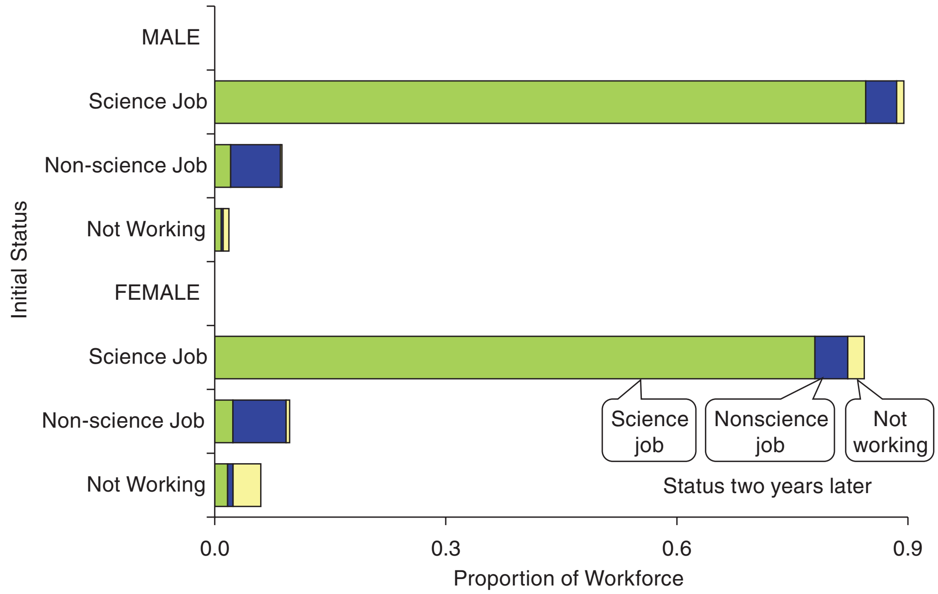

FIGURE D-20 Proportional distribution of the workforce by initial employment status and status two years later: pooled 1993-2006 estimates for all fields combined, by sex.
SOURCE: Data extracted from National Science Foundation Survey of Doctorate Recipients, 1993-2006.

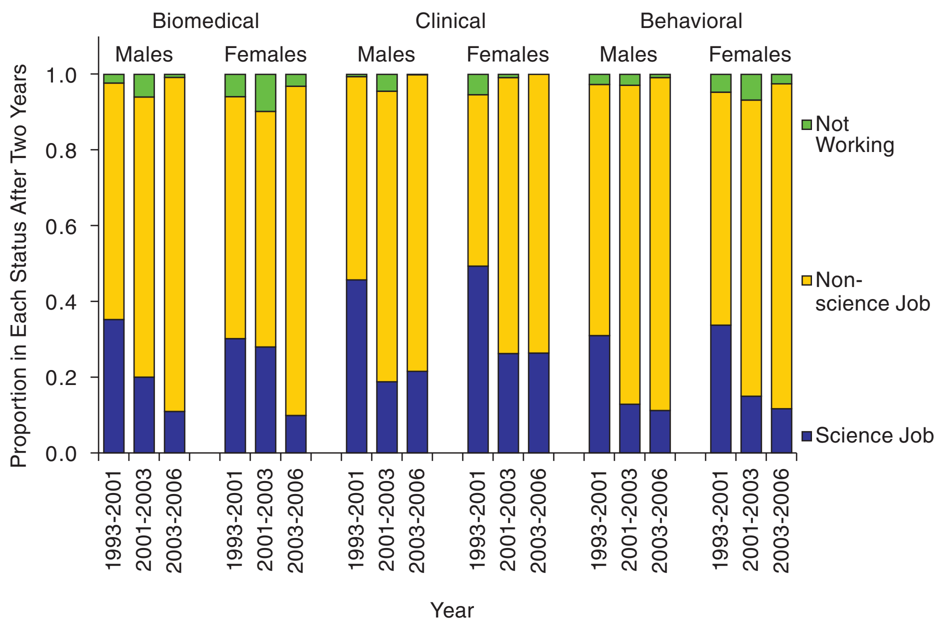

FIGURE D-21 Proportional distribution two years later of those in nonscience jobs, by major field and sex, selected periods.
SOURCE: Data extracted from National Science Foundation Survey of Doctorate Recipients, 1993-2006.

survey of the Ph.D. workforce, and 2016. We estimate the likely entrants in this period and allow the workforce to age, so a certain number retire or die. We run these calculations by age and sex, so we can see how the demographic composition of the workforce will change. In order to determine how many will probably be engaged in scientific work, we also model transitions into and out of science jobs. We focus on Ph.D.s, both U.S.- and foreign-trained, leaving out M.D.s with research interests, for whom recent data have not been released.

The base for the projection is the research workforce in 2006, distributed by major field, age, sex, and employment status. The survey gives two-year age groups, and in order to facilitate annual projections, we divide each age group in two, not equally but proportional to the size of the neighboring age groups.

Graduates

Among entrants to the workforce, U.S.-trained Ph.D. graduates, should they increase as they have since around 2005 or, even more, in the early 1990s, should see fairly rapid growth in their numbers. However, a reversal could set in, as it did around 2000-2002, leading to much slower growth or even decline. Or the long-term trend since the 1970s or 1980s could reassert itself. We define future trends to represent this range of possibilities. The period from 1988-1992 to 1993-1997 will be used to represent rapid growth in graduates and the period from 1996-2000 to 2001-2005 to represent slow (or no) growth. The average between rapid and slow growth rates, thus defined, will be taken to represent a medium growth trend.

Table D-2 shows the estimated growth rates. The rapid or high growth estimates are close to, although short of, the highest levels since 1990 (see Figure D-9), and similarly the slow or low estimates are close to but not as low as the lowest levels. Medium rates come close to the long-term growth rates since 1970 for biomedical and clinical graduates, and since 1980 for behavioral graduates (for whom a 1970s growth spurt has never been duplicated).

Under these assumptions, biomedical graduates could rise from 6,500 in 2006 to anywhere from 7,100 to 10,300 by 2016 (Figure D-22). Behavioral graduates, who were two-thirds as numerous as biomedical graduates in 2006, would increase at most 13 percent by 2016 or possibly even decrease a little. Clinical graduates would increase the fastest and could, in the right combination of circumstances, almost catch up with behavioral graduates. From 44 percent as numerous as behavioral graduates in 2006, they would rise to at least 57 percent and as much as 94 percent of behavioral graduates by 2016.

To project changes in gender composition of Ph.D. graduates, we linearly extrapolate the trends in the sex ratios from 1995 to 2007 (Table D-3). In this projection, the sex ratio among biomedical graduates will hit 100, meaning equal numbers of both sexes, by 2010 or 2011. For the other two

TABLE D-2 Annual Growth Rates for Ph.D. Graduates in Three Major Fields, Selected Periods

Period	Biomedical	Clinical	Behavioral	Used to Project:
From 1988-1992 to 1993-1997	0.046	0.062	0.011	High growth
From 1996-2000 to 2001-2004	0.006	0.030	–0.011	Low growth
Mean of Preceding Estimates	0.026	0.046	0.000	Medium growth
For Comparison:				
From 1970 to 2007	0.023	0.054	0.012	
From 1980 to 2007	0.026	0.055	0.002	

SOURCE: NSF. 2007. National Science Foundation Survey of Earned Doctorates. Washington, DC: NSF.

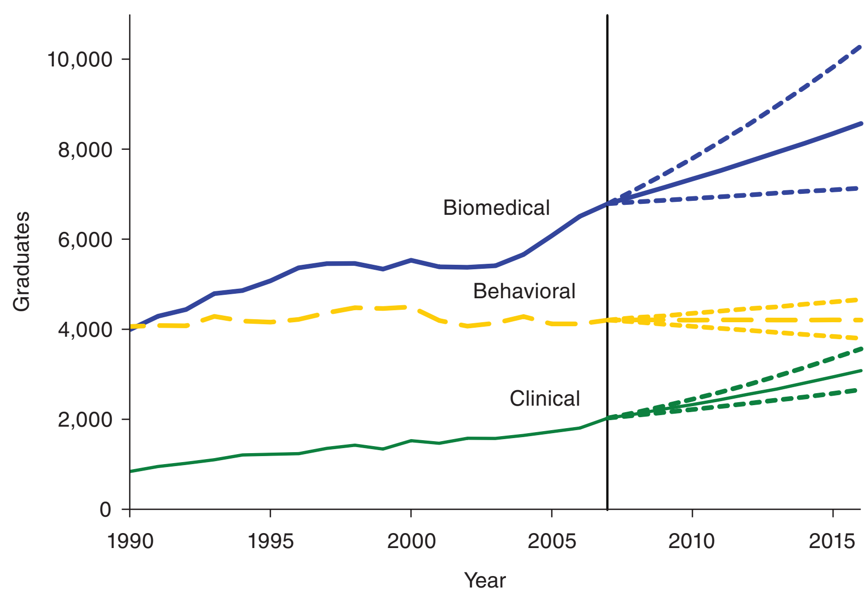

FIGURE D-22 Past and projected trends in Ph.D. graduates under high-, medium-, and low-growth assumptions, by major field, 1990-2016.
SOURCE: Data extracted from National Science Foundation Survey of Earned Doctorates, 2007, and NRC analysis.

TABLE D-3 Linear Regressions for Sex Ratio Among Graduates on Year, 1995-2007, by Major Field

Major Field	Intercept	B	t	R2
Biomedical	5370	–2.622	–10.44	0.908
Clinical	1582	–0.765	–3.64	0.546
Behavioral	2034	–0.990	–7.26	0.827

SOURCE: NRC Analysis.

fields, projected sex ratios are much lower and similar, falling to 40 by 2015 or 2016.

To represent the age distribution among graduates over time, we begin with the percentage distribution for the periods 1993-1997 and 2005-2007 in each field by sex. These distributions are smoothed to eliminate as much as possible alternating increases and decreases in percentages at successive ages. Assuming that changes in age distribution between these periods continue, we extrapolate to give projected age distributions (by field and sex) by 2020 and interpolate for intermediate years. Figure D-23 illustrates the results for male behavioral graduates, among whom median age, 35.2 in 1993-1997 and 34.4 in 2005-2007, would fall to 34.1 in 2015 and 33.9 in 2020.

We need to model changes in the proportion of the graduates who will be temporary residents rather than citizens or permanent residents, since temporary residents are less likely to enter the U.S. workforce. Given the fluctuations in this proportion over time, we select data for particular time periods to give alternatives. Data for the period 1995-2007 give moderate future projections, 2000-2007 data give high projections, and 1990-2007 data give low projections (except for female clinical graduates, for whom we substitute the period 2004-2007). The projections are defined from linear regressions on the logits for the annual proportions in these periods who were temporary residents, separately for males and females in each major field. The resulting projected proportions of temporary residents by 2020 are in Table D-4.

We rely on stated intentions to stay in the United States to determine the proportion of graduates entering the U.S. workforce. For U.S. citizens and permanent residents, we use constant "stay rates" that are the average, by field and sex, of intentions for 2005-2007—i.e., 96-97 percent for each group. For temporary residents, uncertainties about future immigration policy, the job market, and opportunities elsewhere suggest the need for alternatives. The simplest alternative is for stay rates to remain at recent levels, and to represent this we use average 2005-2007 rates for each group by sex and field. Stay rates could also revert to previous lower levels. Average rates for 1993-1997 are used to represent this possibility. Finally, rates could continue their secular rise. We use linear regressions from 1990 to project what rates could be in 2020. For biomedical graduates, however, this would give rates exceeding 100 percent, so instead we use the more moderate trend for 2000-2007. Table D-4 also shows the projected stay rates in 2020 estimated by these methods.

The combination of these varying stay rates for temporary residents and the proportions of them among graduates affects the total numbers of graduates entering the U.S. workforce. However, the effect is small. Relative to projections using medium-variant parameters, the number of graduates entering the workforce in 2016 would be only 1-3 percent higher (varying by field) given the most favorable combi-

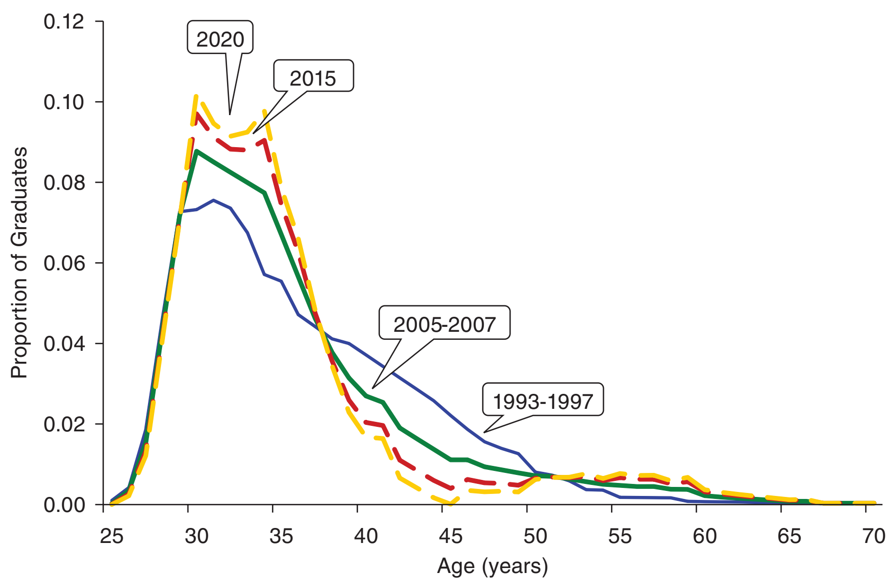

FIGURE D-23 Past and projected age distribution of male behavioral graduates, selected years.
SOURCE: Data extracted from National Science Foundation Survey of Earned Doctorates, 2007, and NRC analysis.

TABLE D-4 Latest and Projected Proportions of Graduates Who Are Temporary Residents and Stay Rates (Proportions of Graduates Who Plan to Stay in the United States) by Citizenship Status, and by Field and Sex

	Biomedical		Clinical		Behavioral	
Status	Male	Female	Male	Female	Male	Female
Proportion of Temporary Residents Among Graduates						
2007	0.320	0.287	0.337	0.181	0.107	0.092
2020, low	0.352	0.360	0.308	0.244	0.112	0.104
2020, mediium	0.414	0.463	0.340	0.255	0.120	0.142
2020, high	0.434	0.514	0.438	0.271	0.180	0.196
Stay Rates, U.S. Citizens and Permanent Residents						
2007	0.974	0.971	0.968	0.972	0.959	0.972
2020	0.969	0.968	0.966	0.973	0.965	0.974
Stay Rates, Temporary Residents						
2007	0.878	0.866	0.754	0.651	0.672	0.646
2020, low	0.763	0.763	0.615	0.464	0.421	0.468
2020, mediium	0.878	0.873	0.734	0.640	0.629	0.650
2020, high	0.917	0.899	0.851	0.757	0.745	0.809

SOURCE: NRC Analysis.

nation of assumptions or 3-4 percent lower given the least favorable. The varying assumptions do have a greater effect on the proportion, among the graduates entering the workforce, who are temporary residents (Figure D-24). Whether, and if so how long, they remain temporary residents, we do not attempt to predict.

Foreign-Trained Ph.D.s

The estimates of immigrant flow described above were projected forward, first to adjust estimates of stock in 2003 and 2006 (and to provide stock estimates for 2001) and then to provide estimates of flow through 2016. The procedure involved several steps.

1. We projected 1990-2000 trends in estimated immigrant cohorts beyond 2000. For male biomedical scientists, based on a linear regression, we assumed 2,850 migrants in 2001, increasing by 190 annually thereafter. For female biomedical scientists, we assumed 2,410 migrants in 2001, increasing by 130 annually thereafter. For the other groups, 1990-2000 flow numbers (combined with five-year estimates for the early 1980s and late 1980s) fluctuated too much—from over 1,000 down to zero from one year to the next—to permit the

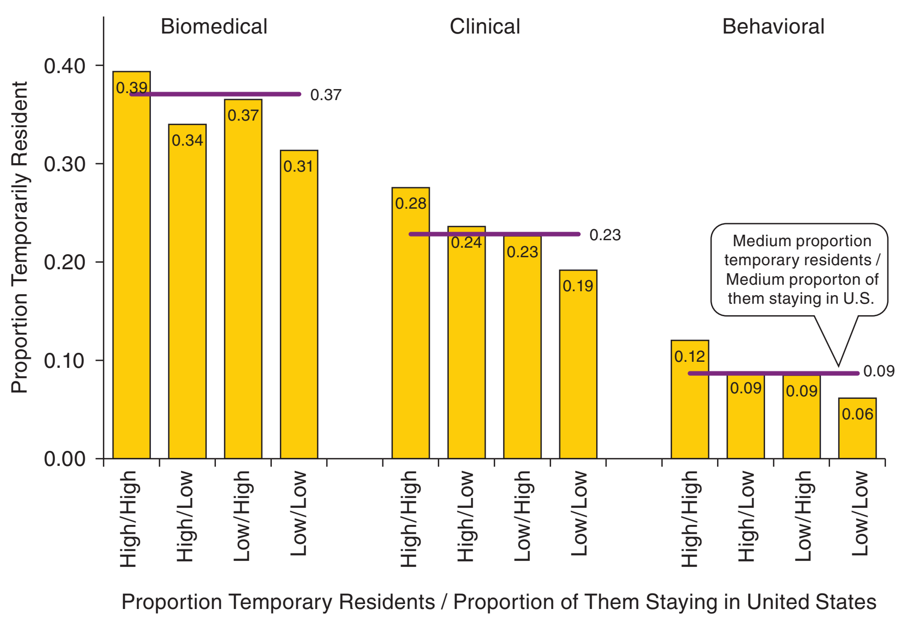

FIGURE D-24 Proportion temporarily resident among graduates entering the workforce in 2016, under various assumptions.
SOURCE: NRC analysis.

extrapolation of trends. We took the average for 1990-2000 and assumed that migrants stay constant at this level, which was 450 annually for male clinical scientists, 470 for female clinical scientists, 130 for male behavioral scientists, and 150 for female behavioral scientists.

2. With the survival rates used is estimating the earlier inflows, we determined how many of each cohort entering after 2000 survived to 2003 and to 2006, and added them to the survey estimates. (We also made estimates, using the entire flow rather than just post-2000 entrants, for 2001.) As part of this calculation, we multiplied the numbers reported in each survey for the 2000 migrant cohort by four, to allow for the fact that the census, dated April 1, 2000, would have covered migrants only in the first quarter of the year. (This adjustment was incorporated in the flow numbers.)

3. We distributed the resulting foreign-trained stock by employment status in 2003 and 2006, relying on proportions in the survey results, or, in a few cases at the extremes of the age distribution where data were sometimes lacking, on proportions for the U.S.-trained workforce.

4. Beyond 2006, we applied the same projected trends to give a medium projection. Alternative high and low projections of migrant inflows were made based on data for particular periods. For biomedical scientists, data for 1995-2000 suggested higher inflows, whereas including data from the 1980s suggested lower inflows. For the other groups, averages over 1990-1995 suggested higher inflows, and averages over 1995-2000 suggested lower inflows. Figure D-25 shows how these alternative projections compare among themselves and with the medium projection for U.S.-trained graduates. Much greater variation is possible in the biomedical field than in the other two fields. Only in the biomedical field, also, is there some possibility that migrants will actually outnumber graduates—and if the high projections for migrants and the medium projections for graduates prove correct, by a substantial margin.

Transitions

For exits from the workforce, as well as for movements between different employment statuses, we use only one set of parameters for each major field, each of them age- and sex-specific. Transition rates are therefore assumed not to change, although the numbers exiting and the numbers in different statuses should change as the composition of the workforce changes.

For future mortality rates, we use the TIAA-CREF mortality table. Mortality rates are applied to the age distribution before other movements are allowed. Unlike other assumed transition rates, mortality rates are assumed not to vary across fields.

Future retirement rates, as well as rates for moving between employment statuses, are derived from the biennial survey data from 1993 to 2003, plus the 2006 survey. The procedure to estimate rates involved these steps:

1. Each individual in two successive surveys is classified by status in both surveys. We sum the numbers in each compound category (e.g., employed in the first survey/retired in the second survey) across all surveys. In effect this gives slightly more weight to surveys with larger numbers, usually later surveys. For the 2003-2006 surveys, numbers are adjusted to allow for the fact that the period between surveys was extended to three years.

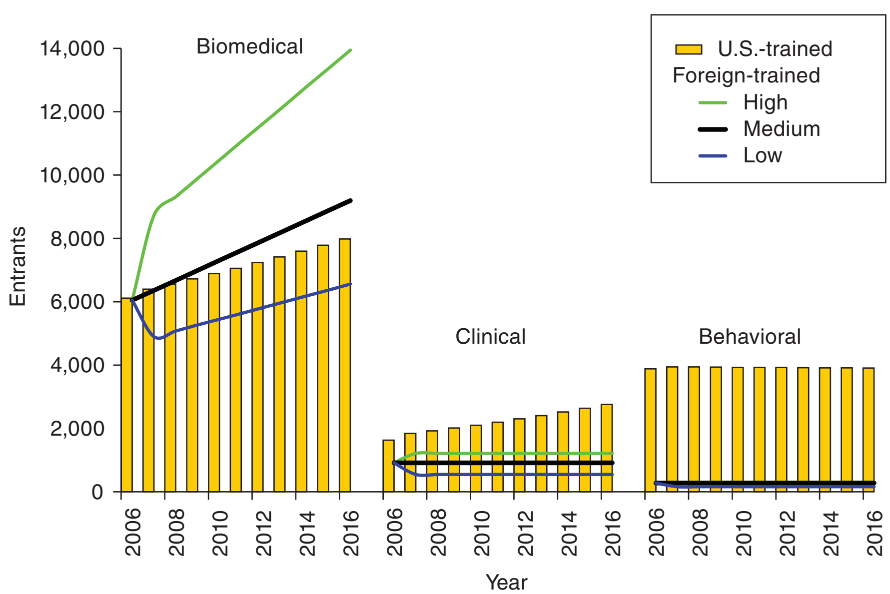

FIGURE D-25 Alternative projections of foreign-trained Ph.D.s entering the workforce (contrasted with medium projection for U.S.-trained graduates), by major field, 2006-2016.
SOURCE: NRC analysis.

2. From these pooled data, we calculate the proportion in each initial status ending up in every other status in two years. These proportions are estimated stepwise. First, we estimate the proportions retiring. Then, leaving out the proportions who have retired, we estimate the proportion of the remainder who become unemployed. Leaving out the retired and the unemployed, we estimate the proportion of the remainder who leave the labor force, followed, in similar fashion, by the proportion who take non-science jobs and the proportion who take employment in science. This stepwise procedure helps ensure that subsequent adjustments of the proportions will not result in total proportions deviating from 100 percent.

3. Each estimated proportion refers to a two-year cohort (e.g., 61-62 years old), and we apply the same proportion to each age. Each estimate x also applies to a two-year period (e.g., 1997-1998), and to estimate a proportion for each year, we use the formula $y = 1 - (1 - x)^{0.5}$.

4. To smooth some of the irregularities across ages, we use the average over five successive ages (or over three ages at the ends of the age distribution), except for the proportion retiring, which is not smoothed because we assume it to have specific peaks.

Scenarios

Alternative projection assumptions have been reviewed regarding four variables: numbers of graduates, proportion of them who are temporary residents, proportion of temporary-resident graduates who stay in the United States, and number of migrating foreign-trained Ph.D.s. To avoid having to sort among 81 different scenarios, we assemble four main scenarios from among these options.

First, a medium-growth scenario is defined as the medium variant regarding each of these variables. Second, a high-growth scenario is defined as the high variant regarding each variable, except for the proportion of graduates who are temporary residents. For this variable, we use the low variant, which leads to more rapid growth because fewer temporary residents means more citizen graduates, who are more likely to enter the U.S. workforce. Third, a low-growth scenario is defined as the low variant on each variable, except for the proportion who are temporary residents, for whom we take the high variant. Finally, to represent an extreme situation in which immigrants cease to arrive, we add a no-migrant scenario. The number of graduates is assumed to be low, the number of migrant foreign-trained Ph.D.s is taken as zero from 2010 on, the proportion of temporary residents among graduates is assumed to be high, and the proportion of them staying in the United States is assumed to be zero from 2008 on.

Table D-5 summarizes the scenarios by giving the projected numbers of graduates and immigrant Ph.D.s. We focus primarily on the medium scenario in the discussion and note what variations from it the alternative scenarios suggest.

PROJECTION RESULTS

In the medium scenario, the projected research workforce in 2016 will total 306,000 biomedical scientists, 64,000

TABLE D-5 Projected Numbers of Ph.D. Graduates and Immigrating Foreign-Trained Ph.D.s in Alternative Projections, by Major Field, 2006-2016

	Graduates			Immigrant Ph.D.s		
Projection and Year	Biomedical	Clinical	Behavioral	Biomedical	Clinical	Behavioral
Medium Projection						
2006	6,514	1,807	4,123	6,050	919	280
2007	6,793	2,028	4,208	6,363	918	281
2008	6,974	2,122	4,210	6,676	918	281
2009	7,154	2,230	4,212	6,993	918	281
2010	7,344	2,327	4,205	7,311	918	281
2011	7,529	2,438	4,210	7,624	918	281
2012	7,731	2,558	4,210	7,938	918	281
2013	7,933	2,673	4,208	8,253	918	281
2014	8,137	2,809	4,206	8,569	918	281
2015	8,351	2,943	4,210	8,885	918	281
2016	8,575	3,084	4,207	9,198	918	281
High Projection						
2006	6,514	1,807	4,123	6,050	919	280
2011	8,174	2,605	4,406	11,063	1,214	299
2016	10,302	3,567	4,663	13,951	1,214	299
Low Projection						
2006	6,514	1,807	4,123	6,050	919	280
2011	6,946	2,287	4,022	5,634	551	165
2016	7,141	2,660	3,800	6,564	551	165

SOURCE: NRC Analysis.

clinical scientists, and 137,000 behavioral scientists, up from 2006 figures of 190,000, 41,000, and 126,000 respectively. Workforce growth will be substantial in the biomedical and clinical fields: 61 percent and 58 percent respectively over the entire period. In the behavioral field, however, growth will be only 9 percent (Table D-6).

Characteristics

The biomedical workforce will grow considerably faster than biomedical Ph.D. graduates—at a rate of 4.8 percent annually rather than just 2.7 percent—which will not be true in the other two fields. In the biomedical field, migrant foreign-trained Ph.D.s will help swell the workforce (Figure D-26). The number of foreign-trained biomedical scientists, already three times the number of foreign-trained clinical and behavioral scientists combined, will be more than four times the combined number in 2016. They will make up 43 percent of all biomedical scientists.

Overall, clinical scientists will increase almost as fast (at 4.6 percent annually), mainly due to an increase in U.S. graduates twice as rapid as in the biomedical sciences. The increase in foreign-trained clinical scientists will be slower but still rapid at 3.6 percent annually, and by 2016 the foreign-trained will be 37 percent of all clinical scientists.

Among behavioral scientists, growth will be slow, at 0.9 percent annually, for a 10-year increment of 11,000 behavioral scientists, only half the increment of clinical scientists and one-tenth the increment of biomedical scientists. Relative to behavioral Ph.D. graduates, whose rate of increase

TABLE D-6 Projected Workforce in Three Major Fields, by Sex, 2006-2016

	Biomedical			Clinical			Behavioral		
Year	Total	Male	Female	Total	Male	Female	Total	Male	Female
2006	189,860	122,754	67,106	40,511	18,291	22,220	125,794	59,639	66,155
2007	200,233	128,207	72,026	42,705	19,062	23,643	127,965	59,703	68,262
2008	210,841	133,711	77,130	44,945	19,819	25,126	129,836	59,609	70,227
2009	221,648	139,267	82,381	47,196	20,560	26,636	131,355	59,307	72,048
2010	232,755	144,943	87,812	49,488	21,295	28,193	132,668	58,900	73,768
2011	244,224	150,782	93,442	51,779	22,011	29,768	133,923	58,505	75,418
2012	255,970	156,677	99,293	54,089	22,732	31,357	134,975	57,978	76,997
2013	267,958	162,603	105,355	56,443	23,464	32,979	135,770	57,245	78,525
2014	280,194	168,594	111,600	58,836	24,215	34,621	136,370	56,430	79,940
2015	292,748	174,702	118,046	61,294	24,995	36,299	136,867	55,632	81,235
2016	305,571	180,876	124,695	63,808	25,771	38,037	137,221	54,752	82,469

SOURCE: NRC Analysis.

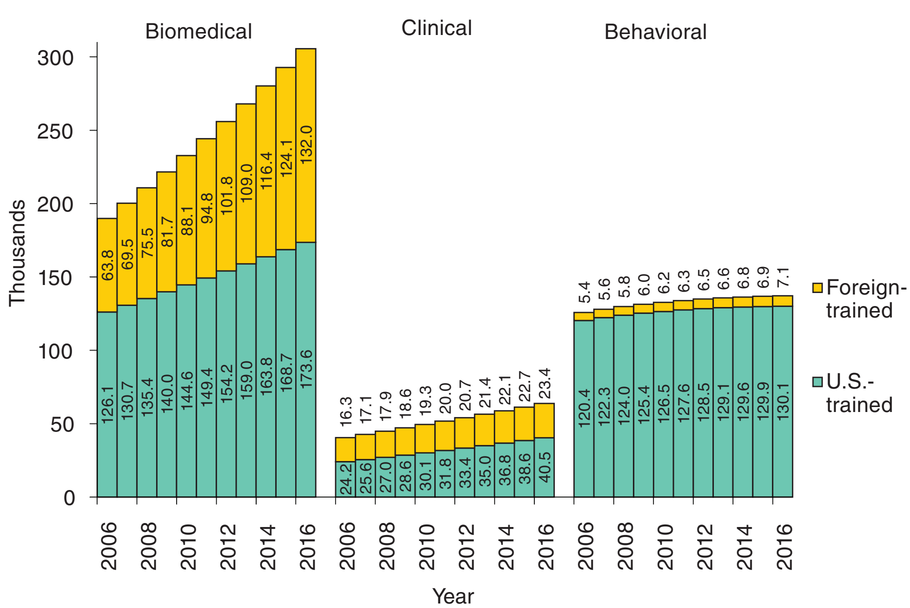

FIGURE D-26 Workforce projections by major field and source of Ph.D., 2006-2016 (thousands).
SOURCE: NRC analysis.

will be an anemic 0.2 percent annually, the foreign-trained will show a respectable rate of growth of 2.7 percent annually, but from a very low level.

The research workforce in each field will be considerably more female than in 2006. Sex ratios in the clinical and behavioral fields—82 and 90 per 100, respectively, in 2006—will be almost identical—68 and 66 in 2016. The sex ratio in the biomedical field, about twice as high as in the other fields in 2006, will also fall by 2016, to 145. The foreign-trained will make different contributions to these changes (Figure D-27). The sex ratio among foreign-trained biomedical scientists is higher than among the U.S.-trained, and although it will decline will remain higher. In the clinical field, the situation is similar, although the gap between the sex ratios among foreign-trained and U.S. trained is and will remain larger. In the behavioral field, the situation is to a degree reversed, with higher sex ratios among the U.S.-trained coming down and by 2016 approximating the constant and low sex ratios among the foreign-trained.

Another perspective is provided by comparing sex ratios in the workforce with sex ratios among potential entrants (Figure D-28): U.S. graduates and immigrants. Sex ratios

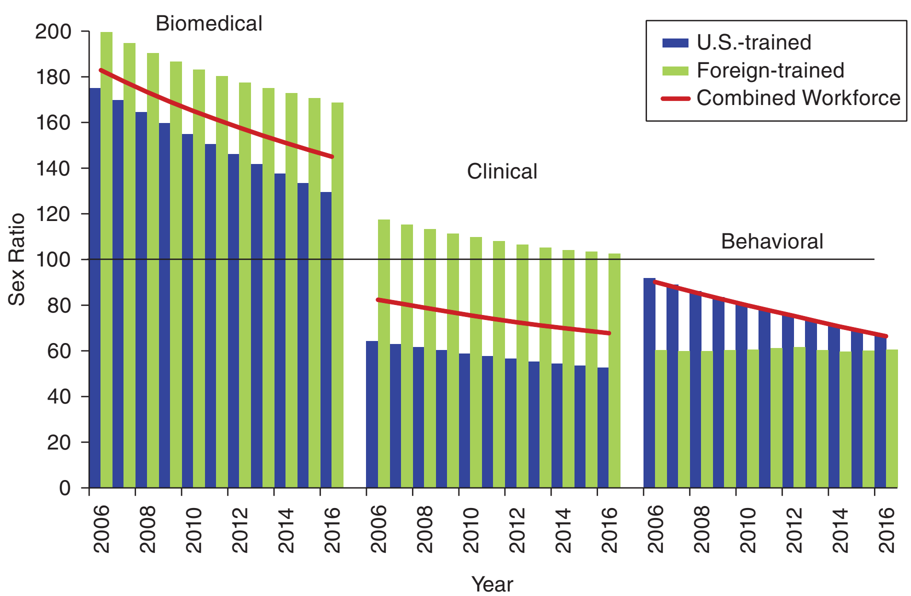

FIGURE D-27 Projected sex ratio by major field and source of Ph.D., 2006-2016.
SOURCE: NRC analysis.

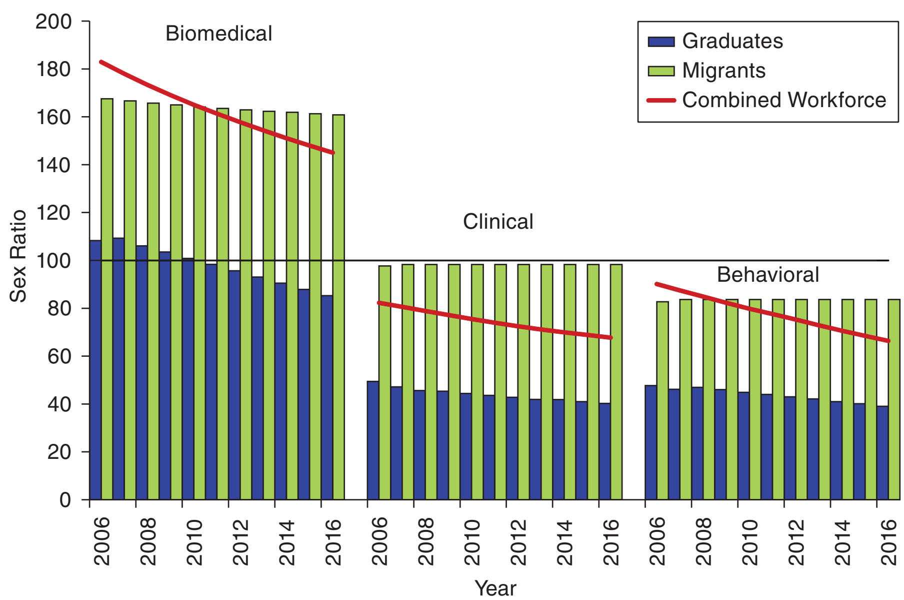

FIGURE D-28 Projected sex ratio of workforce and potential entrants by major field, 2006-2016.
SOURCE: NRC analysis.

among immigrants will be essentially constant (which is expected at least among clinical and behavioral scientists given our assumption of a constant flow). Among U.S. graduates, however, sex ratios will be falling in each field. They are already well below sex ratios in the workforce as a whole—35 to 60 points below—and by 2016 will be 45 to 75 points below, with the greatest gap in the biomedical field. A predominantly male biomedical professoriate, therefore, will be training a majority female student body.

Median ages among behavioral scientists will rise, but in the other two fields, trends will be less clear. Male behavioral scientists, already the oldest in 2006 with a median age of 54.7 years, will become older still, reaching a median of 57 years by 2016. The median age among female behavioral scientists will also rise, from 49.2 to 49.9 years. The median age is lowest among female biomedical scientists, at 41.6 years, and will inch upward to 41.9 years. At the same time the median age for male biomedical scientists will be falling, from 47 to 46.4 years. Trends in median age among clinical scientists will also provide a contrast between males and females, although the trends will not be linear. Among males, median age will rise and then fall; among females it will fall and then rise, in neither case producing much net change.

Some of the complications in age trends are due to differences between U.S.-trained and foreign-trained scientists (Figure D-29). The foreign-trained have been younger than the U.S.-trained in each field and have helped keep the median age down. Median age is projected to rise among the foreign-trained in most cases, however. At the same time, median age should fall among the U.S.-trained biomedical and clinical scientists, while it rises among behavioral scientists.

The aging of the workforce will be most notable among behavioral scientists, among whom the proportion 55 years and older will rise from 39 percent in 2006 to 44 percent in 2016. This proportion is much smaller in the other two fields and will rise only to 24 percent among biomedical scientists and 30 percent among clinical scientists (Figure D-30). Younger foreign-trained researchers clearly help keep ages down in the biomedical and clinical fields, although even without them, the workforce in these fields would be younger than in the behavioral field.

One consequence of having more older scientists is more retirements and deaths. The proportion retiring or dying annually will rise in each field, from a range of 1.2-1.6 percent of the workforce in 2007 to 1.4-2.8 percent in 2016. The proportion retiring or dying will be particularly high among male behavioral scientists, at 3.8 percent by 2016. Among male behavioral scientists, this number already exceeded the number of graduates actually entering the workforce in 2006 (leaving out those not intending to stay in the United States) and will be almost twice as numerous by 2016 (Figure D-31). The 3,800 behavioral scientists, both male and female, projected to retire or die in 2016 will be barely under the number of new Ph.D. graduates, which is projected at 4,200. This does not account for foreign-trained Ph.D.s, but they are few in the behavioral field.

The proportion of the workforce employed in science should stay roughly the same, about 80-85 percent in each field. The proportion working in non-science jobs should also stay at 12 percent in the biomedical field but could drop in the other two fields. It was slightly higher in the clinical field than in the biomedical field in 2006, at 17 percent, and could fall to 11 percent. It was also higher in the behavioral field, at 18 per-

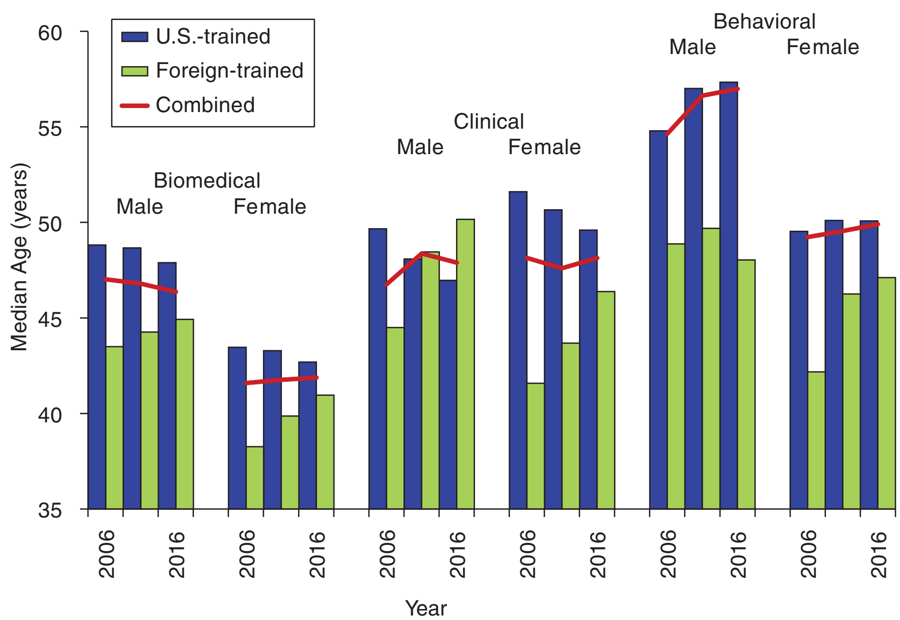

FIGURE D-29 Median age of projected workforce by major field, sex, and source of Ph.D., 2006-2016.
SOURCE: NRC analysis.

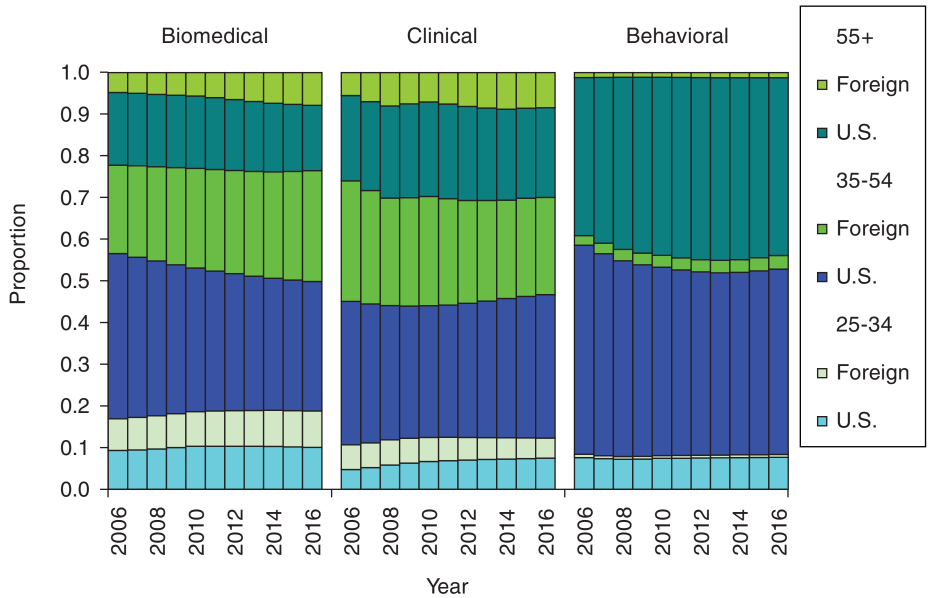

FIGURE D-30 Projected age distribution of the workforce by source of training and major field, 2006-2016.
SOURCE: NRC analysis.

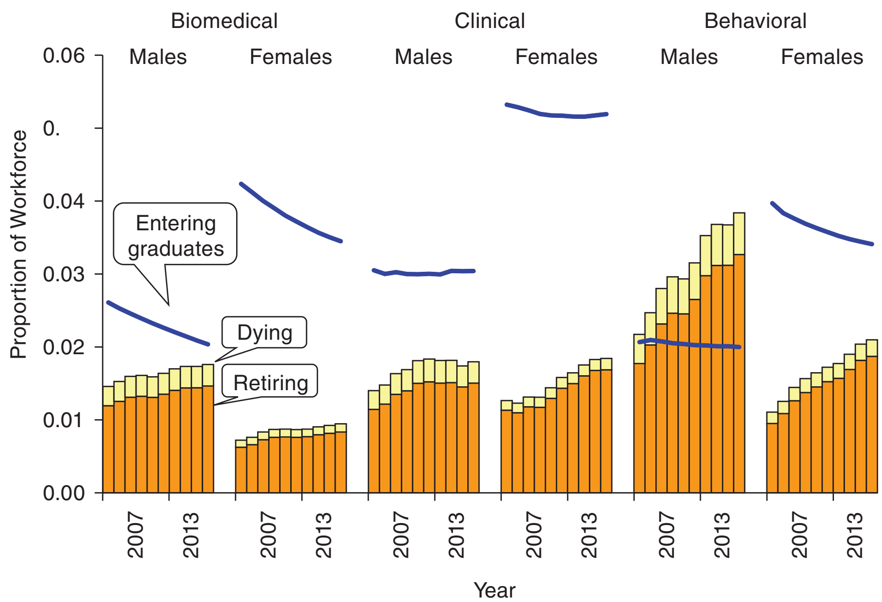

FIGURE D-31 Projected proportions dying and retiring, compared to entering graduates as a proportion of the workforce, by major field and sex, 2007-2016.
SOURCE: NRC analysis.

cent, and could fall to 15 percent. Since transition rates among these statuses were based on rates over more than a decade and not allowed to change, one would expect quite recent changes in transition rates, such as the mid-2000s, increase in proportion out of science, to be reversed to some degree.

The greatest proportional change in employment status could involve the proportion not in the labor force. This small segment of the workforce, between 1.5 and 3 percent of the workforce in 2006, could grow 50-250 percent faster than those employed in science. The greatest increase will be in the biomedical field (Figure D-32). The obvious explanation is the growing proportion of women in the workforce. Although this factor should have a role, decomposition of the change suggests it is not the main explanation. In the biomedical field, it is due instead to a projected change among women themselves. Between 2003 and 2006, the proportion out of the labor force among female biomedical scientists fell by a third, from an unusually high 7.5 percent to a still very

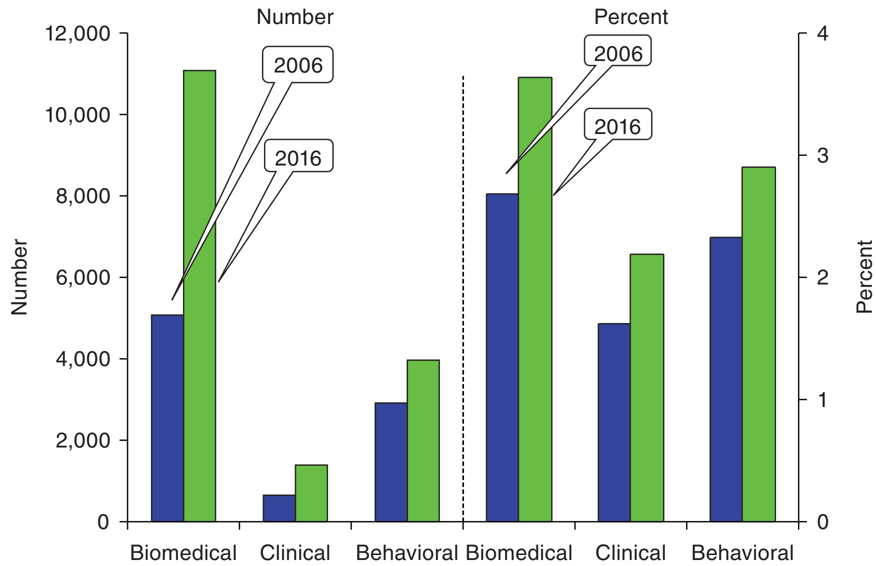

FIGURE D-32 Projected number and percentage of the workforce not in the labor force by major field, 2006 to 2016.
SOURCE: NRC analysis.

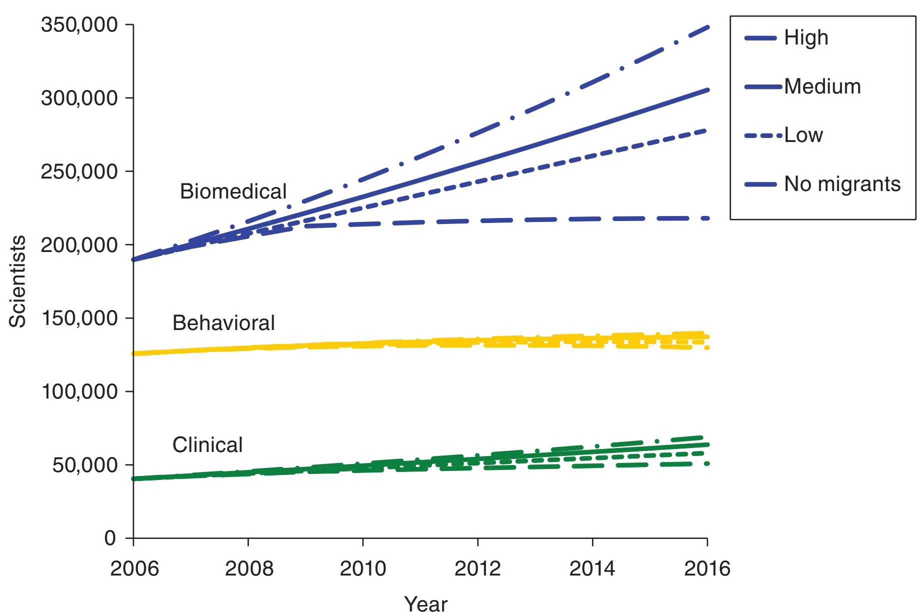

FIGURE D-33 Alternative workforce projections by major field, 2006-2016.
SOURCE: NRC analysis.

high 5.0 percent. With no evidence that this is the start of a long-term trend or even a long-term downward adjustment, we have allowed rates to return to previous levels, which accounts for the major part of the increase in those not in the labor force in this field.

Alternative Scenarios

The alternatives to the medium scenario provide much more variation in the biomedical field than in the other two fields (Figure D-33). The medium scenario gives almost identical 61 percent and 58 percent increases in the workforce between 2006 and 2016 in the biomedical and clinical fields. The high scenario gives an increase in the biomedical field of 84 percent, 23 percentage points higher than the medium scenario (Figure D-34). In the clinical field, the high scenario gives an increase that is only 13 percentage points higher than the medium scenario. In the behavioral field, the medium 10-year increase is only 9 percent, and the high scenario gives an increase only 2 percentage points higher.

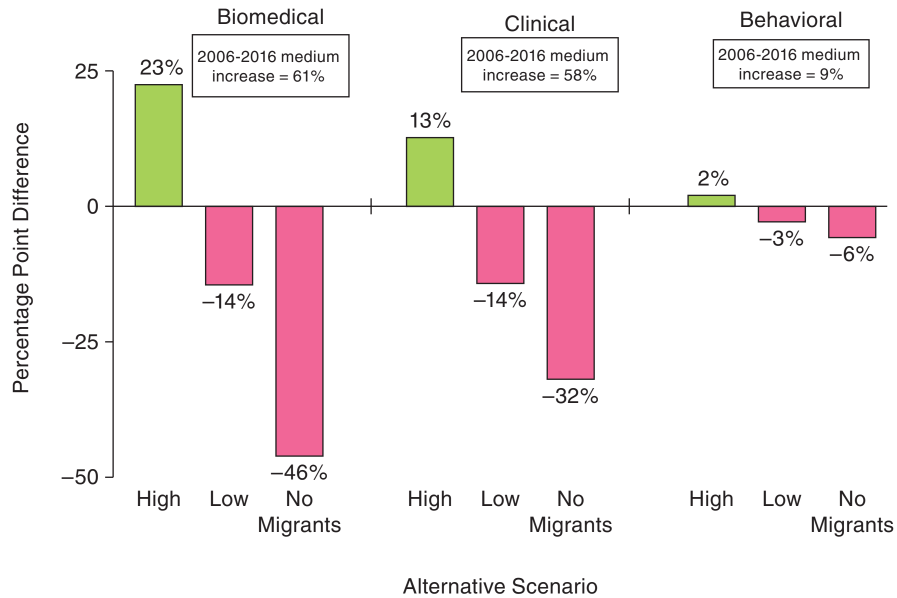

FIGURE D-34 Difference of alternative scenarios from the medium projection in percentage change from 2006 to 2016, by major field.
SOURCE: NRC analysis.

On the other side of the ledger, the low scenario gives a 14 percentage point lower increase in both the biomedical and clinical fields than the medium scenario and a 3 percentage point lower increase in the behavioral field.

One could of course select arbitrarily symmetrical alternative scenarios, but the ones chosen are derived from some past experience with inflows and outflows, and therefore presumably represent more realistic possibilities. The range of past growth rates has been narrower in the clinical field in the past than in the biomedical field, and still narrower in the behavioral field, which is why the scenarios for biomedical researchers produce much more variation.

An extreme scenario has migrant inflows ending and temporary-resident graduates all deciding to work overseas. Combined with the low projection for total graduates, this would produce larger reductions relative to the medium projection, as much as 46 percentage points lower in the biomedical field. But the workforce would still grow in each field.

Could an increase in graduates make up for the hypothesized lack of immigrants in this scenario? We have not assessed the factors that might make a substantial increase in graduates possible, such as faculty, funding, and student interest. We can, however, assess whether this is likely given past trends in graduates, as reflected in the different projection scenarios. Comparing scenarios suggests that, absent an ahistorical boost in graduates, they would not increase enough to fill all the niches that immigrants would potentially leave vacant. Figure D-35 compares additional alternative scenarios with the medium scenario, showing how percentage growth between 2006 and 2016 would be greater or smaller under different combinations of immigrant and graduate growth. Except in the behavioral field, where the foreign-trained workforce is only a small percentage of the total, the variation between high and low numbers of graduates has a smaller effect on the projected workforce than the variation between high and low numbers of immigrants. And high numbers of graduates would clearly not make up for zero immigrants. Still, because zero immigration is in fact an ahistorical situation, one cannot entirely rule out an ahistorical increase in graduates that goes beyond past trends.

The proportion who will be foreign-trained varies in different scenarios, especially in the biomedical field (see Figure D-36 and Table D-7). In the high projection for biomedical scientists, the foreign-trained would reach almost half of the total by 2016, in the low scenario only 40 percent. In the no-migrant scenario, there will still be foreign-trained researchers, because we assume that immigration does not cease until 2010, and in addition do not assume that foreign-trained researchers already in the United States all emigrate. By 2016, they would still be 32 percent of the total. In the clinical field, the proportion foreign-trained in 2016 varies in a more limited range, from 38 percent to 31 percent (in the no-migrant scenario), and in the behavioral field the variation is even more limited.

Across the different scenarios, variations in projected sex ratios are relatively slight. The greatest variation will be in the biomedical field in 2016, when the sex ratio could range from 149 to 138. Variation in age will be somewhat greater.

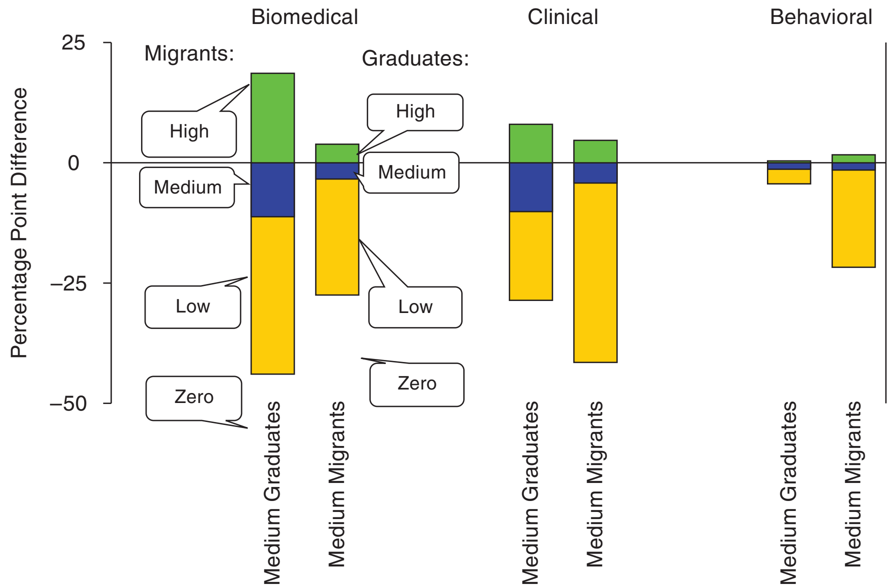

FIGURE D-35 Difference of other projections from the medium projection in percentage change from 2006 to 2016, by major field.
SOURCE: NRC analysis.

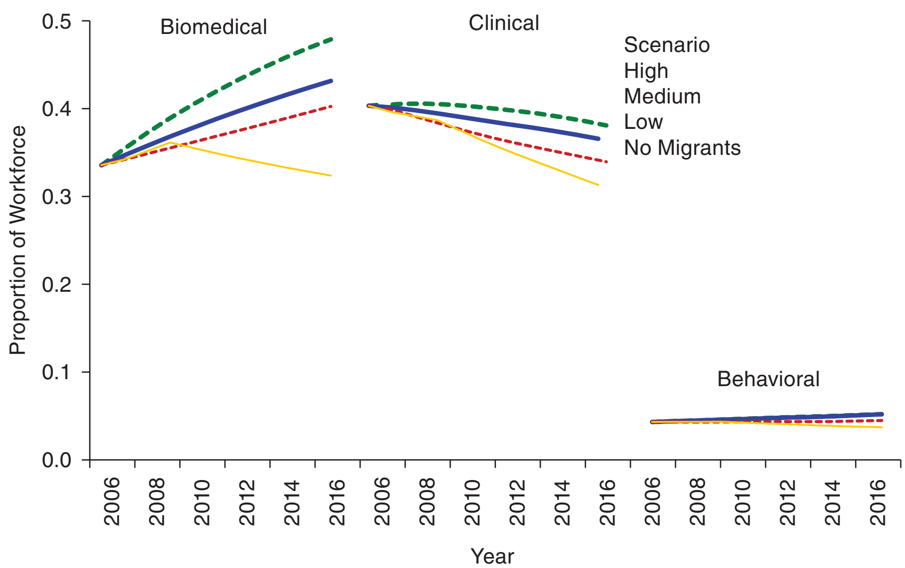

FIGURE D-36 Foreign-trained Ph.D.s as a proportion of the workforce in alternative scenarios, by major field, 2006-2016.
SOURCE: NRC analysis.

In general, more rapid growth implies a younger workforce. Regardless of the scenario, however, behavioral scientists will be older in 2016 than in 2006 (Figure D-37). Clinical scientists will also be older in almost every scenario. But biomedical scientists could be younger in 2016, under the high or medium scenarios, or older, under the low or no-migrant scenarios. When scientists are divided by field and sex, four of the six groups are not that different in current and projected median age. The exceptions are male behavioral scientists, who are clearly older and will get older still, and female biomedical scientists, who are clearly younger and will not catch up in age to any other group in any scenario.

Will Growth Be Adequate?

What workforce growth would be enough to maintain the research infrastructure in various disciplines, to nurture sufficient scientific discovery, and to allow for new disciplines to develop within each field? This would require much more information, as well as value judgments about what is suf-

TABLE D-7 Alternative Workforce Projections by Major Field and Source of Training, 2006, 2011, and 2016

Projection and Year	Biomedical Total	Biomedical U.S.-Trained	Biomedical Foreign-Trained	Clinical Total	Clinical U.S.-Trained	Clinical Foreign-Trained	Behavioral Total	Behavioral U.S.-Trained	Behavioral Foreign-Trained
Medium Projection									
2006	189,860	126,098	63,762	40,511	24,165	16,347	125,794	120,354	5,439
2011	244,224	149,367	94,848	51,779	31,754	20,025	133,923	127,584	6,339
2016	305,571	173,588	131,986	63,808	40,454	23,351	137,221	130,100	7,120
High Projection									
2006	189,860	126,098	63,762	40,511	24,165	16,347	125,794	120,354	5,439
2011	260,153	150,901	109,241	53,660	32,161	21,500	134,533	128,106	6,428
2016	348,292	181,402	166,896	68,966	42,676	26,288	139,804	132,510	7,293
Low Projection									
2006	189,860	126,098	63,762	40,511	24,165	16,347	125,794	120,354	5,439
2011	234,116	147,791	86,319	49,536	31,339	18,198	132,802	127,037	5,766
2016	278,070	166,087	111,985	58,046	38,320	19,723	133,653	127,658	5,994
No-migrants Projection									
2006	189,860	126,098	63,762	40,511	24,165	16,347	125,794	120,354	5,439
2011	215,341	140,073	75,261	47,036	29,936	17,099	131,381	125,945	5,437
2016	218,034	147,388	70,645	50,887	34,942	15,941	129,988	125,134	4,853

SOURCE: NRC Analysis.

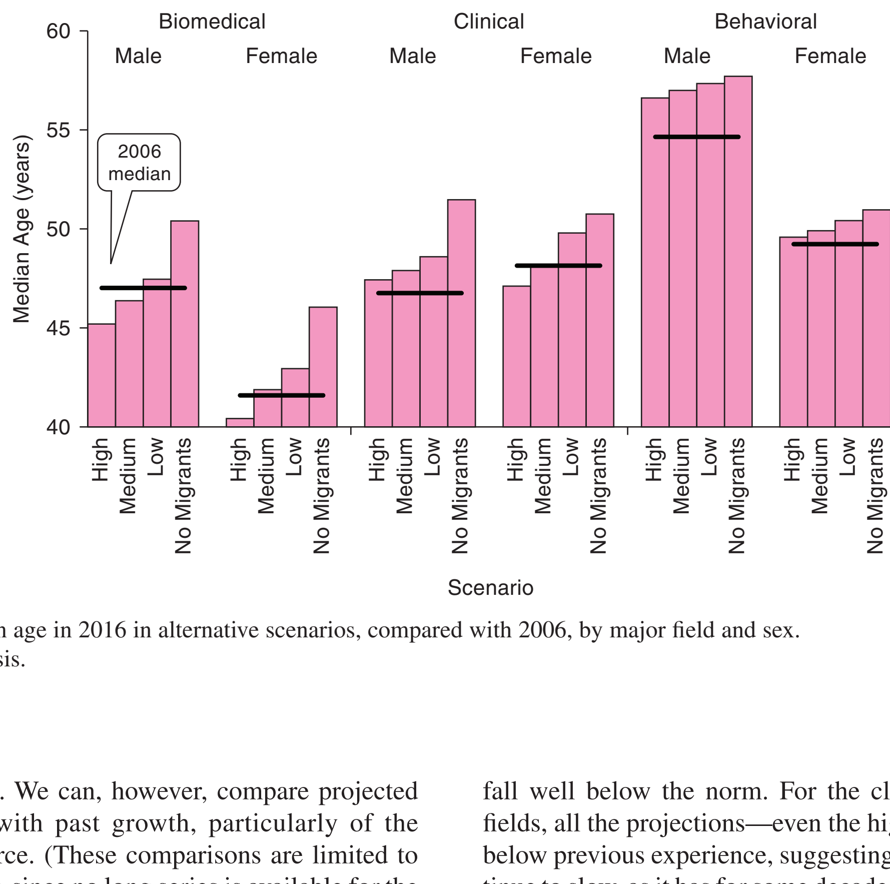

FIGURE D-37 Median age in 2016 in alternative scenarios, compared with 2006, by major field and sex.
SOURCE: NRC analysis.

ficient, to determine. We can, however, compare projected workforce growth with past growth, particularly of the U.S.-trained workforce. (These comparisons are limited to the U.S.-trained only, since no long series is available for the foreign-trained.) As Figure D-38 shows, in the biomedical field projected growth is roughly in the range of percentage increases in the U.S.-trained workforce in previous decades, except for the zero migrant scenario, in which growth would fall well below the norm. For the clinical and behavioral fields, all the projections—even the high scenario—are well below previous experience, suggesting that growth will continue to slow, as it has for some decades, although not stop. A possible hypothesis is that these fields are maturing or have matured, and would need striking and expansive new ideas to reenter a rapid-growth phase.

Research funding levels are of course highly relevant

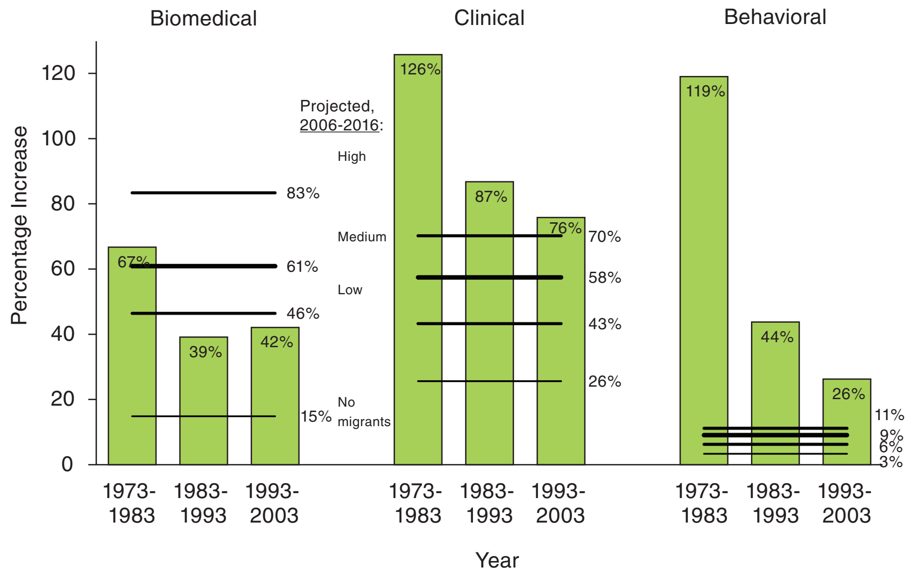

FIGURE D-38 Percentage increases in the U.S.-trained workforce in past decades and alternative projections for the entire Ph.D. workforce for 2006-2016, by major field.
SOURCE: NRC analysis.

to the question of whether the projected workforce will be adequate. In 2003, total U.S. funding for biomedical research—from the NIH and other government sources, industry, and foundations and other private sources—totaled $75.5 billion.[2] If this were distributed equally among Ph.D.s in the three major fields combined, research funds would amount to $232,000 per researcher. The 2006 total of $93.4 billion would imply $262,000 per researcher in that year. This was an apparent increase in funds per researcher of 13.3 percent in three years, but, if one adjusts for rising research costs (using the Biomedical Research and Development Price Index[3]), the increase is reduced to a trivial 0.4 percent. In this period at least, workforce growth and research funding kept pace with each other.

This may not always have been the case. From 1994 to 2003, total U.S. research funding grew at an annual rate of 7.5 percent (adjusted for changing research costs).[4] Figure D-39 shows this earlier trend (expressed as an index, with 2003 levels set to 100), distinguished from the trend since 2003 because data sources differed and gave somewhat higher estimates. In 1994-2003, the U.S.-trained biomedical workforce grew at a rate of 3.5 percent, and the clinical workforce at 5.5 percent. Foreign-trained researchers might have made up the gap, but we do not have adequate data before 2001 to determine this. That some correspondence was maintained between research funding and the workforce is suggested by the fact that funding, in the 1994-2003 period, shifted to some degree from basic biomedical research to clinical research,[5] at the same time that the clinical workforce appeared to be growing faster than the biomedical workforce (at least where U.S.-trained Ph.D.s are concerned).

Whether projected workforce growth keeps pace with research funding depends on the trend in funding. Biomedical Ph.D.s are projected to increase 4.8 percent from 2006 to 2016, clinical Ph.D.s, 4.5 percent. Both these estimates are lower than the annual funding growth rate (adjusted for research costs) of 7.5 percent in 1994-2003 but higher than the more recent growth rate of 3.4 percent in 2003-2007. Since the 3.4 percent rate predates the great recession, one might expect funding growth up to 2016 to slow even further. The additional $8.6 billion from the American Recovery and Reinvestment Act of 2009 provides a short-term boost for 2009 and 2010,[6] but even adding $4.3 billion more for every year thereafter on top of an annual 3.4 percent increase would raise the funding growth rate only to 3.7 percent.

The implication appears to be that growth in the biomedical and clinical workforces will somewhat exceed growth in research funding, if funding growth (in real rather than constant dollars) follows or falls short of the growth rate for 2003-2007. The reverse situation, where funding grows faster than the workforce, may be understandable, but diminishing research funding per capita would seem to be an uncomfort-

[2] Dorsey, E.R., et al. 2010. Funding of U.S. biomedical research, *JAMA* 303(2):137-143.

[3] National Institutes of Health, Office of Budget. 2010, *Biomedical Research and Development Price Index (BRDPI).* Available at: http://officeofbudget.od.nih.gov/gbiPriceIndexes.html.

[4] Moses, H. III, et al. 2005. Financial anatomy of biomedical research. *JAMA* 294(11):1333-1342.

[5] Ibid., pp. 1336-1337.

[6] This includes $8.2 billion for the NIH for extramural scientific research and $0.4 billion for AHRQ for comparative effectiveness research, according to NIH, 2010, PowerPoint presentation on NIH Implementation of ARRA, available at: http://grants.nih.gov/recovery/.

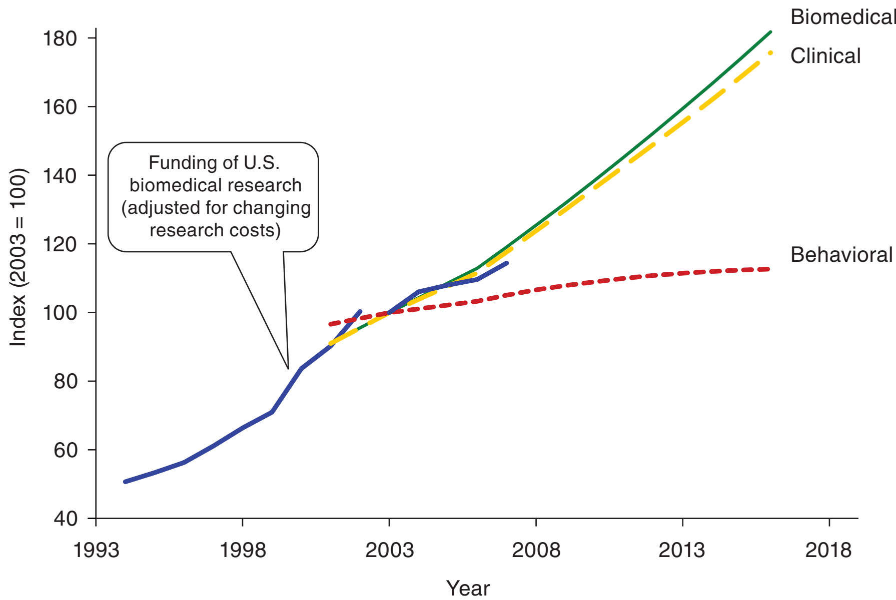

FIGURE D-39 Index of research funding compared with indexed past and projected growth of the research workforce (2003 = 100).
SOURCES: Moses, H. III, et al. 2005. Financial anatomy of biomedical research. *JAMA* 294(11):1333-1342; Dorsey, E.R., et al. 2010. Funding of U.S. biomedical research. *JAMA* 303(2):137-143; and NRC analysis.

able situation. In the low scenario, growth in these two fields is reduced to 3.8 and 3.6 percent annually, which is closer to the expected trend in funding growth if it follows 2003-2007 rates but could still be higher than recession-affected rates. Behavioral Ph.D.s are excluded from this calculation because so much of the funding—from pharmaceutical, biotechnology, and medical device firms—is likely to involve at best limited behavioral research. (These three types of firms accounted for almost 60 percent of research funding in 2007.) However, if one included behavioral Ph.D.s, combining the medium projections for the three fields, the projected workforce growth rate of 3.5 percent annually for 2006-2016 would also be closer to the recent funding growth rate.

Should the research workforce grow more slowly than projected, one possibility would be slower growth in foreign-trained Ph.D.s. The large role of foreign-trained Ph.D.s in the workforce (other than in the behavioral sciences) is probably predictable from research funding patterns. U.S. funding for biomedical research represents 70-80 percent of global funding.[7] We do not have data on the global workforce in these fields, but of science and engineering researchers worldwide, U.S. researchers make up only 25 percent.[8] The probable mismatch between providing so much of the research funding and possibly a smaller share of researchers could help explain why large numbers of foreign researchers are entering the workforce. Their numbers could understandably decline should U.S. funding increase at a slower pace than elsewhere.

Projection Accuracy

The accuracy of these projections cannot be determined prospectively. We can, however, make two types of comparisons: of these projections with projections from other sources and of earlier projections that used the current methodology with subsequent survey estimates.

Alternative projections have been produced by the Bureau of Labor Statistics[9] (BLS), as part of a regular program that produces 10-year projections for all occupations and industries. Comparisons with BLS projections are not straightforward because occupational classifications differ. The closest to our categories of biomedical and clinical scientists (who as earlier noted numbered 190,000 and 40,500, respectively, in 2006) are their categories of biological scientists and medical scientists (95,000 and 114,200, respectively, in 2008). The BLS subcategories are too limited to allow sorting into biomedical and clinical groups, and the categories include some without Ph.D.s. But totals at least are close, and we make comparisons of both BLS categories against both of those used here.

For 2008-2018, BLS projects much slower growth in numbers of both biological and medical scientists than we project for 2006-2016 for biomedical or clinical scientists. Whereas we project annual growth rates of 4.5-4.8 percent,

[7] Dorsey et al., op. cit., p. 141, citing Schweitzer, S. O. 2007. *Pharmaceutical Economics and Policy.* New York: Oxford University Press.

[8] American Association for the Advancement of Science. 2008. Guide to R&D funding data—International comparisons. Available at: http://www.aaas.org/spp/rd/guiintl.htm.

[9] Bureau of Labor Statistics. 2010. National employment matrix. Available at: http://www.bls.gov/emp#data.

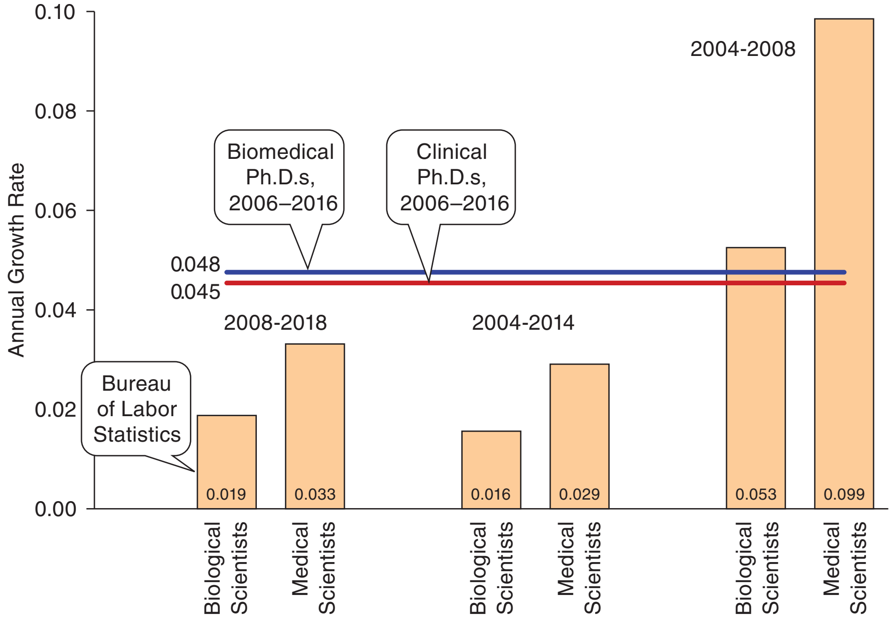

FIGURE D-40 Annual growth rates for biological and medical scientists for various periods from the Bureau of Labor Statistics and current projections for biomedical and clinical Ph.D.s.
SOURCES: Bureau of Labor Statistics data downloaded from www.bls.gov/emp#/data in January 2010; Hecker, D.E. 2005. Occupational employment projections to 2014. *Monthly Labor Review* 128(11):70-101; and NRC analysis.

BLS projects rates of 1.9-3.3 percent. Could BLS be taking into account the current recession, which is not reflected in the survey data from which we derive projection parameters? One way to investigate this possibility is to see how their projections have changed. A paper[10] published in 2005 gives projections for 2004-2014. This paper gives growth rates for their two categories as 1.6 and 2.9 percent, actually less optimistic than the recent ones, so recent economic upsets do not seem to have been a factor in their projecting slow growth. Their earlier projections do give 2004 baseline data, however, which can be compared with the more recent 2008 baseline (Figure D-40). This comparison suggests surprisingly high annual growth rates for 2004-2008 of 5.3 and 9.9 percent. For whatever reason, BLS appears to project far slower growth for these occupations than is actually reflected in the base data they use for their projections. Our projections look much more reasonable in comparison, and the fact that they are lower than the 2004-2008 rates could be justified by the potential impact of the great recession.

BLS categories for behavioral scientists are even more difficult to match with ours. We combine the BLS categories of psychologists, sociologists, and anthropologists, recognizing that the "most significant" source of personnel in some of these categories is individuals with a master's rather than a doctoral degree. The total for these categories is 180,900 in 2008, much greater than our 125,800 behavioral scientists in 2006. (We have excluded speech-language pathologists, who would have added 119,300 to the total.) BLS projects annual growth of 1.7 percent for 2004-2014 and 1.2 percent for 2008-2018 for the combined group, in contrast to our 0.9 percent for 2006-2016 (Figure D-41). The BLS projections, in this case, indicate faster growth than our projections, but its 2004-2008 data actually show annual change of –1.1 percent. As with biomedical and clinical scientists, our projections differ from the BLS's in the direction of relatively more acknowledgment of past trends.

Have projections such as those made here been accurate in the past? The 2005 report on national needs[11] contained similar projections for 2001-2011. From this series, projections up to 2006 can be compared with the 2006 survey results, although this is not a simple matter. The 2001 survey did not count foreign-trained Ph.D.s, who had to be estimated previously and were reestimated in the current exercise from later data. The 2006 survey undercounted the foreign-trained, and immigrants arriving since 2000 had to be estimated and added. We make the comparisons nevertheless in Figure D-42. The growth rates projected in the 2005 report were too low for biomedical scientists, too high for clinical scientists, and slightly too high for behavioral scientists. The range between high and low projections was

[10] Hecker, D.E. 2005. Occupational employment projections to 2014. *Monthly Labor Review* 128(11):70-101.

[11] National Research Council. 2005. *Advancing the Nation's Health Needs.* Washington, DC: The National Academies Press.

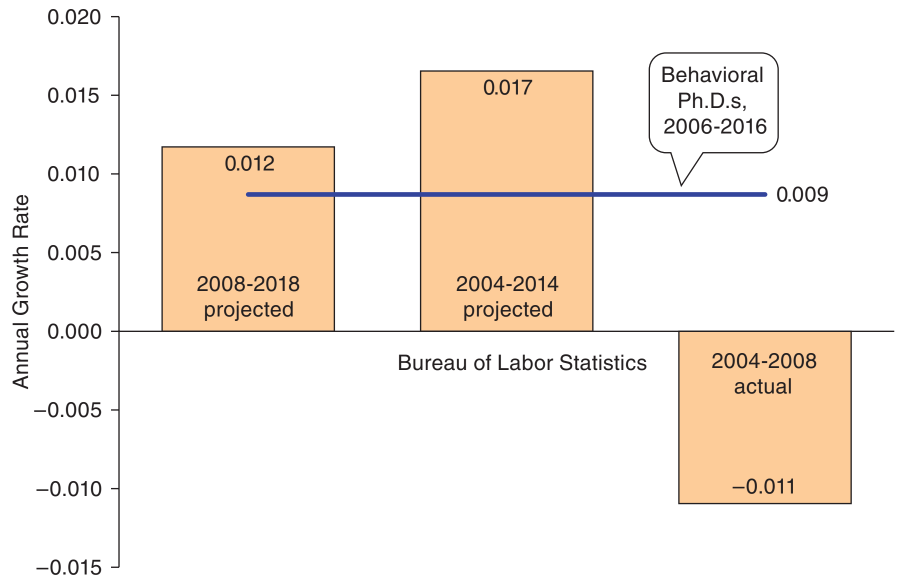

FIGURE D-41 Annual growth rates for psychologists, sociologists, and anthropologists for various periods from the Bureau of Labor Statistics and current projections for behavioral Ph.D.s.
SOURCES: Bureau of Labor Statistics data downloaded from www.bls.gov/emp#/data in January 2010; Hecker, D.E. 2005. Occupational employment projections to 2014. *Monthly Labor Review* 128(11):70-101; and NRC analysis.

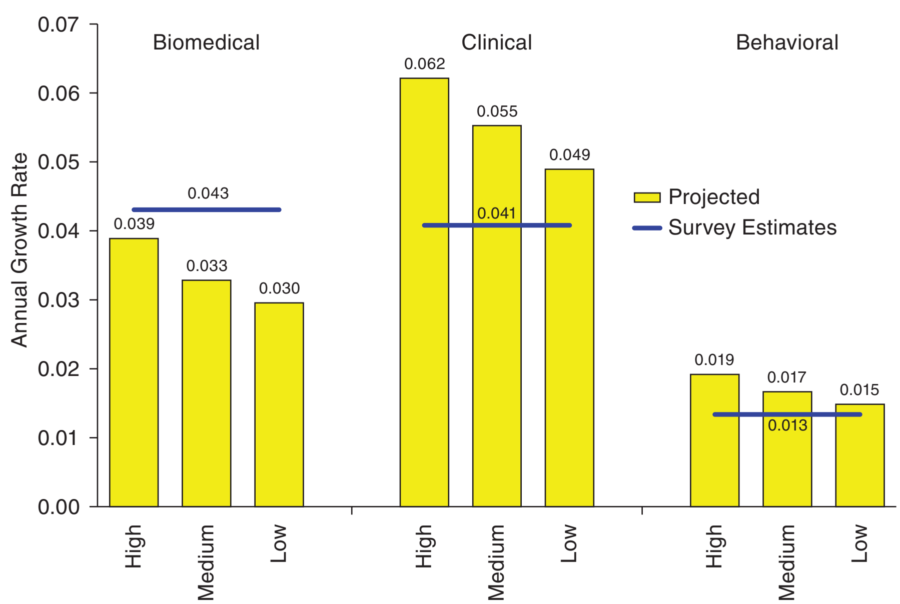

FIGURE D-42 Workforce annual growth rates, 2001-2006, as previously projected and as derived from surveys, by major field.
SOURCE: National Research Council. 2005. *Advancing the Nation's Health Needs.* Washington, DC: The National Academies Press; and NRC analysis.

apparently not wide enough to encapsulate actual (or at least estimated) trends.

The 2005 biomedical projection may have been too low mainly because foreign-trained Ph.D.s were estimated from 1993 survey data and projected forward to 2001 to provide the base for a further projection to 2011. The substantial increase in immigrants in 1999 and 2000 was therefore not factored into the projection. The errors regarding the clinical projection, in contrast, may involve the size of the group, which is relatively small and was fast growing, with considerable year-to-year volatility.

One implication that should be drawn, clearly, is that the alternative high and low projections here should not be taken to represent the limits of possible future variation. They are not based on the most extreme trends in past data and should not be taken to represent the extreme future possibilities, but are rather alternatives that depart somewhat modestly from the main scenario. A second implication is probably that better, up-to-date data are needed on foreign-trained Ph.D.s.

CONCLUSION

Projecting the research workforce in three major fields—biomedical, clinical, and behavioral—indicates that each faces different prospects. This variation in prospects is visible from a close examination of survey data on the workforce and on graduates. Running projections serves to confirm and concretize conclusions that might be drawn from such an examination.

The biomedical research workforce has grown rapidly, particularly in recent years. From 2001 to 2006, it expanded 24 percent, adding 37,000 scientists. The behavioral research workforce, in contrast, grew only 7 percent in the same period, adding only 8,000 scientists. The clinical research workforce is much smaller than the other two, in total only slightly larger than the 2001-2006 increment in the biomedical workforce. It grew almost as fast as the biomedical workforce, at 23 percent.

Reflecting this recent history, the biomedical workforce is projected to grow, over a decade from 2006 to 2016, by 61 percent, the clinical workforce almost as fast at 58 percent, and the behavioral workforce by an anemic 9 percent. Slow growth in the past has gone with less volatility, and alternative projections for behavioral and clinical scientists show less variation than alternatives for biomedical scientists.

Among those with U.S. Ph.D.s, behavioral scientists were almost as numerous as biomedical scientists in 2006, and actually more numerous up to 2001. However, behavioral Ph.D. graduates of U.S. universities have hardly changed in number since 1990, a period during which biomedical Ph.D. graduates have increased strongly. In addition, and just as crucially, foreign-trained Ph.D.s are far more numerous in the biomedical field than in the behavioral field and are also increasing.

The biomedical workforce could therefore be more strongly affected than the behavioral or clinical workforces by an interruption in immigrant flow. In the most extreme situation modeled, immigration would cease in 2010, and none of the U.S. Ph.D. graduates who are temporary residents would stay in the U.S., beginning with the 2008 cohort. Under these conditions, the decadal increment to the biomedical workforce would drop from 116,000 to 28,000—which would still be double the highest projected increment to the behavioral workforce. For the biomedical workforce to actually decline by 2016, a still more extreme situation would have to be imagined, such as, in addition, the departure of all foreign-trained Ph.D.s now in the United States. They were a third of the biomedical workforce in 2006, and their departure, together with a halt to immigration, would reduce the 2016 biomedical workforce by 42,000 from its 2006 level.

An increasing proportion of U.S.-trained Ph.D.s in the workforce are female. In the U.S.-trained clinical workforce, they have been the majority since 1994, and in the behavioral workforce, they became the majority around 2004. In both cases, their majority is projected to become larger. In the biomedical field, they are still the minority. Although they will remain so until 2016, the gap will narrow, with the sex ratio falling from 183 males per 100 females in 2006 to 146 in 2016. In the biomedical workforce as a whole, however, the gap will be greater, because women are a smaller minority among foreign-trained Ph.D.s, both in the biomedical and clinical field, although not in the behavioral field. Even among the foreign-trained, however, the sex ratio appears generally to be falling.

The workforce will almost certainly age in the slow-growing behavioral field, where the proportion 55 years and older will reach 44 percent by 2016. Whether the workforce will also age in the other two fields is less clear, since an increase in the smaller proportions 55 years and older is to some extent balanced by increases in the proportions under age 35.

Will sufficient research funding be available for the projected workforce? For 2006, total U.S. biomedical research funding, from government, industry, and foundations, was $93.4 billion, or $262,000 per scientist in the three major fields combined. Real growth in funding, from 2003 to 2007, was 3.4 percent annually. If the growth rate stays at this level (or declines because of recession), funding growth will be slower than the projected growth of the biomedical or clinical workforces, which will be more than 1 percentage point faster.

How accurate projections of this sort can be, drawing on data and trends that predate the economic crisis, it is not possible to say. It may take a while for data to emerge that would permit more confident projections.

Appendix E

Demographic Projections of the Research Workforce in the Biomedical, Clinical, and Behavioral Sciences, 2006-2016 (Using the System Dynamics Simulation Methodology)

OVERVIEW

Appendix D provides demographic projections of the research workforce in the biomedical, clinical, and behavioral sciences for the years 2006-2016 using a traditional statistical (actuarial) approach. This appendix provides additional demographic projections for the same workforces using an alternative approach called system dynamics that is based on the "structure" of the system (i.e., the interconnections among the various entities or parts of the system). In this case, the system under study is the scientific research workforce.

For each of the biomedical, clinical, and behavioral sciences workforces, projections will be shown for the total population along with the populations in the following four (4) demographic categories:

1. U.S.-trained males
2. U.S.-trained females
3. Foreign-trained males
4. Foreign-trained females

In each projection, the beginning population values are the actual values for 2006, the latest published set of data points. For each of the three major workforces (i.e., biological, clinical, and behavioral sciences), three (3) scenarios will be considered.

1. Scenario 1 (Moderate Risk): Use 50 percent of the value of the specified annual growth rate for each subgroup of the workforce. This is rated moderate risk because it is the most likely scenario and has the workforce projections that are most expected.

2. Scenario 2 (High Risk): Use 75 percent of the value of the specified annual growth rate for each subgroup of the workforce. This is rated high risk because it produces very large workforces over the 10-year simulation.

3. Scenario 3 (Low Risk): Use Ph.D. student growth rates in a "pipeline" model into the workforce. This is rated low risk because it is the most conservative set of projections for the workforces.

Figure E-1 shows the projections for the three major workforces for Scenario 1, the most likely scenario.

SUMMARY PROJECTIONS FOR ALL THREE SCENARIOS

Figures E-2 through E-4 show the projections for each of the three major workforces for each of the three scenarios in line-graph form. Tables E-1 through E-3 then show the projections for each of the three major workforces for each of the three scenarios in table form.

DEMOGRAPHIC DETAILS FOR SCENARIO 1 (MODERATE RISK)

Figure E-5 shows the projections for each of the four demographic groups for the biomedical sciences workforce for Scenario 1 in bar-graph form, and Table E-4 shows the same projections in table form.

Figure E-6 shows the projections for each of the four demographic groups for the behavioral sciences workforce for Scenario 1 in bar-graph form, and Table E-5 shows the same projections in table form.

Figure E-7 shows the projections for each of the four demographic groups for the clinical sciences workforce for Scenario 1 in bar-graph form, and Table E-6 shows the same projections in table form.

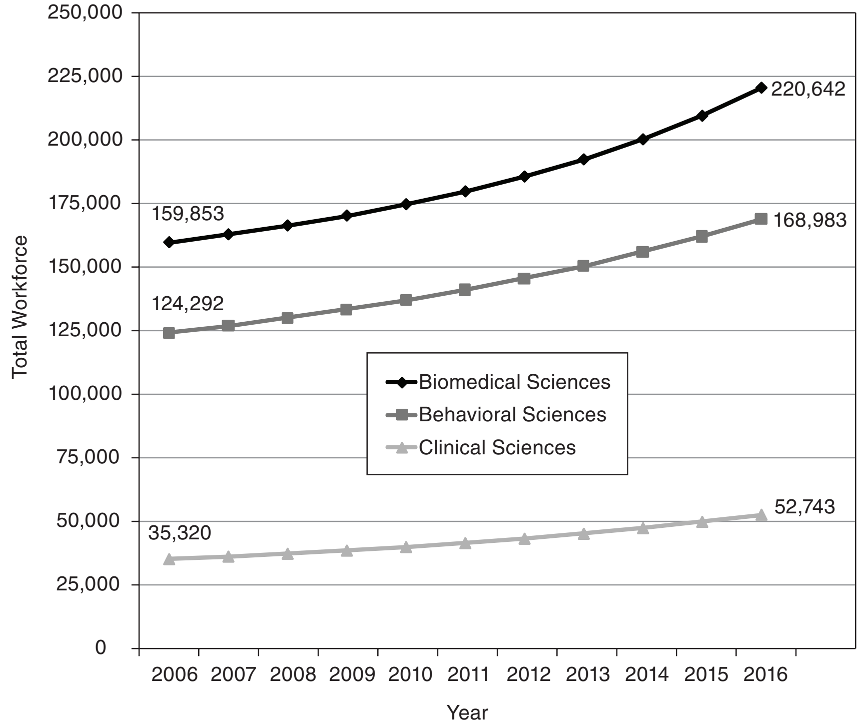

FIGURE E-1 Total biomedical, behavioral, and clinical sciences workforces, 2006-2016, scenario 1.
SOURCE: NRC analysis.

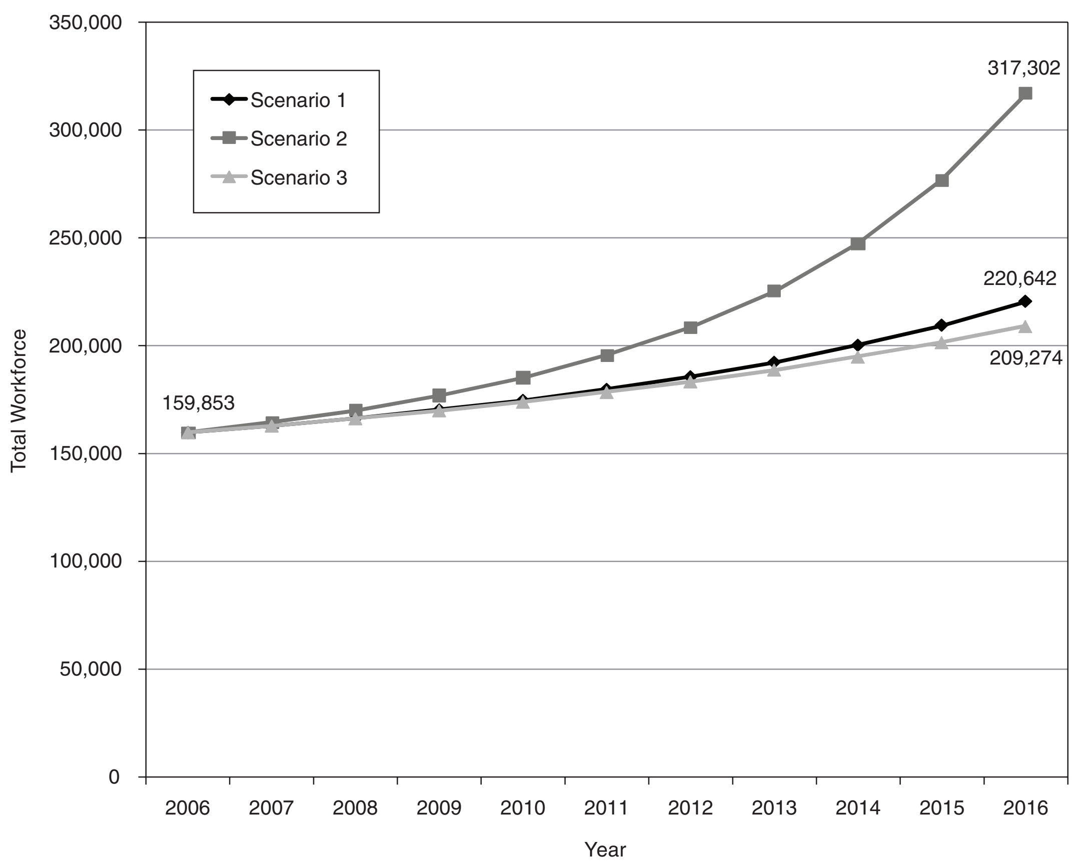

FIGURE E-2 Total biomedical sciences workforce, 2006-2016.
SOURCE: NRC analysis.

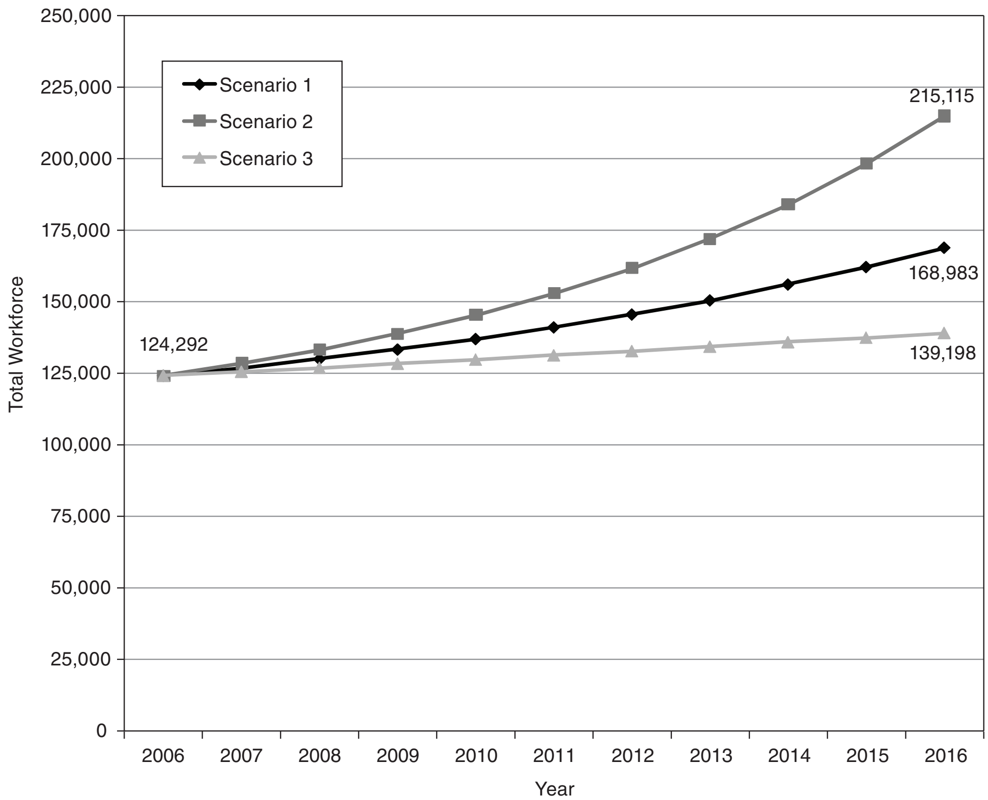

FIGURE E-3 Total behavioral sciences workforce, 2006-2016.
SOURCE: NRC analysis.

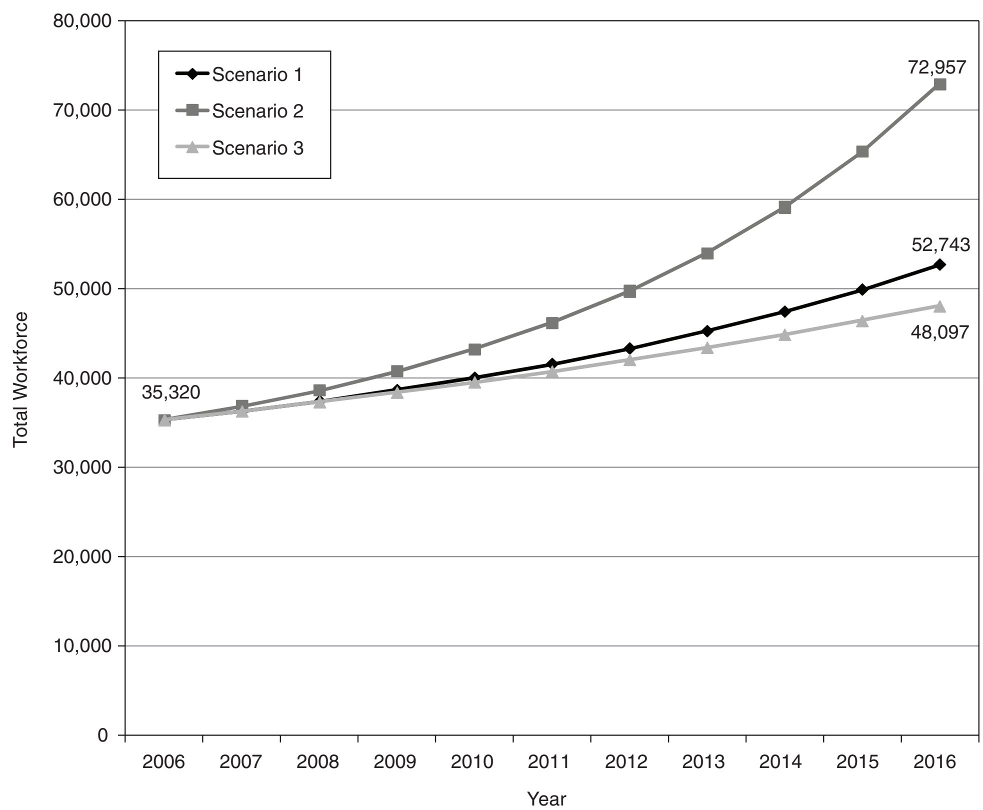

FIGURE E-4 Total clinical sciences workforce, 2006-2016.
SOURCE: NRC analysis.

TABLE E-1 Biomedical Sciences Workforce Projections for All Scenarios

	BIOMEDICAL		
	Scenario 1	Scenario 2	Scenario 3
2006	159,853	159,853	159,853
2007	162,950	164,598	162,926
2008	166,423	170,244	166,296
2009	170,339	177,046	169,995
2010	174,782	185,354	174,063
2011	179,854	195,662	178,543
2012	185,684	208,677	183,489
2013	192,437	225,425	188,959
2014	200,321	247,417	195,024
2015	209,607	276,908	201,764
2016	220,642	317,302	209,274

SOURCE: NRC analysis.

TABLE E-2 Behavioral Sciences Workforce Projections for All Scenarios

	BEHAVIORAL		
	Scenario 1	Scenario 2	Scenario 3
2006	124,292	124,292	124,292
2007	127,049	128,501	125,660
2008	130,079	133,351	127,051
2009	133,414	138,958	128,465
2010	137,091	145,459	129,906
2011	141,149	153,018	131,373
2012	145,634	161,832	132,871
2013	150,599	172,137	134,399
2014	156,100	184,214	135,962
2015	162,203	198,404	137,561
2016	168,983	215,115	139,198

SOURCE: NRC analysis.

TABLE E-3 Clinical Sciences Workforce Projections for All Scenarios

	CLINICAL		
	Scenario 1	Scenario 2	Scenario 3
2006	35,320	35,320	35,320
2007	36,327	36,859	36,291
2008	37,441	38,654	37,319
2009	38,680	40,763	38,408
2010	40,061	43,256	39,562
2011	41,605	46,221	40,785
2012	43,335	49,765	42,082
2013	45,279	54,024	43,456
2014	47,470	59,162	44,913
2015	49,943	65,388	46,458
2016	52,743	72,957	48,097

SOURCE: NRC analysis.

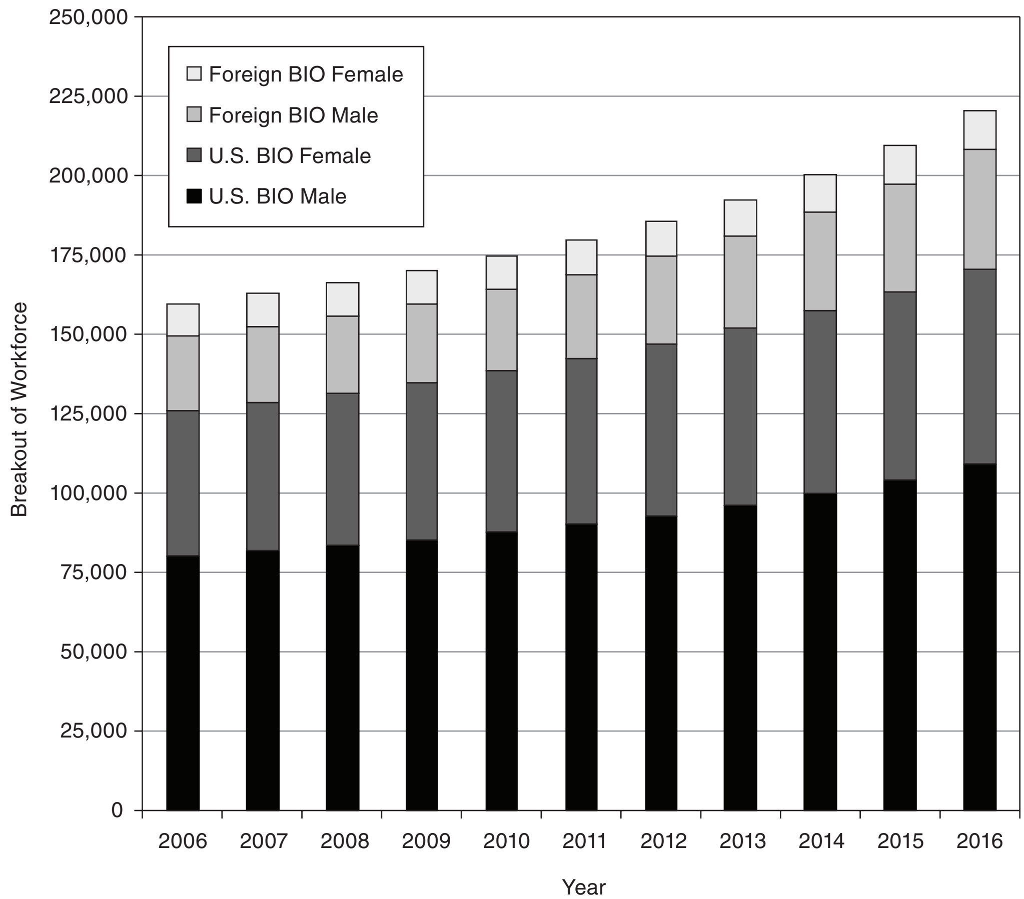

FIGURE E-5 Breakout of biomedical sciences workforce, 2006-2016, scenario 1.
SOURCE: NRC analysis.

TABLE E-4 Breakout of Biomedical Sciences Workforce, 2006-2016, Scenario 1

	BIOMEDICAL - SCENARIO 1 DETAILS			
	US Male	US Female	Foreign Male	Foreign Female
2006	80,268	45,828	23,636	10,121
2007	81,782	46,989	23,943	10,236
2008	83,502	48,218	24,337	10,366
2009	85,455	49,522	24,848	10,515
2010	87,675	50,906	25,517	10,684
2011	90,198	52,378	26,401	10,876
2012	93,066	53,946	27,577	11,095
2013	96,327	55,618	29,147	11,345
2014	100,034	57,403	31,254	11,629
2015	104,250	59,312	34,091	11,953
2016	109,044	61,356	37,919	12,322

SOURCE: NRC analysis.

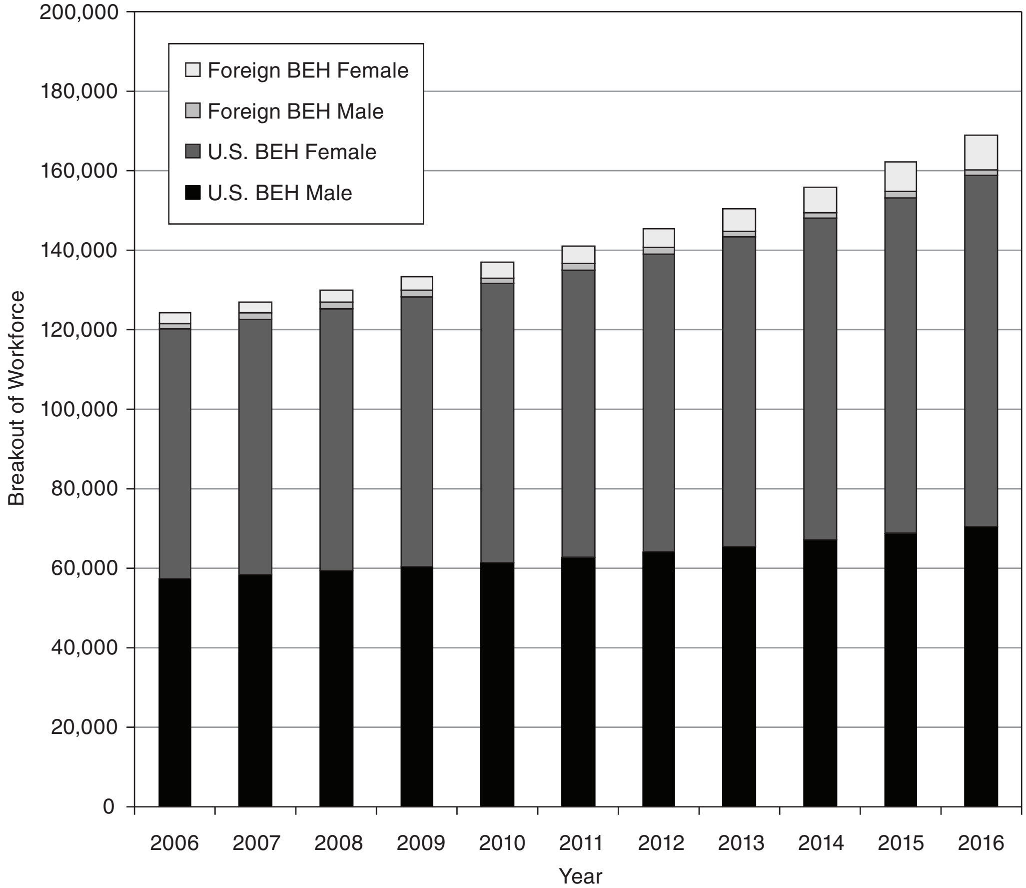

FIGURE E-6 Breakout of behavioral sciences workforce, 2006-2016, scenario 1.
SOURCE: NRC analysis.

TABLE E-5 Breakout of Behavioral Sciences Workforce, 2006-2016, Scenario 1

	BEHAVIORAL - SCENARIO 1 DETAILS			
	US Male	US Female	Foreign Male	Foreign Female
2006	57,593	62,758	1,457	2,484
2007	58,495	64,335	1,464	2,755
2008	59,471	66,066	1,471	3,071
2009	60,525	67,971	1,478	3,440
2010	61,665	70,069	1,485	3,871
2011	62,897	72,384	1,492	4,375
2012	64,230	74,941	1,499	4,964
2013	65,671	77,770	1,507	5,652
2014	67,229	80,901	1,514	6,457
2015	68,914	84,371	1,521	7,398
2016	70,736	88,221	1,529	8,498

SOURCE: NRC analysis.

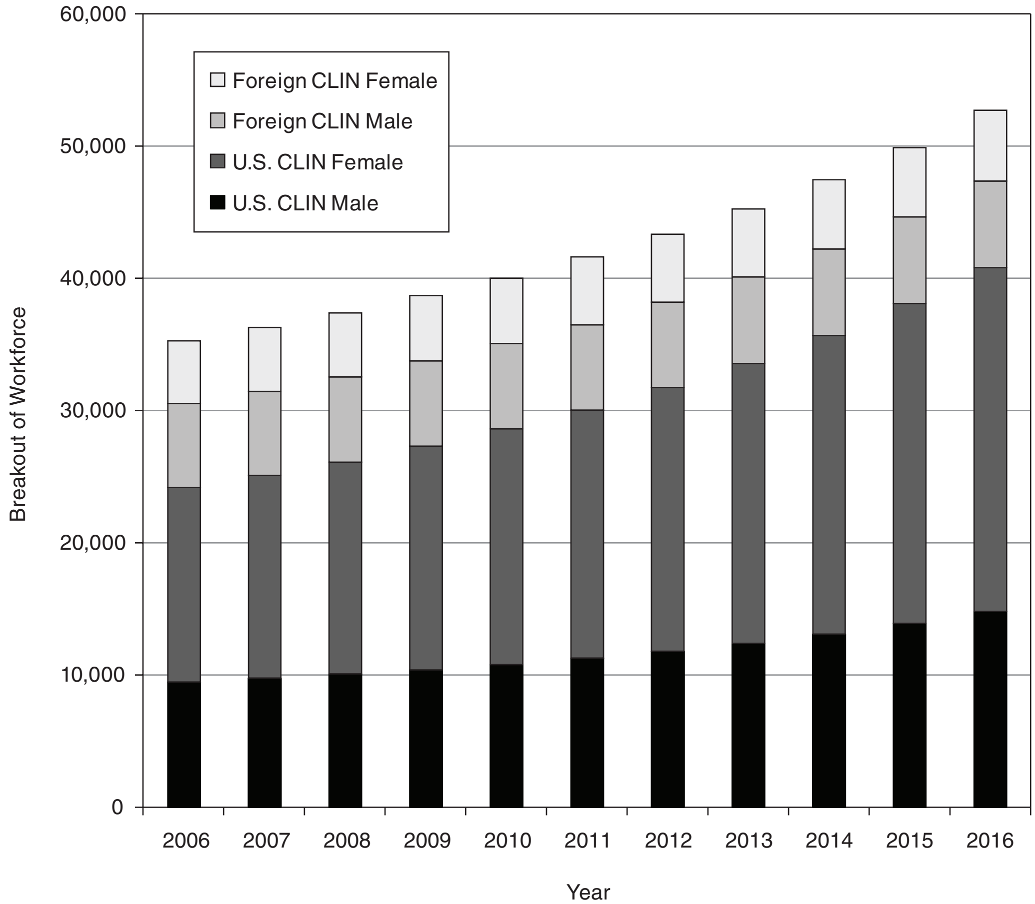

FIGURE E-7 Breakout of clinical sciences workforce, 2006-2016, scenario 1.
SOURCE: NRC analysis.

TABLE E-6 Breakout of Clinical Sciences Workforce, 2006-2016, Scenario 1

	CLINICAL - SCENARIO 1 DETAILS			
	US Male	US Female	Foreign Male	Foreign Female
2006	9,457	14,706	6,359	4,798
2007	9,737	15,368	6,378	4,844
2008	10,055	16,096	6,398	4,893
2009	10,417	16,902	6,417	4,944
2010	10,829	17,797	6,436	4,998
2011	11,299	18,794	6,456	5,056
2012	11,835	19,909	6,475	5,116
2013	12,446	21,159	6,495	5,179
2014	13,143	22,566	6,515	5,246
2015	13,938	24,154	6,534	5,317
2016	14,846	25,952	6,554	5,391

SOURCE: NRC analysis.

DEMOGRAPHIC DETAILS FOR SCENARIO 2 (HIGH RISK)

Figure E-8 shows the projections for each of the four demographic groups for the biomedical sciences workforce for Scenario 2 in bar-graph form, and Table E-7 shows the same projections in table form.

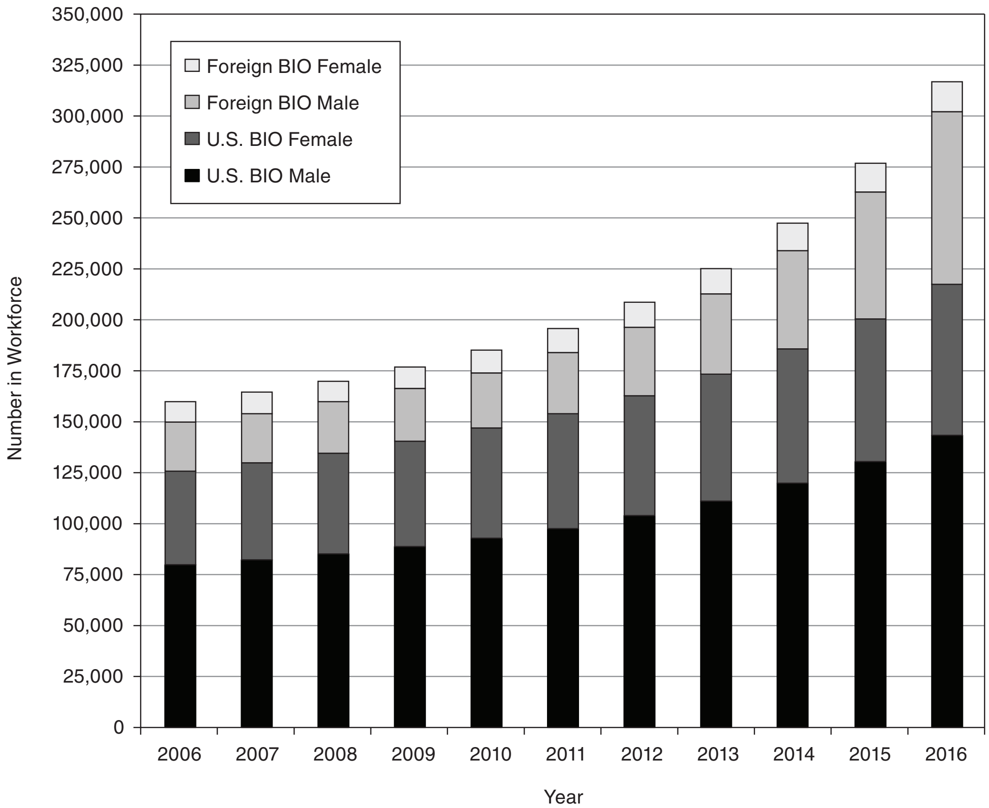

FIGURE E-8 Breakout of biomedical sciences workforce, 2006-2016, scenario 2.
SOURCE: NRC analysis.

TABLE E-7 Breakout of Biomedical Sciences Workforce, 2006-2016, Scenario 2

	BIOMEDICAL - SCENARIO 2 DETAILS			
	US Male	US Female	Foreign Male	Foreign Female
2006	80,268	45,828	23,636	10,121
2007	82,594	47,588	24,119	10,297
2008	85,406	49,507	24,820	10,511
2009	88,808	51,605	25,863	10,770
2010	92,923	53,908	27,439	11,084
2011	97,903	56,441	29,852	11,466
2012	103,933	59,238	33,578	11,929
2013	111,235	62,333	39,367	12,490
2014	120,078	65,769	48,398	13,171
2015	130,791	69,591	62,528	13,998
2016	143,771	73,855	84,676	15,000

SOURCE: NRC analysis.

Figure E-9 shows the projections for each of the four demographic groups for the behavioral sciences workforce for Scenario 2 in bar-graph form, and Table E-8 shows the same projections in table form.

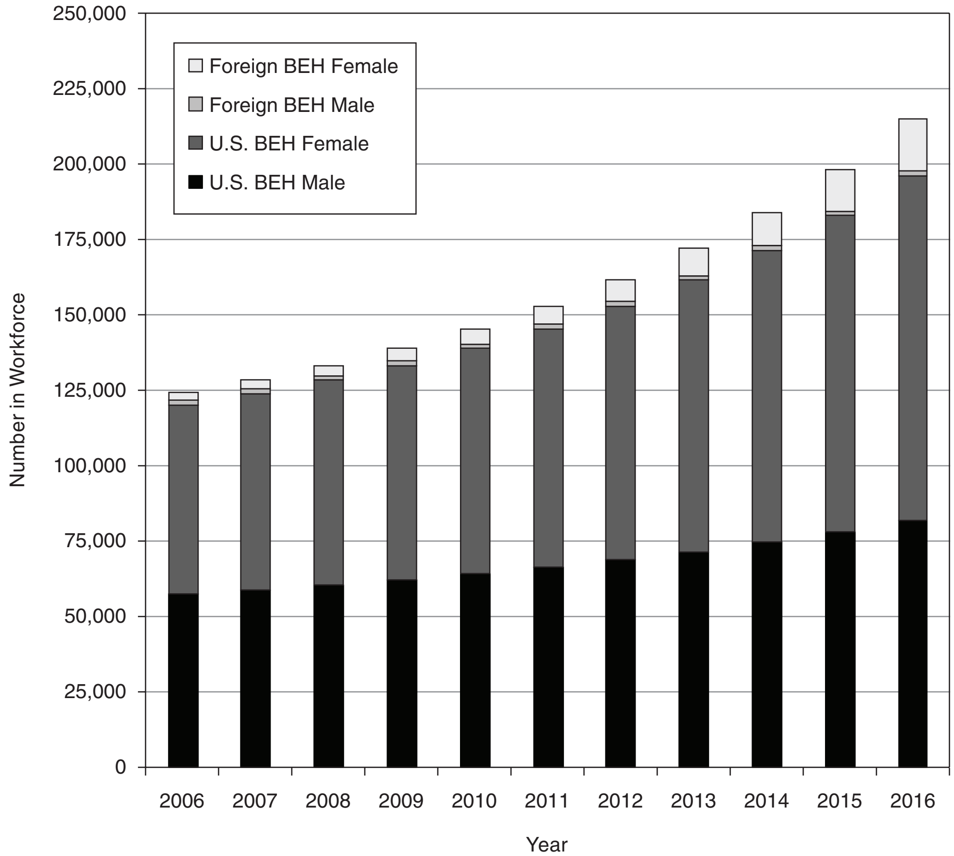

FIGURE E-9 Breakout of behavioral sciences workforce, 2006-2016, scenario 2.
SOURCE: NRC analysis.

TABLE E-8 Breakout of Behavioral Sciences Workforce, 2006-2016, Scenario 2

	BEHAVIORAL - SCENARIO 2 DETAILS			
	US Male	US Female	Foreign Male	Foreign Female
2006	57,593	62,758	1,457	2,484
2007	58,966	65,165	1,467	2,902
2008	60,509	67,936	1,478	3,429
2009	62,242	71,135	1,489	4,092
2010	64,190	74,842	1,499	4,928
2011	66,378	79,148	1,510	5,982
2012	68,838	84,162	1,521	7,311
2013	71,602	90,014	1,532	8,988
2014	74,710	96,856	1,544	11,105
2015	78,204	104,868	1,555	13,778
2016	82,132	114,264	1,567	17,154

SOURCE: NRC analysis.

Figure E-10 shows the projections for each of the four demographic groups for the clinical sciences workforce for Scenario 2 in bar-graph form, and Table E-9 shows the same projections in table form.

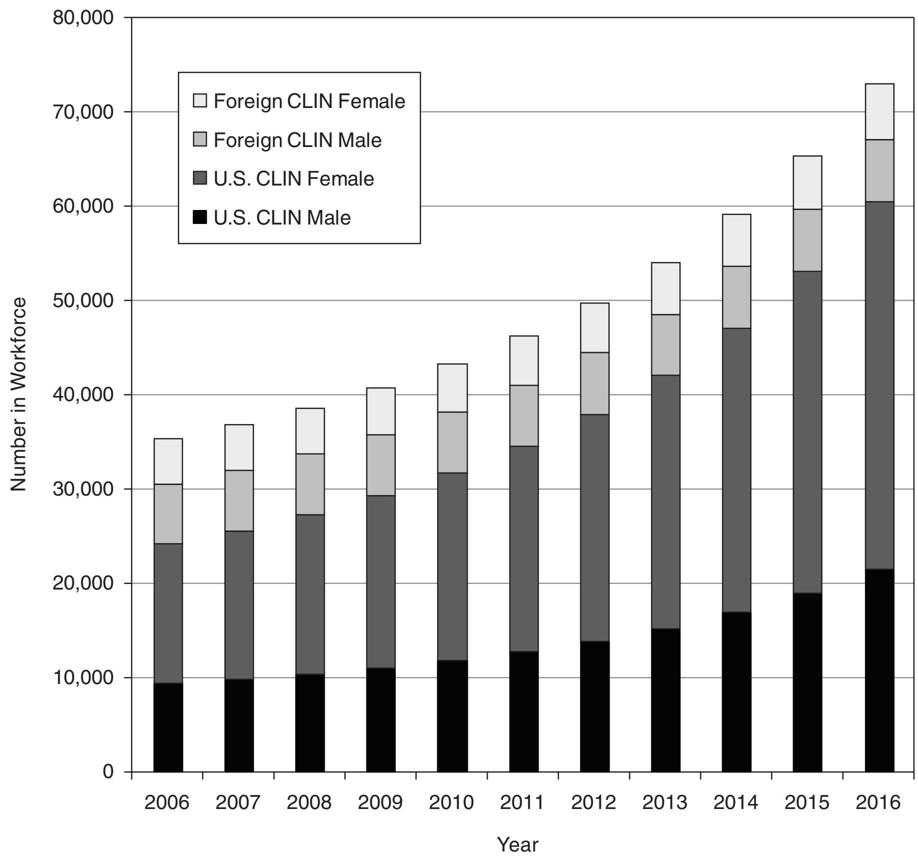

FIGURE E-10 Breakout of clinical sciences workforce, 2006-2016, scenario 2.
SOURCE: NRC analysis.

TABLE E-9 Breakout of Clinical Sciences Workforce, 2006-2016, Scenario 2.

	CLINICAL - SCENARIO 2 DETAILS			
	US Male	US Female	Foreign Male	Foreign Female
2006	9,457	14,706	6,359	4,798
2007	9,887	15,716	6,388	4,868
2008	10,408	16,886	6,417	4,944
2009	11,040	18,252	6,446	5,026
2010	11,808	19,859	6,475	5,115
2011	12,741	21,765	6,505	5,211
2012	13,877	24,040	6,534	5,315
2013	15,259	26,773	6,564	5,427
2014	16,943	30,076	6,594	5,549
2015	18,995	34,088	6,624	5,682
2016	21,496	38,982	6,654	5,825

SOURCE: NRC analysis.

DEMOGRAPHIC DETAILS FOR SCENARIO 3 (LOW RISK)

Figure E-11 shows the projections for each of the four demographic groups for the biomedical sciences workforce for Scenario 3 in bar-graph form, and Table E-10 shows the same projections in table form.

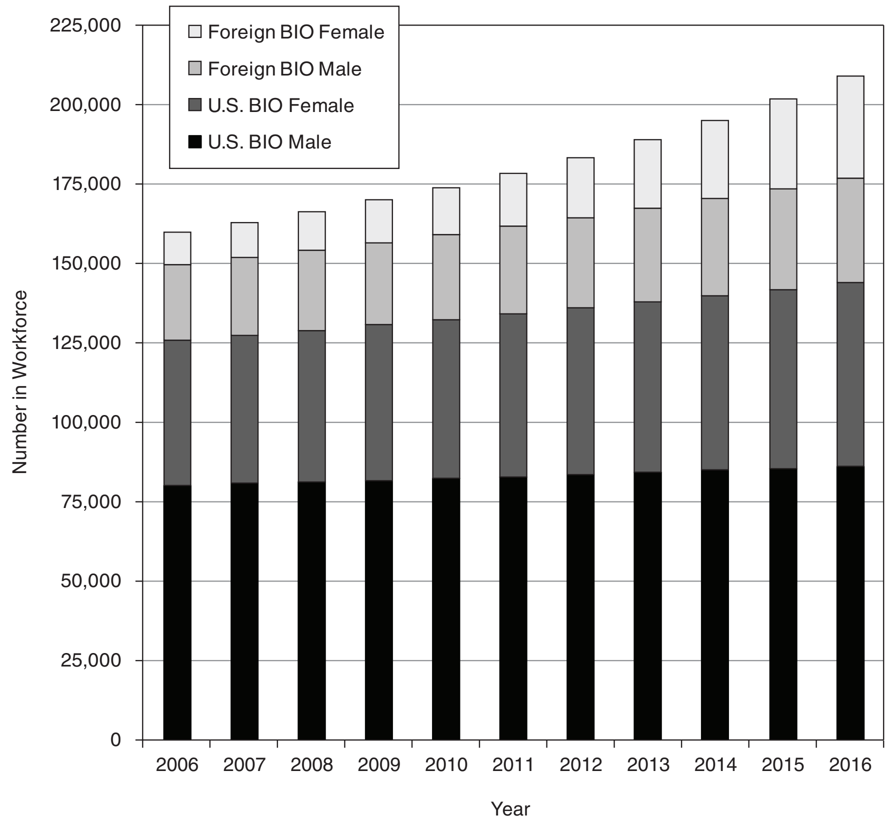

FIGURE E-11 Breakout of biomedical sciences workforce, 2006-2016, scenario 3.
SOURCE: NRC analysis.

TABLE E-10 Breakout of Biomedical Sciences Workforce, 2006-2016, Scenario 3

	BIOMEDICAL - SCENARIO 3 DETAILS			
	US Male	US Female	Foreign Male	Foreign Female
2006	80,268	45,828	23,636	10,121
2007	80,747	46,823	24,295	11,060
2008	81,255	47,858	25,008	12,175
2009	81,792	48,934	25,776	13,494
2010	82,358	50,051	26,602	15,052
2011	82,953	51,211	27,490	16,889
2012	83,577	52,416	28,444	19,052
2013	84,230	53,666	29,465	21,597
2014	84,913	54,963	30,559	24,588
2015	85,626	56,308	31,730	28,101
2016	86,369	57,702	32,981	32,223

SOURCE: NRC analysis.

Figure E-12 shows the projections for each of the four demographic groups for the behavioral sciences workforce for Scenario 3 in bar-graph form, and Table E-11 shows the same projections in table form.

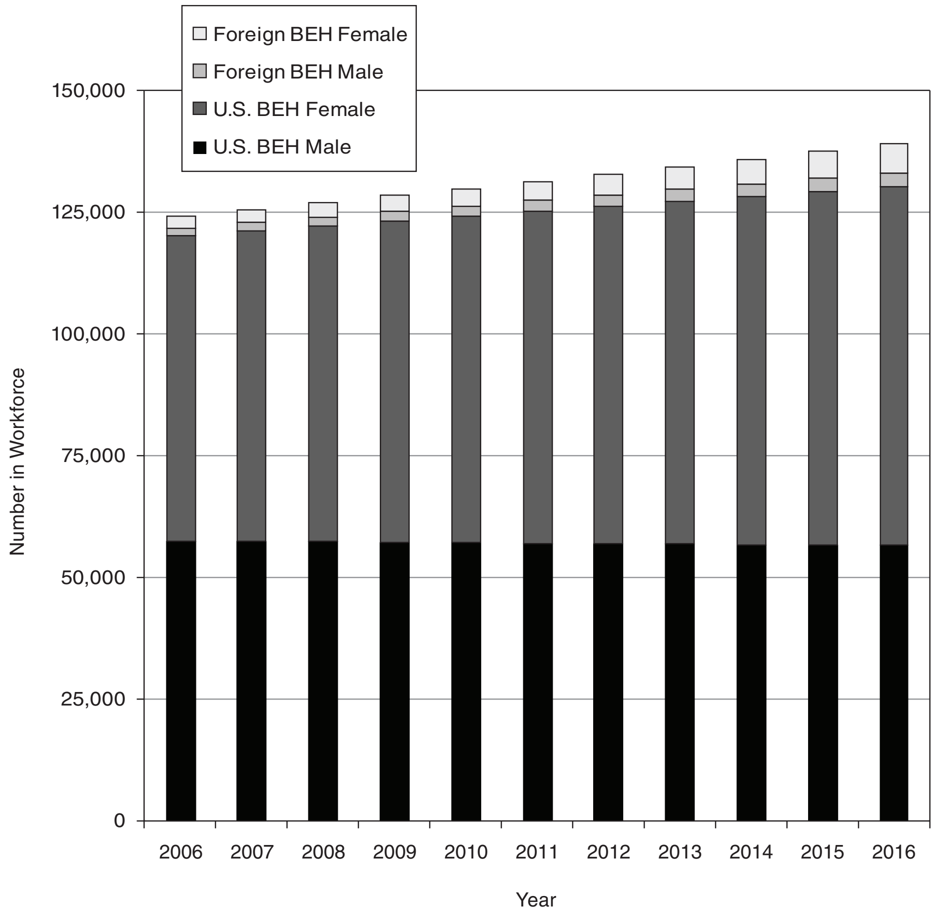

FIGURE E-12 Breakout of behavioral sciences workforce, 2006-2016, scenario 3.
SOURCE: NRC analysis.

TABLE E-11 Breakout of Behavioral Sciences Workforce, 2006-2016, Scenario 3

	BEHAVIORAL - SCENARIO 3 DETAILS			
	US Male	US Female	Foreign Male	Foreign Female
2006	57,593	62,758	1,457	2,484
2007	57,491	63,830	1,605	2,735
2008	57,391	64,907	1,750	3,003
2009	57,293	65,990	1,892	3,291
2010	57,197	67,078	2,031	3,600
2011	57,102	68,172	2,167	3,932
2012	57,010	69,273	2,301	4,287
2013	56,920	70,379	2,432	4,669
2014	56,831	71,493	2,560	5,078
2015	56,744	72,613	2,686	5,518
2016	56,659	73,739	2,809	5,991

SOURCE: NRC analysis.

Figure E-13 shows the projections for each of the four demographic groups for the clinical sciences workforce for Scenario 3 in bar-graph form, and Table E-12 shows the same projections in table form.

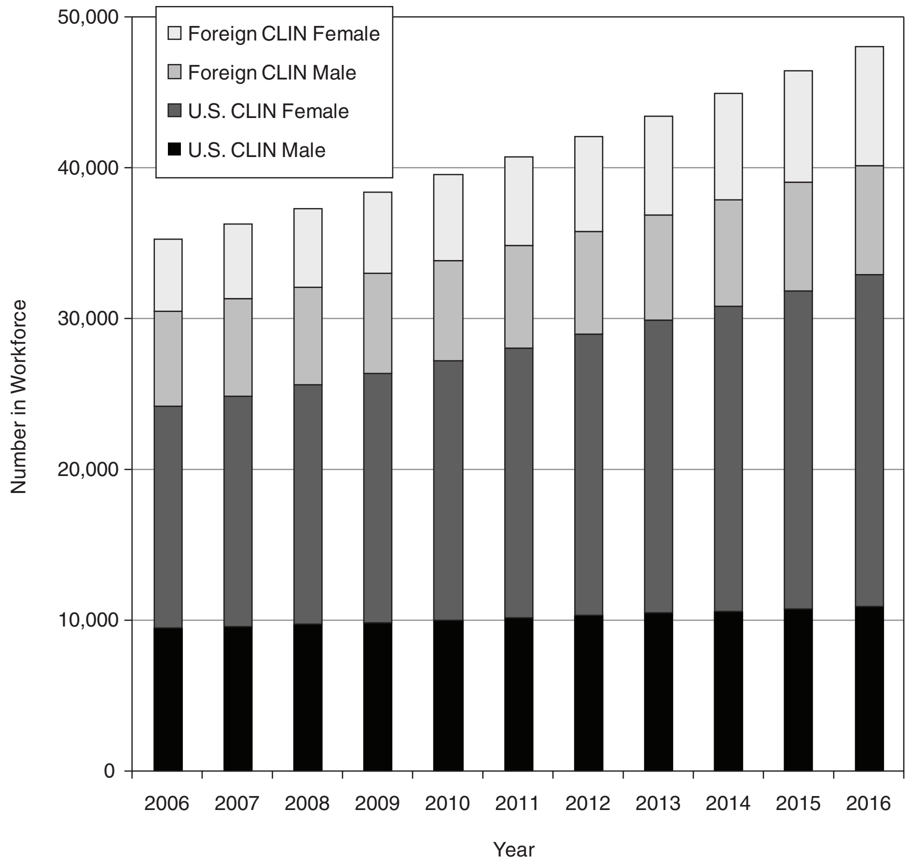

FIGURE E-13 Breakout of clinical sciences workforce, 2006-2016, scenario 3.
SOURCE: NRC analysis.

TABLE E-12 Breakout of Clinical Sciences Workforce, 2006-2016, Scenario 3

	CLINICAL - SCENARIO 3 DETAILS			
	US Male	US Female	Foreign Male	Foreign Female
2006	9,457	14,706	6,359	4,798
2007	9,591	15,283	6,439	4,978
2008	9,728	15,890	6,520	5,181
2009	9,869	16,528	6,604	5,408
2010	10,013	17,199	6,689	5,661
2011	10,160	17,904	6,777	5,944
2012	10,311	18,645	6,866	6,259
2013	10,466	19,424	6,958	6,608
2014	10,624	20,242	7,052	6,995
2015	10,785	21,101	7,148	7,424
2016	10,950	22,004	7,246	7,897

SOURCE: NRC analysis.

DESCRIPTION OF DATA USED FOR WORKFORCE PROJECTIONS

Table E-13 shows the data for U.S.-trained Ph.D.s. In Table E-13, the values in the rightmost columns are the average annual growth rates using the past 5 years of data (i.e., 2001 to 2006) and the past 7 years of data (i.e., 1999 to 2006). The numbers in these columns that are shaded gray are the annual growth rates used for those demographic groups in the workforce projections. To mitigate large changes, the smaller of the two annual growth rates is typically used, or the most reasonable value is used based on inspection.

TABLE E-13 Data for U.S.-Trained Ph.D.s

Clinical PhD's							Annual Avg Growth	
	1995	**1997**	**1999**	**2001**	**2003**	**2006**	Last 5 yrs	Last 7 yrs
Males Emp, in S&E	5464	6629	6782	7406	6595	7477	0.2%	1.5%
Males Emp, out of S&E	740	478	541	546	1760	1600	38.6%	27.9%
Males Unemp, Seeking Work	103	71	101	3	88	6	18.8%	-13.4%
Males Unemp, Not Seeking, Not Retired	49	99	39	74	29	34	-10.8%	-1.7%
Males Retired	520	550	880	858	907	862	0.1%	-0.3%
Males Postdoc	212	204	139	136	206	340	30.0%	20.6%
Females Emp, in S&E	6051	7087	7997	9358	9505	11375	4.3%	6.0%
Females Emp, out of S&E	575	307	685	846	2084	2172	31.3%	31.0%
Females Unemp, Seeking Work	68	99	102	124	168	124	0.1%	3.1%
Females Unemp, Not Seeking, Not Retired	217	289	294	332	349	486	9.2%	9.4%
Females Retired	299	407	428	503	765	868	14.5%	14.7%
Females Postdoc	273	310	292	280	254	549	19.2%	12.6%
Biomedical PhD's							Annual Avg Growth	
	1995	**1997**	**1999**	**2001**	**2003**	**2006**	Last 5 yrs	Last 7 yrs
Males Emp, in S&E	52075	56819	60727	62814	59582	60794	-0.6%	0.0%
Males Emp, out of S&E	5052	4370	3818	4657	10032	10772	26.3%	26.0%
Males Unemp, Seeking Work	824	538	561	713	1240	464	-7.0%	-2.5%
Males Unemp, Not Seeking, Not Retired	1089	1159	1205	1337	1385	796	-8.1%	-4.8%
Males Retired	5533	5252	6939	7617	8010	8312	1.8%	2.8%
Males Postdoc	5973	7355	7080	6342	5706	7442	3.5%	0.7%
Females Emp, in S&E	16928	24119	22257	25768	28068	29814	3.1%	4.9%
Females Emp, out of S&E	2687	2289	2500	3434	4967	6604	18.5%	23.5%
Females Unemp, Seeking Work	408	487	576	305	792	582	18.2%	0.1%
Females Unemp, Not Seeking, Not Retired	1670	2290	2280	2576	3116	2302	-2.1%	0.1%
Females Retired	1082	1667	1533	1831	1924	3033	13.1%	14.0%
Females Postdoc	4218	5169	5745	5332	4547	6526	4.5%	1.9%
Behavioral PhD's							Annual Avg Growth	
	1995	**1997**	**1999**	**2001**	**2003**	**2006**	Last 5 yrs	Last 7 yrs
Males Emp, in S&E	48571	50030	51792	51820	25702	45454	-2.5%	-1.7%
Males Emp, out of S&E	6242	4881	5025	5634	25609	10668	17.9%	16.0%
Males Unemp, Seeking Work	284	395	418	281	5888	224	-4.0%	-6.6%
Males Unemp, Not Seeking, Not Retired	579	723	583	649	524	302	-10.7%	-6.9%
Males Retired	4630	5214	5638	5982	509	6512	1.8%	2.2%
Males Postdoc	714	1171	640	763	6325	945	4.8%	6.8%
Females Emp, in S&E	34103	39240	42004	45131	31908	47806	1.2%	2.0%
Females Emp, out of S&E	4271	2926	3598	4996	18568	10715	22.9%	28.3%
Females Unemp, Seeking Work	289	277	554	509	4171	449	-2.4%	-2.7%
Females Unemp, Not Seeking, Not Retired	1763	2061	2621	2769	2486	2333	-3.2%	-1.6%
Females Retired	1329	1637	2328	2992	708	4775	11.9%	15.0%
Females Postdoc	1154	1460	1524	1374	4386	1455	1.2%	-0.6%

SOURCE: Data adapted from National Science Foundation Survey of Doctoral Recipients, 1995-2006.

Table E-14 shows the data for foreign-trained Ph.D.s. It should be noted that information regarding foreign-trained Ph.D. students is not as well documented as the information for U.S.-trained Ph.D. students. In Table E-14, the values in the rightmost column are the average annual growth rates using the past 3 years of data (e.g., 2003 to 2006) because there are no data available for 2001. These are the annual growth rates used for the various foreign-trained Ph.D. groups in the workforce projections. Where there are "blanks" in the 2003 or 2006 data, values have been assumed to be the same as either the preceding data or the succeeding data. These cells are shaded gray and will show no growth between 2003 and 2006 because the same numbers are used for both years.

TABLE E-14 Data for Foreign-Trained Ph.D.s

Clinical PhD's							Annual Avg Growth
	1995	**1997**	**1999**	**2001**	**2003**	**2006**	Last 3 yrs
Males Emp, in S&E	6073	5629	4982		4621	4716	0.7%
Males Emp, out of S&E	956	465	680		1328	1344	0.4%
Males Unemp, Seeking Work	81		205		123	123	0.0%
Males Unemp, Not Seeking, Not Retired	74	177	389		176	176	0.0%
Males Retired	1223	1137	821		1672	213	-29.1%
Males Postdoc							
Females Emp, in S&E	1007	1051	1689		5494	3841	-10.0%
Females Emp, out of S&E	172	185	204		641	846	10.7%
Females Unemp, Seeking Work	163		89		52	52	0.0%
Females Unemp, Not Seeking, Not Retired	232	142			229	59	-24.7%
Females Retired	596	824	621		367	442	6.8%
Females Postdoc							
Biomedical PhD's							Annual Avg Growth
	1995	**1997**	**1999**	**2001**	**2003**	**2006**	Last 3 yrs
Males Emp, in S&E	6760	6246	6864		21386	20381	-1.6%
Males Emp, out of S&E	68		85		1908	2275	6.4%
Males Unemp, Seeking Work	135	175			737	332	-18.3%
Males Unemp, Not Seeking, Not Retired	121	73	189		222	648	64.0%
Males Retired	471	708	873		1508	2207	15.5%
Males Postdoc							
Females Emp, in S&E	2575	2781	2622		8859	8857	0.0%
Females Emp, out of S&E	178	96	244		461	826	26.4%
Females Unemp, Seeking Work	176	128			647	269	-19.5%
Females Unemp, Not Seeking, Not Retired	406	236	331		704	169	-25.3%
Females Retired	71	318	298		1584	744	-17.7%
Females Postdoc							
Behavioral PhD's							Annual Avg Growth
	1995	**1997**	**1999**	**2001**	**2003**	**2006**	Last 3 yrs
Males Emp, in S&E	987	667	827		690	1044	17.1%
Males Emp, out of S&E	776	573	672		397	259	-11.6%
Males Unemp, Seeking Work							
Males Unemp, Not Seeking, Not Retired					154	154	0.0%
Males Retired		456	192		296	95	-22.6%
Males Postdoc							
Females Emp, in S&E	779	947	992		768	1513	32.3%
Females Emp, out of S&E	257	234	71		1260	817	-11.7%
Females Unemp, Seeking Work							
Females Unemp, Not Seeking, Not Retired	89				108	154	14.2%
Females Retired	60	65	156		71	71	0.0%
Females Postdoc							

SOURCE: Dara adopted from National Science Foundation Survey of College Graduates, 1995-2006.

DESCRIPTION OF SYSTEM DYNAMICS MODELS

System dynamics (SD) is the application of feedback control systems principles and techniques to managerial, organizational, and socioeconomic problems. As such, the methodology seeks to bring together multiple views or aspects of the same problem under study and integrate them into a conceptual and meaningful whole. In fact, most difficulties to fully understanding complex issues arise from looking independently at various elements of an issue instead of considering pertinent interrelations. Consequently, optimization is sought for each separate element in the system, which inadvertently leads to sub-optimization of total system performance. With SD, it is possible to take hypotheses about the separate parts of a system, to combine them in a computer simulation model, and to learn both the "local" and "global" consequences of decisions and actions, as well as the impact of these decisions and actions on short-term and long-term performance. Most of the time, the impact on short-term and long-term performance are opposite: an action that looks positive in the short-term is often very detrimental in the long-term. Conversely, an action that produces favorable long-term performance must usually suffer poor performance in the short-term.

SD extends modeling methods traditionally associated with engineering design and feedback control theory into the arena of policy evaluation and management decision making. The following characteristics distinguish SD models from traditional decision support methodologies:

- Its building blocks are feedback loops;
- It can accommodate non-linear relationships among variables;
- It enforces causality;
- It can include delays;
- It can model "soft" variables;
- It can model management policies; and
- It presents a dynamic environment for decision analysis.

These characteristics are important because they allow SD models to capture the key structural relationships that define a social system. The structure, in turn, produces the dynamic behavior of interest. The resulting simulation mirrors reality because the underlying model structure includes the appropriate feedback loops, causality, delays, and other relationships. SD models include real-world causal logic, which allows someone to trace through the model to see why things happen the way they do.

The SD modeling and simulation approach is different from traditional statistical approaches in several ways. First, the models are more realistic because they capture cause-and-effect linkages, feedback loops, delays, non-linear relationships, and management policies. Second, the simulations are more accurate and reliable because they provide a sanity check on assumptions and are more rigorous than mental models or spreadsheets, allow for analysis of a wider range of issues, and identify the actions that are most effective (and least effective) for improving performance. Third, communication is more effective because the approach is graphical (the connections are easily seen and understood), logical (the results can be traced back to their root causes), and experiential (we learn best by doing and simulation is a good substitute for the real world).

In SD models, a "stock" and "flow" methodology is used in which stocks represent accumulations of "things" (e.g., people, inventory), and flows are the movement of these "things" into, out of, and between stocks (Figure E-14). For Scenario 1 (moderate risk) and Scenario 2 (high risk), a very basic SD model was used in which the stocks represent groups of people in the following categories (which were established based on available data):

- *In Science and Engineering (S&E)*—The number of people employed in science and engineering positions (not considered postdoctorates).
- *Out of S&E*—The number of people employed in areas other than science and engineering.
- *Unemp Seeking Work*—The number of people currently unemployed but are seeking work.
- *Unemp Not Seeking Work*—The number of people currently unemployed but not seeking work, but are not retired.
- *Retired*—The number of people currently retired.
- *Postdoctorate*—The number of people employed as postdoctorates.

The total number of people considered in the "workforce" is the sum of all people that are not retired. Thus, the workforce for any particular demographic group (e.g., U.S.-trained males in biomedical science) is the following:

Workforce = *In S&E* + *Out of S&E* + *Unemp Seeking Work* + *Unemp Not Seeking Work* + *Postdoctorate*

The flows in and out of the stocks (e.g., *In 1*, *Out 1*) are based on growth rates determined from the data for the specific demographic group and shown earlier in Tables E-13 and E-14. If the growth rate is greater than zero (i.e., positive), then people are added to the stock through the *In* flow. If the growth rate is less than zero (i.e., negative), then people are removed from the stock through the *Out* flow. The amount of people that are added or removed is based on the percentage growth rate multiplied by the current number of people in the stock. For example, if 100 people were in a stock and the growth rate is 5 percent, then 5 people would be added to the stock during that simulation step.

Figure E-14 below shows this stock-and-flow diagram for the U.S.-trained males in biomedical science. This exact same model structure is used for all other demographic

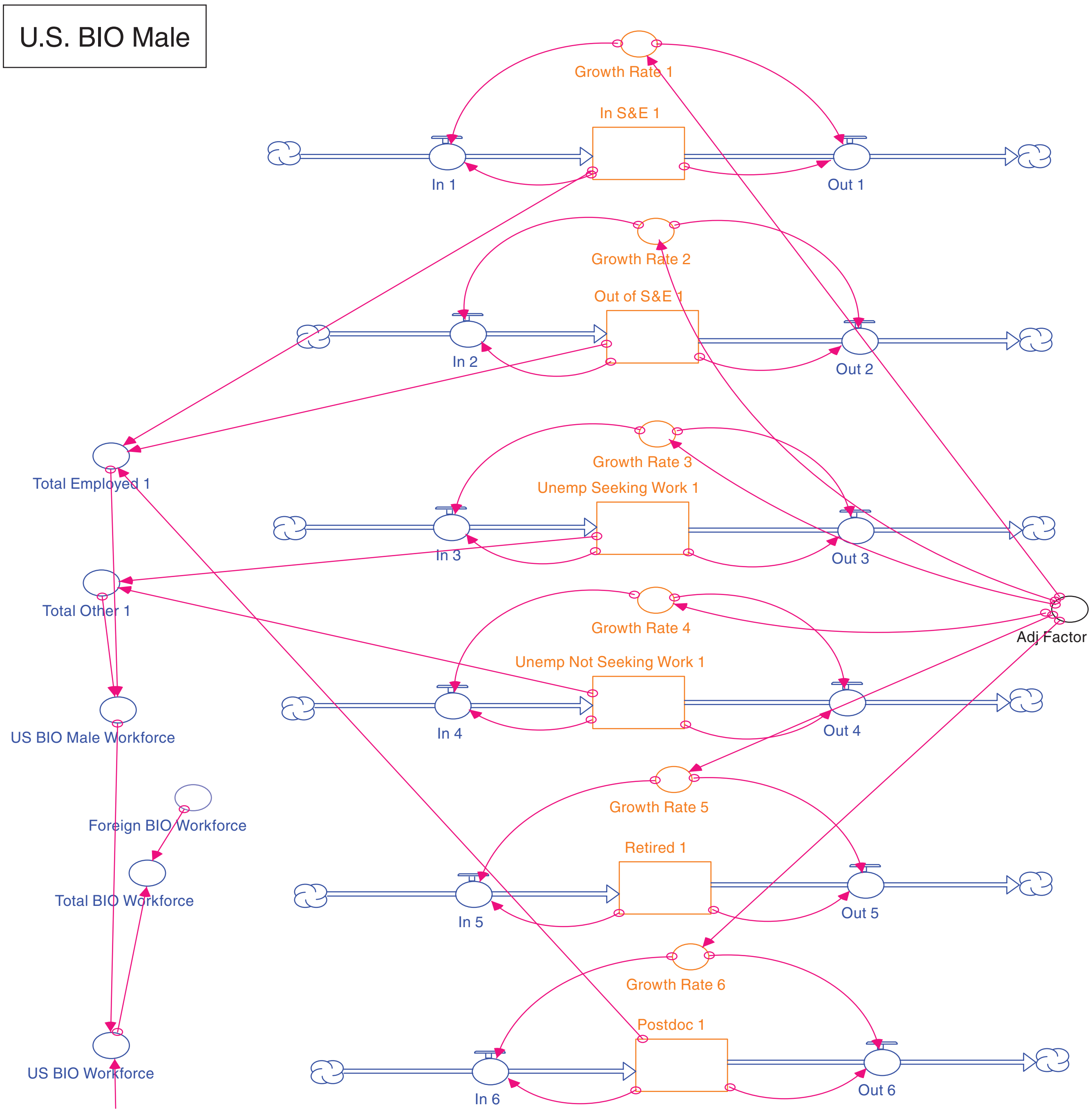

FIGURE E-14 Model for U.S.-trained males in biomedical science for scenarios 1 and 2.

groups (e.g., U.S.-trained females in biomedical science, foreign-trained males in clinical science, etc.). However, different data are used to initialize the model based on which specific demographic group is being modeled.

For Scenario 3, a slightly different stock-and-flow structure is used that includes more of the "supply pipeline" (Figure E-15). For each demographic group, a stock of Ph.D. students is also included that precedes the stock for the entire workforce. (At this point, because the data for Ph.D. students is aggregate, the workforce is represented as aggregate to maintain consistency, as opposed to multiple portions of the workforce as in Scenarios 1 and 2 and in Figure E-14.) The inclusion of the supply pipeline in Scenario 3 is the reason that this scenario is considered low risk. Adding the Ph.D. student pool produces limits to the growth of the following workforce, which is more realistic than letting the workforce

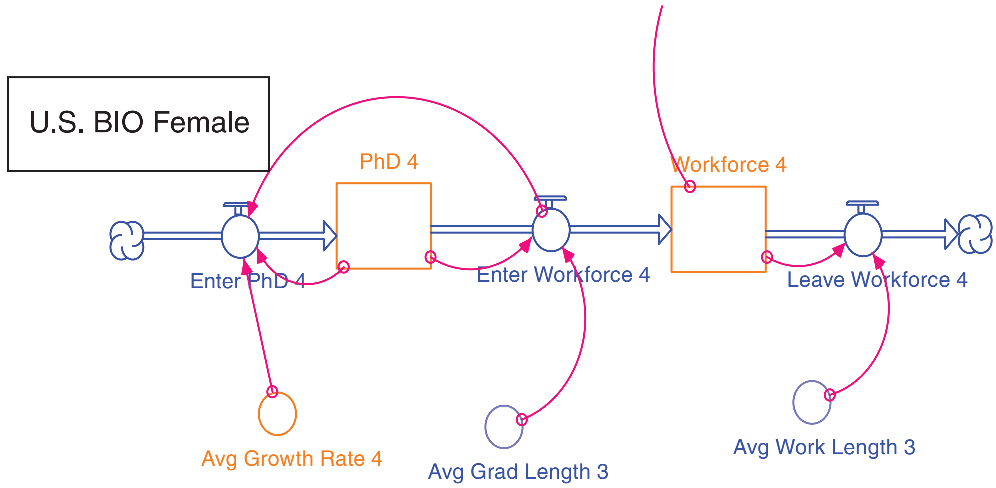

FIGURE E-15 Model for U.S.-trained females in biomedical science for scenario 3.

continue to grow (or shrink) at its current pace. Consequently, the workforce projection numbers are lower for all three major workforces (i.e., biomedical science, clinical science, and behavioral science).

In the pipeline model for each demographic group, the model starts with the number of Ph.D. students and uses the growth rate for Ph.D. students to determine how many Ph.D. students enter the Ph.D. pool. The *Avg Grad Length* then determines how quickly students move through the Ph.D. pool to enter the workforce. For the purposes of this analysis, the average graduation time is assumed to be 7 years. Thus, 1/7th of the Ph.D. pool enters the workforce each year. For the *Workforce*, the *Avg Work Length* determines how many people retire or move out of the workforce each year. For the purposes of this analysis, the average time that someone spends in the workforce is assumed to be 50 years. Thus, 1/50th of the people leave the workforce each year of the simulation.

Table E-15 shows the data used for the Ph.D. pipeline model. The values in the rightmost columns are the average annual growth rates using the past 5 years of data (i.e., 2001 to 2006), as highlighted by the gray shaded cells. The 5-year average annual growth rates are the ones used in the Scenario 3 model for the growth of the Ph.D. student population.

It should be noted that the pipeline model is not complete. Additional stocks could precede the Ph.D. pool (e.g., undergraduate students, K-12 students, etc.) to represent the full pipeline of students progressing up to employment in the workforce. In addition, based on detailed data for the Ph.D. pool, several pipeline models could be used to show the movement through the pipelines for the fields of science, engineering, etc. in addition to the separation of male/female and U.S./foreign.

TABLE E-15 Ph.D. Data Used in Scenario 3

Doctorates by Year, Citizenship and Gender

FEMALES	1999	2000	2001	2002	2003	2004	2005	2006	Annual Avg Growth Last 5 yrs
Biomedical Sciences									
Citizens	1528	1683	1670	1596	1639	1738	1830	1897	2.7%
Permanent Residents	218	176	182	182	151	126	142	185	0.3%
Temporary Residents	442	532	476	480	549	600	754	897	17.7%
Unknown	17	7	5	4	20	29	35	16	44.0%
Clinical Sciences									
Citizens	650	762	713	762	797	826	827	860	4.1%
Permanent Residents	34	41	43	42	33	48	52	54	5.1%
Temporary Residents	133	144	140	172	149	180	207	214	10.6%
Unknown	7	9	4	8	12	11	22	9	25.0%
Behavioral Sciences									
Citizens	2487	2523	2317	2250	2301	2240	2260	2325	0.1%
Permanent Residents	81	79	72	69	63	69	85	88	4.4%
Temporary Residents	124	159	142	152	186	190	187	206	9.0%
Unknown	6	2	6	5	6	18	12	13	23.3%

MALES	1999	2000	2001	2002	2003	2004	2005	2006	Annual Avg Growth Last 5 yrs
Biomedical Sciences									
Citizens	1910	1937	1965	1974	1913	1990	2018	2074	1.1%
Permanent Residents	259	188	155	134	114	102	111	118	-4.8%
Temporary Residents	782	804	725	742	788	805	889	995	7.4%
Unknown	30	4	17	7	15	20	27	26	10.6%
Clinical Sciences									
Citizens	275	307	298	299	316	307	326	322	1.6%
Permanent Residents	47	33	32	21	27	20	29	32	0.0%
Temporary Residents	117	131	150	131	154	155	167	174	3.2%
Unknown	8	4	8	7	8	8	7	12	10.0%
Behavioral Sciences									
Citizens	1310	1296	1200	1158	1138	1201	1110	1049	-2.5%
Permanent Residents	38	56	42	47	33	28	31	25	-8.1%
Temporary Residents	141	151	133	113	135	142	163	153	3.0%
Unknown	7	4	5	2	11	9	5	5	0.0%

Appendix F

Characteristics of Doctorates

TABLE F-1 Characteristics of Doctorates in the Biomedical Sciences, 1970-2008

	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988
Total Doctorates	2,882	3,132	3,116	3,135	3,013	3,085	3,150	3,050	3,118	3,212	3,396	3,356	3,444	3,338	3,399	3,313	3,369	3,465	3,769
Male	2,420	2,572	2,530	2,474	2,340	2,347	2,424	2,351	2,311	2,351	2,440	2,383	2,417	2,224	2,315	2,192	2,197	2,214	2,377
Female	462	560	586	661	673	738	726	699	807	861	956	973	1,027	1,114	1,084	1,121	1,172	1,251	1,392
Citizens	2,385	2,591	2,573	2,582	2,381	2,556	2,610	2,528	2,628	2,738	2,905	2,898	2,927	2,854	2,868	2,727	2,751	2,670	2,858
Permanent residents	160	198	215	231	209	194	165	169	147	133	147	125	114	108	109	113	118	153	176
Temporary residents	312	266	256	253	283	256	277	261	259	253	273	248	294	291	308	364	343	455	515
Unknown	25	77	72	69	140	79	98	92	84	88	71	85	109	85	114	109	157	187	220
Minorities	N/A	N/A	N/A	80	84	86	80	78	108	79	83	91	94	86	99	104	119	128	123
Postdoctoral training in U.S.																			
Postdoctoral fellowship	772	739	739	731	607	804	896	911	1034	1048	1079	1036	1057	1025	1096	1086	1122	1196	1285
Postdoctoral research	243	300	295	330	376	402	406	408	402	386	470	474	452	516	451	477	518	495	540
Postdoctoral traineeship	60	74	71	40	29	47	46	66	65	88	87	56	65	65	54	55	51	56	69
Other training	70	67	110	125	139	165	167	114	117	174	175	193	234	201	190	157	160	173	179
Total Postdoctorates	1,145	1,180	1,215	1,226	1,151	1,418	1,515	1,499	1,618	1,696	1,811	1,759	1,808	1,807	1,791	1,775	1,851	1,920	2,073
Percent planning	56.3%	56.6%	59.4%	58.9%	60.1%	68.0%	70.1%	73.4%	75.9%	75.3%	76.1%	76.1%	76.6%	77.2%	78.1%	77.7%	79.5%	80.2%	80.4%
Employment in U.S.	839	854	790	812	719	633	615	525	496	544	546	541	534	514	479	489	457	453	483
Other	48	49	42	44	44	33	31	19	19	12	23	11	19	21	23	20	21	20	22
Ph.D. with plans	2,032	2,083	2,047	2,082	1,914	2,084	2,161	2,043	2,133	2,252	2,380	2,311	2,361	2,342	2,293	2,284	2,329	2,393	2,578
Time to degree	6.00	6.00	6.16	6.17	6.25	6.17	6.17	6.17	6.25	6.25	6.25	6.33	6.50	6.67	6.92	7.00	7.00	7.00	7.00
Age at time of degree	28.92	29.00	29.42	29.58	29.42	29.25	29.25	29.34	29.38	29.41	29.25	29.33	29.59	29.83	30.25	30.42	30.59	30.50	30.83

TABLE F-1 Characteristics of Doctorates in the Biomedical Sciences, 1970-2008 (continued)

	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
Total Doctorates	3,793	3,992	4,294	4,442	4,794	4,863	5,079	5,366	5,459	5,465	5,340	5,547	5,397	5,375	5,412	5665	6091	6521	6798	7095
Male	2,348	2,477	2,655	2,740	2,864	2,887	2,955	3,102	3,110	3,113	3,074	3,060	2,984	3,015	2,960	3075	3187	3393	3550	3584
Female	1,445	1,515	1,639	1,702	1,930	1,976	2,124	2,264	2,349	2,352	2,266	2,478	2,403	2,358	2,439	2590	2896	3130	3248	3511
Citizens	2,850	2,899	3,050	3,072	3,264	3,203	3,278	3,291	3,451	3,492	3,438	3,620	3,623	3,563	3,534	3728	3849	3972	4140	4339
Permanent Residents	173	183	210	240	296	641	831	801	562	533	477	364	341	315	266	228	253	303	282	271
Temporary Residents	570	814	987	1,078	1,165	980	918	1,173	1,233	1,213	1,224	1,336	1,202	1,222	1,341	1405	1644	1893	1956	2080
Unknown	200	96	62	66	98	57	73	121	243	241	218	227	231	275	366	49	62	45	47	82
Minorities	135	135	159	162	190	223	243	246	261	277	308	315	364	367	358	400	448	474	537	571
Postdoctoral training in U.S.																				
Postdoctoral fellowship	1322	1336	1434	1496	1614	1577	1630	1708	1685	1682	1629	1718	1590	1655	1635	1717	1892	1977	1931	1858
Postdoctoral research	511	593	592	629	662	685	684	696	674	743	679	653	645	634	664	731	767	778	986	981
Postdoctoral traineeship	54	58	71	63	76	89	79	87	65	52	63	124	81	82	146	41	33	49	27	35
Other training	229	193	238	247	262	250	271	325	175	224	407	320	346	240	276	387	437	420	174	116
Total Postdoctorates	2,116	2,180	2,335	2,435	2,614	2,601	2,664	2,816	2,599	2,701	2,778	2,815	2,662	2,611	2,721	2,876	3,129	3,224	3,118	2,990
Percent planning	79.4%	81.9%	81.9%	81.4%	81.8%	82.6%	83.7%	83.1%	76.3%	77.4%	80.8%	78.7%	76.9%	76.0%	79.9%	84.1%	83.9%	79.9%	81.7%	79.9%
Employment in U.S.	534	457	489	541	559	532	497	550	730	746	647	743	785	796	661	528	586	791	683	745
Other	16	24	27	14	22	16	23	21	76	41	15	20	15	27	25	14	15	20	16	8
Ph.D. with plans	2,666	2,661	2,851	2,990	3,195	3,149	3,184	3,387	3,405	3,488	3,440	3,578	3,462	3,434	3,407	3,418	3,730	4,035	3,817	3,743
Time to degree	7.00	7.25	7.00	7.25	7.25	7.33	7.33	7.25	7.08	7.00	7.00	7.00	7.00	7.00	6.91	6.58	6.67	6.67	6.67	6.58
Age at time of degree	30.92	31.17	31.08	31.17	31.17	31.17	31.25	31.25	31	30.92	30.83	30.91	30.83	30.67	30.58	30.5	30.41	30.41	30.41	30.41

SOURCE: NSF. 2008. *Survey of Earned Doctorates*. Washington, DC: NSF.

TABLE F-2 Employment Characteristics of Biomedical Doctorates from U.S. Institutions, 1973-2006

	1973	1975	1977	1979	1981	1983	1985	1987
Total employed in S&E	34,367	39,661	43,411	48,591	53,357	56,481	61,810	65,800
	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
Minority	848	1,124	1,213	1,405	1,594	1,597	1,870	1,973
	2.5%	2.8%	2.8%	2.9%	3.0%	2.8%	3.0%	3.0%
Citizens and permanent residents	32,095	37,271	40,526	45,010	50,285	53,753	58,840	62,509
	93.4%	94.0%	93.4%	92.6%	94.2%	95.2%	95.2%	95.0%
Temporary residents	793	777	1,055	1,645	503	331	473	581
	2.3%	2.0%	2.4%	3.4%	0.9%	0.6%	0.8%	0.9%
Total academics	23,423	27,219	29,889	33,188	36,165	36,797	39,307	41,027
	68.2%	68.6%	68.9%	68.3%	67.8%	65.1%	63.6%	62.4%
Faculty with rank appointments	20,138	22,898	24,572	26,064	27,868	28,510	30,454	31,280
	58.6%	57.7%	56.6%	53.6%	52.2%	50.5%	49.3%	47.5%
Tenured faculty	4,567	13,376	14,345	15,636	17,836	18,884	20,114	19,157
	13.3%	33.7%	33.0%	32.2%	33.4%	33.4%	32.5%	29.1%
Tenure-track faculty (not tenured)	15,571	8,854	9,170	5,952	6,446	5,673	6,644	6,149
	45.3%	22.3%	21.1%	12.2%	12.1%	10.0%	10.7%	9.3%
Academic postdoctorates	1,713	2,615	3,507	4,358	4,722	4,405	4,450	4,784
	5.0%	6.6%	8.1%	9.0%	8.8%	7.8%	7.2%	7.3%
Other academic appointments	1,572	1,706	1,810	3,092	3,575	3,882	4,403	4,963
	4.6%	4.3%	4.2%	6.4%	6.7%	6.9%	7.1%	7.5%
Industry (non-postdoctorate)	4,470	5,273	5,543	6,286	7,881	9,589	11,841	13,366
	13.0%	13.3%	12.8%	12.9%	14.8%	17.0%	19.2%	20.3%
Industrial postdoctorates	27	53	40	27	70	46	126	222
	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%	0.2%	0.3%
Government (non-postdoctorate)	3,675	3,785	3,914	4,449	4,545	4,843	5,026	5,725
	10.7%	9.5%	9.0%	9.2%	8.5%	8.6%	8.1%	8.7%
Government postdoctorates	156	245	336	327	286	444	373	529
	0.5%	0.6%	0.8%	0.7%	0.5%	0.8%	0.6%	0.8%
Other sectors	2,539	3,055	3,436	4,103	4,303	4,657	5,043	4,847
	7.4%	7.7%	7.9%	8.4%	8.1%	8.2%	8.2%	7.4%
Doctorates w/ fed. research support	19,841	22,152	23,884	26,183	26,640	29,439	27,377	38,171
	57.7%	55.9%	55.0%	53.9%	49.9%	52.1%	44.3%	58.0%

TABLE F-2 Employment Characteristics of Biomedical Doctorates from U.S. Institutions, 1973-2006 (continued)

	1989	1991	1993	1995	1997	1999	2001	2003	2006
Total employed in S&E	70,593	71,962	76,449	79,077	88,481	95,780	100,224	97,903	104,585
	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
Minority	2,379	2,833	2,945	3,352	3,904	4,721	5,345	3,338	3,787
	3.4%	3.9%	3.9%	4.2%	4.4%	4.9%	5.3%	3.4%	3.6%
Citizens and permanent residents	66,944	68,184	71,599	72,948	80,826	85,107	97,126	94,589	100,350
	94.8%	94.8%	93.7%	92.2%	91.3%	88.9%	96.9%	96.6%	96.0%
Temporary residents	884	945	1,410	1,251	1,376	2,680	3,098	3,314	4,235
	1.3%	1.3%	1.8%	1.6%	1.6%	2.8%	3.1%	3.4%	4.0%
Total academics	43,572	40,581	45,258	48,622	53,026	55,682	57,227	59,150	61,745
	61.7%	56.4%	59.2%	61.5%	59.9%	58.1%	57.1%	60.4%	59.0%
Faculty with rank appointments	31,862	28,672	32,180	33,496	36,122	36,987	38,299	40,027	40,223
	45.1%	39.8%	42.1%	42.4%	40.8%	38.6%	38.2%	40.9%	38.5%
Tenured faculty	19,755	17,106	19,070	19,516	20,326	21,535	21,695	21,208	21,106
	28.0%	23.8%	24.9%	24.7%	23.0%	22.5%	21.6%	21.7%	20.2%
Tenure-track faculty (not tenured)	5,872	7,556	7,722	8,259	8,974	8,909	8,784	9,518	9,612
	8.3%	10.5%	10.1%	10.4%	10.1%	9.3%	8.8%	9.7%	9.2%
Academic postdoctorates	5,993	4,819	6,431	7,701	9,620	10,145	9,692	8,777	11,244
	8.5%	6.7%	8.4%	9.7%	10.9%	10.6%	9.7%	9.0%	10.8%
Other academic appointments	5,717	7,090	6,647	7,436	7,296	8,550	9,236	11,623	11,778
	8.1%	9.9%	8.7%	9.4%	8.2%	8.9%	9.2%	11.9%	11.3%
Industry (non-postdoctorate)	15,376	18,309	19,538	18,949	21,643	26,216	28,935	25,869	28,297
	21.8%	25.4%	25.6%	24.0%	24.5%	27.4%	28.9%	26.4%	27.1%
Industrial postdoctorates	206	204	376	531	561	591	293	702	1582
	0.3%	0.3%	0.5%	0.7%	0.6%	0.6%	0.3%	0.7%	1.5%
Government (non-postdoctorate)	5,776	6,157	6,143	6,074	7,212	7,240	7,886	7,649	8,034
	8.2%	8.6%	8.0%	7.7%	8.2%	7.6%	7.9%	7.8%	7.7%
Government postdoctorates	514	432	1,057	1,111	1,437	1,180	1,050	766	1,151
	0.7%	0.6%	1.4%	1.4%	1.6%	1.2%	1.0%	0.8%	1.1%
Other sectors	5,034	5,984	4,077	3,790	4,602	4,871	4,213	3,759	3,776
	7.1%	8.3%	5.3%	4.8%	5.2%	5.1%	4.2%	3.8%	3.6%
Doctorates w/ fed. research support	40,655	38,490	-	31,513	34,678	41,707	42,012	43,113	46,428
	57.6%	53.5%	0.0%	39.9%	39.2%	43.5%	41.9%	44.0%	44.4%

SOURCE: NSF. *Survey of Doctorate Recipients, 1973-2006.* Washington, DC: NSF.

TABLE F-3 Characteristics of Doctorates in the Behavioral and Social Sciences, 1970-2008

	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988
Total doctorates	2,683	3,094	3,220	3,433	3,661	3,835	4,047	4,098	4,082	4,120	4,015	4,339	4,023	4,263	4,141	3,964	3,979	3,988	3,844
Male	2,079	2,352	2,391	2,452	2,549	2,611	2,733	2,634	2,554	2,445	2,315	2,461	2,240	2,265	2,087	1,993	1,962	1,912	1,749
Female	604	742	829	981	1,112	1,224	1,314	1,464	1,528	1,675	1,700	1,878	1,783	1,998	2,054	1,971	2,017	2,076	2,095
Citizens	2,458	2,812	2,928	3,128	3,231	3,461	3,722	3,724	3,676	3,728	3,630	3,935	3,600	3,799	3,662	3,487	3,426	3,352	3,232
Permanent residents	78	88	96	89	85	92	85	92	95	92	98	85	82	90	75	91	108	111	107
Temporary residents	121	150	140	157	165	214	183	167	152	161	152	173	151	182	190	179	185	180	194
Unknown	26	44	56	59	180	68	57	115	159	139	135	146	190	192	214	207	260	345	312
Minorities	N/A	N/A	N/A	84	115	172	202	234	235	266	244	256	269	271	272	261	278	255	266
Postdoctoral training in U.S.																			
Postdoctoral fellowship	150	156	144	149	128	151	205	214	246	225	278	284	232	283	262	279	297	289	289
Postdoctoral research	44	43	48	53	61	64	53	67	77	80	69	96	80	75	64	79	85	112	109
Postdoctoral traineeship	17	33	23	25	34	46	32	45	70	55	67	69	55	66	65	69	70	48	52
Other training	12	21	26	31	43	35	56	50	43	37	39	41	28	42	35	28	43	39	32
Total postdoctoral	223	253	241	258	266	296	346	376	436	397	453	490	395	466	426	455	495	488	482
Percent planning	11.4%	11.3%	10.8%	10.9%	11.1%	11.9%	13.4%	14.9%	18.0%	15.7%	17.8%	17.7%	16.3%	18.5%	17.5%	19.0%	20.1%	20.9%	20.4%
Employment in U.S.	1694	1942	1931	2069	2074	2134	2175	2102	1934	2094	2058	2233	2000	2008	1974	1906	1937	1815	1844
Other	39	43	58	50	52	49	54	43	49	33	36	42	34	45	29	33	30	34	33
Ph.D. with plans	1,956	2,238	2,230	2,377	2,392	2,479	2,575	2,521	2,419	2,524	2,547	2,765	2,429	2,519	2,429	2,394	2,462	2,337	2,359
Time to degree	6.25	6.25	6.50	6.50	6.67	6.75	6.75	6.92	7.00	7.25	7.50	7.91	8.00	8.17	8.50	8.67	8.91	9.00	9.09
Age at time of degree	29.66	29.58	29.75	30.08	30.08	30.25	30.25	30.58	30.59	31.16	31.33	31.92	32.08	32.5	32.75	33.08	33.58	33.75	34.33

TABLE F-3 Characteristics of Doctorates in the Behavioral and Social Sciences, 1970-2008 (continued)

	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
Total doctorates	3,975	4,064	4,087	4,080	4,289	4,185	4,162	4,224	4,371	4,481	4,466	4,507	4,230	4,064	4,139	4287	4124	4126	4213	4,281
Male	1,796	1,745	1,624	1,745	1,720	1,671	1,606	1,555	1,565	1,595	1,596	1,595	1,475	1,411	1,411	1511	1408	1332	1332	1,403
Female	2,179	2,319	2,463	2,335	2,569	2,514	2,556	2,669	2,806	2,886	2,870	2,908	2,751	2,649	2,724	2777	2716	2793	2881	2,878
Citizens	3,221	3,497	3,560	3,490	3,702	3,623	3,587	3,644	3,608	3,757	3,797	3,821	3,548	3,400	3,426	3441	3370	3374	3360	3,454
Permanent residents	95	107	124	132	146	155	177	170	151	142	119	135	114	113	97	97	116	113	116	124
Temporary residents	244	267	296	334	329	311	303	307	292	315	265	310	276	265	323	332	350	359	376	399
Unknown	415	193	112	133	123	104	101	111	360	285	301	241	292	286	293	27	17	18	25	39
Minorities	267	320	339	321	349	340	394	419	428	494	534	545	537	544	553	551	523	571	543	633
Postdoctoral training in U.S.																				
Postdoctoral fellowship	304	313	389	386	464	459	491	524	492	608	675	671	694	676	707	721	764	752	802	809
Postdoctoral research	73	96	94	93	97	113	107	122	123	132	129	142	155	132	158	166	155	184	194	204
Postdoctoral traineeship	69	69	45	54	45	55	59	50	39	49	34	55	41	47	56	27	23	11	25	19
Other training	33	25	31	30	44	34	28	47	15	21	56	30	38	30	33	93	96	106	89	93
Total Postdoctorates	479	503	559	563	650	661	685	743	669	810	894	898	928	885	954	1,007	1,038	1,053	1,110	1,125
Percent planning	20.1%	20.6%	22.6%	23.4%	26.6%	27.4%	29.8%	31.2%	29.7%	33.7%	36.0%	33.8%	36.1%	35.9%	38.7%	42.5%	43.1%	41.8%	45.5%	46.1%
Employment in U.S.	1876	1902	1892	1810	1758	1717	1574	1601	1546	1553	1555	1713	1607	1548	1488	1336	1352	1444	1305	1296
other	32	37	19	31	39	36	38	40	40	38	34	46	37	31	24	24	18	21	25	19
Ph.D. with plans	2,387	2,442	2,470	2,404	2,447	2,414	2,297	2,384	2,255	2,401	2,483	2,657	2,572	2,464	2,466	2,367	2,408	2,518	2,440	2,440
Time to degree	9.00	9.17	9.00	9.00	8.91	8.59	8.58	8.33	8.00	8.00	8.00	8.00	8.00	8.25	8.17	8.00	8.00	7.96	7.83	7.58
Age at time of degree	34.33	34.42	34.66	34.67	34.58	34.17	34.25	33.83	33.42	33.24	33.00	32.84	32.75	32.75	32.82	33.00	32.83	32.75	32.58	32.42

SOURCE: NSF. 2008. *Survey of Earned Doctorates*. Washington, DC: NSF.

TABLE F-4 Employment Characteristics of Behavioral and Social Sciences Doctorates from U.S. Institutions, 1973-2006

	1973	1975	1977	1979	1981	1983	1985	1987
Total employed in S&E	27,356	34,360	39,237	45,532	51,743	58,458	64,616	68,852
	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
Minority	544	861	1,088	1,587	2,081	2,553	2,908	3,174
	2.0%	2.5%	2.8%	3.5%	4.0%	4.4%	4.5%	4.6%
Citizens and permanent residents	26,751	33,692	38,589	44,376	50,593	57,205	63,160	67,473
	97.8%	98.1%	98.3%	97.5%	97.8%	97.9%	97.7%	98.0%
Temporary residents	107	172	122	369	168	247	156	59
	0.4%	0.5%	0.3%	0.8%	0.3%	0.4%	0.2%	0.1%
Total academics	18,178	22,333	24,287	26,972	29,995	32,267	34,985	34,911
	66.4%	65.0%	61.9%	59.2%	58.0%	55.2%	54.1%	50.7%
Faculty with rank appointments	17,095	20,937	22,623	23,888	25,364	27,442	29,079	28,678
	62.5%	60.9%	57.7%	52.5%	49.0%	46.9%	45.0%	41.7%
Tenured faculty	3,560	11,606	13,139	14,812	16,982	19,302	19,833	18,761
	13.0%	33.8%	33.5%	32.5%	32.8%	33.0%	30.7%	27.2%
Tenure-track faculty (not tenured)	13,535	8,311	8,244	5,336	5,204	4,963	5,623	4,989
	49.5%	24.2%	21.0%	11.7%	10.1%	8.5%	8.7%	7.2%
Academic postdoctorates	205	481	594	836	775	798	901	664
	0.7%	1.4%	1.5%	1.8%	1.5%	1.4%	1.4%	1.0%
Other academic appointments	878	915	1,070	3,141	3,856	4,027	5,005	5,569
	3.2%	2.7%	2.7%	6.9%	7.5%	6.9%	7.7%	8.1%
Industry (non-postdoctorate)	2,682	3,666	4,883	6,695	9,357	12,891	15,469	17,621
	9.8%	10.7%	12.4%	14.7%	18.1%	22.1%	23.9%	25.6%
Industrial postdoctorates	0	0	4	0	0	4	80	14
	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	0.0%
Government (non-postdoctorate)	2,680	2,603	3,216	3,718	3,938	4,627	4,632	5,390
	9.8%	7.6%	8.2%	8.2%	7.6%	7.9%	7.2%	7.8%
Government postdoctorates	22	15	53	49	88	85	22	51
	0.1%	0.0%	0.1%	0.1%	0.2%	0.1%	0.0%	0.1%
Other sectors	3,760	5,700	6,582	7,780	8,259	8,500	9,382	10,719
	13.7%	16.6%	16.8%	17.1%	16.0%	14.5%	14.5%	15.6%
Doctorates w/ fed. research support	10,881	12,965	13,790	15,213	15,689	16,648	13,651	21,864
	39.8%	37.7%	35.1%	33.4%	30.3%	28.5%	21.1%	31.8%

TABLE F-4 Employment Characteristics of Behavioral and Social Science Doctorates from U.S. Institutions, 1973-2006 (continued)

	1989	1991	1993	1995	1997	1999	2001	2003	2006
Total employed in S&E	74,570	75,420	81,126	84,408	91,662	95,909	99,154	91,941	95,564
	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
Minority	3,738	4,561	5,012	5,649	6,561	7,140	8,534	5,447	5,991
	5.0%	6.0%	6.2%	6.7%	7.2%	7.4%	8.6%	5.9%	6.3%
Citizens and permanent residents	73,054	73,534	79,280	82,526	89,186	93,155	98,725	91,263	94,811
	98.0%	97.5%	97.7%	97.8%	97.3%	97.1%	99.6%	99.3%	99.2%
Temporary residents	194	164	190	195	329	378	429	678	753
	0.3%	0.2%	0.2%	0.2%	0.4%	0.4%	0.4%	0.7%	0.8%
Total academics	36,961	33,280	37,617	39,905	43,736	45,402	47,206	44,961	47,153
	49.6%	44.1%	46.4%	47.3%	47.7%	47.3%	47.6%	48.9%	49.3%
Faculty with rank appointments	30,239	26,852	29,402	30,787	32,941	33,837	34,491	34,352	35,862
	40.6%	35.6%	36.2%	36.5%	35.9%	35.3%	34.8%	37.4%	37.5%
Tenured faculty	20,041	18,201	19,858	20,720	22,266	22,032	22,196	21,226	20,824
	26.9%	24.1%	24.5%	24.5%	24.3%	23.0%	22.4%	23.1%	21.8%
Tenure-track faculty (not tenured)	5,379	5,400	5,956	5,991	6,032	6,364	6,510	6,713	7,684
	7.2%	7.2%	7.3%	7.1%	6.6%	6.6%	6.6%	7.3%	8.0%
Academic postdoctorates	993	416	534	1,329	1,641	1,458	1,543	1,064	1,868
	1.3%	0.6%	0.7%	1.6%	1.8%	1.5%	1.6%	1.2%	2.0%
Other academic appointments	5,729	6,012	7,681	7,789	9,154	10,136	11,194	10,853	10,576
	7.7%	8.0%	9.5%	9.2%	10.0%	10.6%	11.3%	11.8%	11.1%
Industry (non-postdoctorate)	19,998	23,995	27,236	27,348	28,735	31,318	32,561	31,457	32,494
	26.8%	31.8%	33.6%	32.4%	31.3%	32.7%	32.8%	34.2%	34.0%
Industrial postdoctorates	5	20	50	151	462	211	201	458	297
	0.0%	0.0%	0.1%	0.2%	0.5%	0.2%	0.2%	0.5%	0.3%
Government (non-postdoctorate)	5,557	5,565	8,867	9,310	9,692	9,696	9,877	8,588	8,558
	7.5%	7.4%	10.9%	11.0%	10.6%	10.1%	10.0%	9.3%	9.0%
Government postdoctorates	11	84	147	176	267	210	165	252	139
	0.0%	0.1%	0.2%	0.2%	0.3%	0.2%	0.2%	0.3%	0.1%
Other sectors	11,863	11,931	7,209	7,518	8,770	9,072	8,960	6,050	6,923
	15.9%	15.8%	8.9%	8.9%	9.6%	9.5%	9.0%	6.6%	7.2%
Doctorates w/ fed. research support	23,831	20,902	-	15,385	16,308	20,487	22,549	20,643	22,372
	32.0%	27.7%	0.0%	18.2%	17.8%	21.4%	22.7%	22.5%	23.4%

SOURCE: NSF. *Survey of Doctorate Recipients, 1973-2006.* Washington, DC: NSF.

TABLE F-5 Characteristics of Doctorates in the Clinical Sciences, 1970-2008

	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988
Total Doctorates	273	329	306	323	339	340	357	385	387	432	464	524	575	526	621	619	677	699	788
Male	218	271	245	249	252	233	248	266	256	271	273	303	319	249	262	244	259	290	302
Female	55	58	61	74	87	107	109	119	131	161	191	221	256	277	359	375	418	409	486
Citizens	210	263	219	250	239	258	273	296	305	339	370	429	457	401	492	458	489	527	573
Permanent residents	19	20	40	34	37	35	32	41	26	39	32	33	33	30	36	32	30	33	38
Temporary residents	37	30	29	31	33	35	40	42	38	37	53	48	64	70	66	85	93	84	108
Unknown	7	16	18	8	30	12	12	6	18	17	9	14	21	25	27	44	65	55	69
Minorities	N/A	N/A	N/A	N/A	N/A	N/A	N/A	22	N/A	22	N/A	19	30	23	34	31	32	38	50
Postdoctoral training in U.S.																			
Postdoctoral fellowship	16	17	26	19	10	24	26	34	24	37	37	35	34	25	47	34	35	48	40
Postdoctoral research	2	4	11	16	21	11	6	16	15	16	11	16	20	12	13	17	18	17	26
Postdoctoral traineeship	1	2	1	.	1	1	1	3	3	3	3	5	3	3	4	1	4	4	6
Other training	7	4	6	11	6	4	5	7	6	10	15	13	4	3	8	1	9	11	10
Total postdoctoral	26	27	44	46	38	40	38	60	48	66	66	69	61	43	72	53	66	80	82
Percent planning	15.5%	13.2%	23.8%	22.2%		17.4%	16.5%		20.4%	23.6%	20.6%	19.6%	17.0%	13.6%	18.6%	14.1%	16.8%	18.1%	17.5%
Employment in U.S.	137	170	135	153	153	183	185	172	185	204	250	277	287	264	306	321	319	349	375
Other	5	8	6	8	8	7	7	3	2	10	5	6	11	10	10	3	7	13	11
Ph.D. with plans	168	205	185	207	199	230	230	235	235	280	321	352	359	317	388	377	392	442	468
Time to degree	7.59	7.00	7.00	7.00	7.92	7.79	7.75	7.50	7.67	7.75	7.92	8.50	8.79	9.41	9.29	10.08	10.25	10.09	10.58
Age at time of degree	31.21	29.96	30.33	30.59	30.67	31.83	31.58	30.75	31.67	31.75	32.00	32.37	32.87	34.08	34.33	35.58	35.92	35.92	36.42

TABLE F-5 Characteristics of Doctorates in the Clinical Sciences, 1970-2008 (continued)

	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
Total doctorates	881	840	950	1022	1100	1208	1225	1237	1354	1425	1338	1527	1558	1579	1574	1642	1727	1810	2036	2002
Male	313	322	333	363	396	420	456	435	469	474	480	518	566	510	528	520	563	598	644	638
Female	568	518	617	659	704	788	769	802	885	951	858	1007	981	1069	1039	1122	1161	1209	1382	1364
Citizens	656	630	706	739	803	897	857	865	911	1003	925	1070	1036	1058	1115	1133	1153	1182	1319	1299
Permanent residents	29	34	58	48	63	91	102	87	77	85	81	74	76	63	60	68	81	86	83	102
Temporary residents	118	145	161	213	202	214	236	253	256	266	250	275	293	300	299	335	374	388	427	425
Unknown	78	31	29	30	44	15	41	41	126	77	92	108	153	158	100	19	29	21	33	36
Minorities	38	41	56	49	79	70	90	83	85	97	105	116	112	106	137	165	177	169	192	172
Postdoctoral training in U.S.																				
Postdoctoral fellowship	39	52	50	69	62	97	76	97	88	93	88	95	142	147	154	182	177	201	212	215
Postdoctoral research	21	35	23	34	27	21	37	39	47	38	38	38	45	45	57	55	56	70	88	102
Postdoctoral traineeship	4	6	2	10	5	5	6	4	6	6	12	12	6	11	18	9	12	6	7	12
Other training	10	13	10	15	14	9	10	14	7	8	29	17	14	10	21	27	30	33	13	15
Total postdoctoral	116	165	141	192	185	226	236	239	225	230	167	162	207	213	250	273	275	310	320	344
Percent planning	13%	20%	15%	19%	17%	19%	19%	19%	17%	16%	12%	11%	13%	19%	27%	29%	27%	29%	28%	30%
Employment in U.S.	459	373	468	491	525	503	489	531	589	606	591	732	643	733	666	652	719	760	799	782
Other	8	9	11	9	12	11	11	18	17	26	12	17	15	31	19	12	11	15	13	17
Ph.D. with plans	583	547	620	692	722	740	736	788	831	862	770	911	865	977	935	937	1,005	1,085	1,132	1,143
Time to degree	11.00	11.17	11.41	11.67	11.75	11.41	11.25	11.59	11.50	11.50	10.92	11.25	10.09	11.25	10.50	9.58	9.59	9.50	9.50	9.25
Age at time of degree	36.75	37.17	37.83	37.75	38.42	37.79	38.08	38.46	38.58	38.25	37.24	38.33	36.92	38.17	37.08	36.67	36.17	36.24	35.75	35.42

SOURCE: NSF. 2008. *Survey of Earned Doctorates*. Washington, DC: NSF.

TABLE F-6 Employment Characteristics of Clinical Doctorates from U.S. Institutions, 1973-2006

	1973	1975	1977	1979	1981	1983	1985	1987
Total employed in S&E	2,682	3,475	3,748	4,489	5,312	6,003	7,188	7,669
	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
Minority	105	153	163	203	208	250	307	342
	3.9%	4.4%	4.3%	4.5%	3.9%	4.2%	4.3%	4.5%
Citizens and permanent residents	2,462	3,236	3,454	4,105	4,914	5,668	6,776	7,614
	91.8%	93.1%	92.2%	91.4%	92.5%	94.4%	94.3%	99.3%
Temporary residents	69	83	86	133	44	8	79	55
	2.6%	2.4%	2.3%	3.0%	0.8%	0.1%	1.1%	0.7%
Total academics	1,478	1,856	2,064	2,564	2,963	3,225	3,938	4,164
	55.1%	53.4%	55.1%	57.1%	55.8%	53.7%	54.8%	54.3%
Faculty with rank appointments	1,359	1,671	1,852	2,259	2,642	2,922	3,413	3,675
	50.7%	48.1%	49.4%	50.3%	49.7%	48.7%	47.5%	47.9%
Tenured faculty	276	931	1,031	1,271	1,424	1,516	1,968	1,960
	10.3%	26.8%	27.5%	28.3%	26.8%	25.3%	27.4%	25.6%
Tenure-track faculty (not tenured)	1,083	684	743	565	780	921	1,002	931
	40.4%	19.7%	19.8%	12.6%	14.7%	15.3%	13.9%	12.1%
Academic postdoctorates	40	107	108	105	139	100	177	90
	1.5%	3.1%	2.9%	2.3%	2.6%	1.7%	2.5%	1.2%
Other academic appointments	79	78	104	231	182	203	348	399
	2.9%	2.2%	2.8%	5.1%	3.4%	3.4%	4.8%	5.2%
Industry (non-postdoctorate)	536	739	733	992	1,259	1,485	1,793	1,940
	20.0%	21.3%	19.6%	22.1%	23.7%	24.7%	24.9%	25.3%
Industrial postdoctorates	0	0	0	0	0	8	5	14
	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	0.1%	0.2%
Government (non-postdoctorate)	383	491	462	446	527	585	689	745
	14.3%	14.1%	12.3%	9.9%	9.9%	9.7%	9.6%	9.7%
Government postdoctorates	5	9	8	11	35	34	14	8
	0.2%	0.3%	0.2%	0.2%	0.7%	0.6%	0.2%	0.1%
Other sectors	280	380	455	436	501	645	749	760
	10.4%	10.9%	12.1%	9.7%	9.4%	10.7%	10.4%	9.9%
Doctorates w/ fed. research support	1,416	1,804	1,836	2,041	2,179	2,416	2,307	3,275
	52.8%	51.9%	49.0%	45.5%	41.0%	40.2%	32.1%	42.7%

TABLE F-6 Employment Characteristics of Clinical Doctorates from U.S. Institutions, 1973-2006 (continued)

	1989	1991	1993	1995	1997	1999	2001	2003	2006
Total employed in S&E	8,991	9,251	10,748	11,996	14,069	15,268	17,180	16,550	19,750
	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
Minority	533	614	766	899	1,113	1,357	1,497	1,057	1,330
	5.9%	6.6%	7.1%	7.5%	7.9%	8.9%	8.7%	6.4%	6.7%
Citizens and permanent residents	8,522	8,726	10,142	11,253	13,128	13,930	16,822	16,005	19,036
	94.8%	94.3%	94.4%	93.8%	93.3%	91.2%	97.9%	96.7%	96.4%
Temporary residents	72	65	175	58	194	335	358	545	714
	0.8%	0.7%	1.6%	0.5%	1.4%	2.2%	2.1%	3.3%	3.6%
Total academics	4,959	4,706	5,827	6,684	7,609	8,855	9,730	10,037	11,856
	55.2%	50.9%	54.2%	55.7%	54.1%	58.0%	56.6%	60.6%	60.0%
Faculty with rank appointments	4,371	4,077	5,084	5,705	6,325	7,374	8,124	8,536	10,084
	48.6%	44.1%	47.3%	47.6%	45.0%	48.3%	47.3%	51.6%	51.1%
Tenured faculty	2,191	1,890	2,341	2,770	3,081	3,507	3,647	3,629	3,989
	24.4%	20.4%	21.8%	23.1%	21.9%	23.0%	21.2%	21.9%	20.2%
Tenure-track faculty (not tenured)	1,337	1,426	1,784	1,988	1,878	2,138	2,384	2,505	3,371
	14.9%	15.4%	16.6%	16.6%	13.3%	14.0%	13.9%	15.1%	17.1%
Academic postdoctorates	152	116	144	342	416	324	321	349	516
	1.7%	1.3%	1.3%	2.9%	3.0%	2.1%	1.9%	2.1%	2.6%
Other academic appointments	436	513	599	637	868	1,157	1,285	1,313	1,514
	4.8%	5.5%	5.6%	5.3%	6.2%	7.6%	7.5%	7.9%	7.7%
Industry (non-postdoctorate)	2,307	2,564	2,869	2,923	3,568	3,731	4,413	4,258	5,088
	25.7%	27.7%	26.7%	24.4%	25.4%	24.4%	25.7%	25.7%	25.8%
Industrial postdoctorates	3	4	4	17	49	10	21	27	198
	0.0%	0.0%	0.0%	0.1%	0.3%	0.1%	0.1%	0.2%	1.0%
Government (non-postdoctorate)	916	1,064	1,144	1,309	1,467	1,250	1,604	1,513	1,917
	10.2%	11.5%	10.6%	10.9%	10.4%	8.2%	9.3%	9.1%	9.7%
Government postdoctorates	2	16	67	101	47	50	30	74	156
	0.0%	0.2%	0.6%	0.8%	0.3%	0.3%	0.2%	0.4%	0.8%
Other sectors	778	847	837	962	1,329	1,372	1,339	641	535
	8.7%	9.2%	7.8%	8.0%	9.4%	9.0%	7.8%	3.9%	2.7%
Doctorates w/ fed. research support	3,951	4,125	3,016	3,323	3,849	5,172	5,822	6,192	7,551
	43.9%	44.6%	28.1%	27.7%	27.4%	33.9%	33.9%	37.4%	38.2%

SOURCE: NSF. *Survey of Doctorate Recipients, 1973-2006.* Washington, DC: NSF.