BEYOND BIAS AND BARRIERS

FULFILLING THE POTENTIAL OF WOMEN IN ACADEMIC SCIENCE AND ENGINEERING

Committee on Maximizing the Potential of Women in Academic Science and Engineering

Committee on Science, Engineering, and Public Policy

NATIONAL ACADEMY OF SCIENCES,
NATIONAL ACADEMY OF ENGINEERING, *AND*
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Denice Dee Denton, 1959-2006

A valued member of this committee, Denice Denton was an extraordinarily talented scholar, educational leader, and relentless voice for progress. She helped shape the direction of our nation's science and engineering enterprise through her research, teaching, technology development, service, leadership, mentoring, public communication of science and engineering, initiatives to promote diversity and inclusion, and outreach to our schools.

She was bigger than life. She opened doors, and stood in them to let others through. She mentored young scholars and students. Her enthusiasm for science was clear and infectious.

She was a force—a magnificent force. She pushed the institutions she inhabited to be better than they wanted to be.

With her tragic death we lost a friend, a colleague, and a champion. We proudly dedicate this report to her.

We will miss her.

Donna E. Shalala
Chair, Committee on Maximizing the Potential
of Women in Academic Science and Engineering

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Preface

When I started graduate school at Syracuse University in the late sixties, the chair of my department informed me that I would not be eligible for fellowships, because I was a woman. Pulling out a page of statistics, he pointed to the data indicating that women didn't finish PhD programs, and if they did, they interrupted their academic careers for marriage and children and therefore didn't go back to catch up with their peers. They were, he concluded, "a bad investment" for the department and the university.

Needless to say, with assistance from the Dean and other more progressive members of the faculty, I did finish my PhD. Then I went to New York to begin my academic career at the City University. At the end of my second semester of teaching, the department chair called me in for an evaluation. After pointing out that I was an excellent teacher and had published more than all of the other professors in the department put together, he said that he felt it necessary to be candid with me. "We have never tenured a woman, and never will; a bad investment," he said. I immediately called a department chair at Columbia University who had been trying to recruit me and moved over there.

Overt gender discrimination is now very rare, but it is still an issue. There has been considerable progress since I started my career, but it has been painfully slow, especially in science and engineering. The playing field is still not level. Growing numbers of women have earned undergraduate, graduate, and professional degrees. More and more of these well-qualified scientists and engineers have sought to pursue their calling in both academic and nonacademic settings. However, although women have risen to the challenge of scientific, medical, and technical study and research, the nation's academic institutions have not hired them for their faculties. The academy has a disappointing record. Institutional policies for attaining tenure are still based on a rigid apprentice system that assumes that a total commitment to an academic career is possible throughout one's life. Women—and sometimes men who shoulder significant care-giving responsibilities—are still perceived to be "a bad investment." Women also must deal with lifelong questioning of their ability in science and mathematics and their commitment to a career. As a result, women are underrepresented in science and engineering, particularly in the higher faculty ranks and leadership positions. Women scientists and engineers with minority racial and ethnic backgrounds are virtually absent from the nation's leading science and engineering departments.

This needless waste of the nation's scientific talent must end. In addition to considerations of equity that govern employment in other sectors of the nation's workforce, the United States now faces stiffening science and engineering competition from other nations. We urgently need to make full use of all of our talent to maintain our nation's leadership. Affording women scientists and engineers the academic career opportunities merited by their educational and professional achievements must be given a high priority by our nation.

The Committee on Science, Engineering, and Public Policy formed our Committee on Maximizing the Potential of Women in Academic Science and Engineering and charged it to recommend methods for achieving that goal. The committee's mandate was to gather and analyze the best available information on the status of women in academic science and engineering and to propose ways of putting their abilities to the best use.

Specifically, our committee was charged

- To review and assess the research on gender issues in science and engineering, including innate differences in cognition, implicit bias, and faculty diversity.
- To examine institutional culture and the practices in academic institutions that contribute to and discourage talented individuals from realizing their full potential as scientists and engineers.
- To determine effective practices to ensure that women who receive their doctorates in science and engineering have access to a wide array of career opportunities in the academy and in other research settings.
- To determine effective practices for recruiting women scientists and engineers to faculty positions and retaining them in these positions.
- To develop findings and provide recommendations based on these data and other information to guide faculty, deans, department chairs, and

other university leaders; scientific and professional societies; funding organizations; and government agencies in maximizing the potential of women in science and engineering careers.

Our committee, composed of distinguished scientists and engineers who have attained outstanding careers in academic research and university governance, undertook its task with enthusiasm and dedication. As people who have held major administrative positions, committee members were able to put gender issues into the broadest context. In fulfillment of its mandate, the committee met in Washington, DC, on three occasions to examine evidence and consult with leading experts. We also conferred by conference call on numerous other occasions.

In December 2005, we hosted a public convocation with outstanding researchers to explore the impact of sex and gender on the cognitive and intellectual abilities of men and women and on the attitudes and social institutions that affect the education, recruitment, hiring, promotion, and retention of academic science and engineering faculty. Over 150 interested people from academe, government, private funding agencies, and other organizations listened to the presentations, enriched the discussion with questions and comments, and presented their research in a poster session.

The convocation speakers discussed a number of crucial and, in some cases, controversial questions in light of the latest research findings. What does sex-difference research tell us about capability, achievement, and behavior? What are the effects of socialization and social roles on career development? What role do gender attitudes and stereotypes play in evaluation of people, their work, and their potential? What institutional features promote or deter the success of female scientists and engineers? What are the overlapping issues of sex, race, and ethnicity? What else do we need to know, and what key research is needed? The convocation informed the thinking and research that underlie the committee's final report; the proceedings with invited papers and poster abstracts have been collected into a workshop report, *Biological, Social, and Organizational Components of Success for Women in Academic Science and Engineering*, published by the National Academies Press.

During the committee's February 2006 meeting, the committee heard presentations by nationally recognized experts on topics ranging from recent developments in employment discrimination law to programs and strategies used by universities and other employers to advance the careers of women scientists and engineers. At its March meeting, the committee reviewed and refined the report's findings and recommendations. Throughout the spring, multiple meetings by teleconference permitted our committee to exchange views and information and to prepare our final findings and recommendations.

At all those sessions and throughout the months-long process of examining the evidence and developing this exhaustive report, in addition to data and opinions supplied by experts, committee members brought their own substantial expertise, insights, energy, and dedication to bear on this project and its goals. We have tried to carry out our task with great rigor, understanding the extraordinary impact that answering these questions and developing strategies can have on the next generation of women in science and engineering. It is our hope that in the future women in science and engineering will not face attitudes and institutional structures that denigrate their work and careers as "questionable" investments. Instead, our work will help ensure that women scientists and engineers take their unquestioned place as full, valued, and vital members of the nation's academic community.

We have no doubt that a combination of leadership, resources, peer pressure, law enforcement, and public outcry can fundamentally change the culture and opportunities at our research universities. We need look no further than our playing fields for evidence that the academy is capable of cultural and behavioral change when faced with a national imperative. It is time—our time—for a peaceful, thoughtful revolution.

Donna E. Shalala, Chair
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This report is the result of the efforts of many people. We would like to thank those who spoke at our convocation and our committee meetings. They were (in alphabetical order)

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Next, we thank the reviewers of the report. This report has been reviewed in draft form by people selected for their knowledge, expertise, and wide range of perspectives in accordance with the procedures approved by the National Research Council's Report Review Committee. The purpose of this independent review is to provide candid and critical comments that will assist the institution in making the published report as sound as possible and to ensure that the report meets institutional standards of objectivity, evidence, and responsiveness to the study charge. The review comments and draft manuscript remain confidential to protect the integrity of the deliberative process. We thank the following for their participation in the review of this report:

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Although the reviewers had many constructive comments and suggestions about the report, they were not asked to endorse the findings and recommendations of the report, nor did they see a final draft of the report before its release. The report review was overseen by May Berenbaum [NAS], Professor and Head of the Department of Entymology at the University of Illinois Urbana-Champaign, and MRC Greenwood [IOM], Professor of Nutrition and Internal Medicine at the University of California at Davis, appointed by the Report Review Committee, who 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 author committee and the institution.

In addition, we thank the guidance group that oversaw this project:

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Summary

The U.S. economy relies on the productivity, entrepreneurship, and creativity of its people. To maintain its scientific and engineering leadership amid increasing economic and educational globalization, the United States must aggressively pursue the innovative capacity of *all* of its people—women and men. Women make up an increasing proportion of science and engineering majors at all institutions, including top programs such as those at the Massachusetts Institute of Technology where women make up 51% of its science undergraduates and 35% of its engineering undergraduates. For women to participate to their full potential across all science and engineering fields, they must see a career path that allows them to reach their full intellectual potential. Much remains to be done to achieve that goal.

Women are a small portion of the science and engineering faculty members at research universities, and they typically receive fewer resources and less support than their male colleagues. The representation of women in leadership positions in our academic institutions, scientific and professional societies, and honorary organizations is low relative to the numbers of women qualified to hold these positions. It is not lack of talent, but unintentional biases and outmoded institutional structures that are hindering the access and advancement of women. Neither our academic institutions nor our nation can afford such underuse of precious human capital in science and engineering. The time to take action is now.

The National Academies, under the oversight of the Committee on Science, Engineering, and Public Policy, created the Committee on Maximizing the Potential of Women in Academic Science and Engineering to develop specific recommendations on how to make the fullest possible use of a large source of our nation's talent: women in academic science and engineering. This report presents the consensus views and judgment of the committee members, who include five university presidents and chancellors, provosts and named professors, former top government officials, leading policy analysts, and outstanding scientists and engineers—nine of whom are members of the National Academy of Sciences, National Academy of Engineering, or the Institute of Medicine, and many of whom have dedicated great thought and action to the advancement of women in science and engineering. The committee's recommendations—if implemented and coordinated across educational, professional, and government sectors—will transform our institutions, improve the working environment for women and men, and profoundly enhance our nation's talent pool.

FINDINGS

1. Women have the ability and drive to succeed in science and engineering. Studies of brain structure and function, of hormonal modulation of performance, of human cognitive development, and of human evolution have not found any significant biological differences between men and women in performing science and mathematics that can account for the lower representation of women in academic faculty and scientific leadership positions in these fields. The drive and motivation of women scientists and engineers is demonstrated by those women who persist in academic careers despite barriers that disproportionately disadvantage them.

2. Women who are interested in science and engineering careers are lost at every educational transition. With each step up the academic ladder, from high school on through full professorships, the representation of women in science and engineering drops substantially. As they move from high school to college, more women than men who have expressed an interest in science or engineering decide to major in something else; in the transition to graduate school, more women than men with science and engineering degrees opt into other fields of study; from doctorate to first position, there are proportionately fewer women than men in the applicant pool for tenure-track positions; active recruiting can overcome this deficit.

3. The problem is not simply the pipeline. In several fields, the pipeline has reached gender parity. For over 30 years, women have made up over 30% of the doctorates in social sciences and behavioral sciences and over 20% in the life sciences. Yet, at the top research institutions, only 15.4% of the full professors in the social and behavioral sciences and 14.8% in the life sciences are women—and these are the only fields in science and engineering where the proportion of women reaches into the double digits.

Women from minority racial and ethnic backgrounds are virtually absent from the nation's leading science and engineering departments.

4. Women are very likely to face discrimination in every field of science and engineering. Considerable research has shown the barriers limiting the appointment, retention, and advancement of women faculty. Overall, scientists and engineers who are women or members of racial or ethnic minority groups have had to function in environments that favor—sometimes deliberately but often inadvertently—the men who have traditionally dominated science and engineering. Well-qualified and highly productive women scientists have also had to contend with continuing questioning of their own abilities in science and mathematics and their commitment to an academic career. Minority-group women are subject to dual discrimination and face even more barriers to success. As a result, throughout their careers, women have not received the opportunities and encouragement provided to men to develop their interests and abilities to the fullest; this accumulation of disadvantage becomes acute in more senior positions.

These barriers have differential impact by field and by career stage. Some fields, such as physics and engineering, have a low proportion of women bachelor's and doctorates, but hiring into faculty positions appears to match the available pool. In other fields, including chemistry and biological sciences, the proportion of women remains high through bachelor's and doctorate degrees, but hiring into faculty positions is well below the available pool.

5. A substantial body of evidence establishes that most people—men and women—hold implicit biases. Decades of cognitive psychology research reveals that most of us carry prejudices of which we are unaware but that nonetheless play a large role in our evaluations of people and their work. An impressive body of controlled experimental studies and examination of decision-making processes in real life show that, on the average, people are less likely to hire a woman than a man with identical qualifications, are less likely to ascribe credit to a woman than to a man for identical accomplishments, and, when information is scarce, will far more often give the benefit of the doubt to a man than to a woman. Although most scientists and engineers believe that they are objective and intend to be fair, research shows that they are not exempt from those tendencies.

6. Evaluation criteria contain arbitrary and subjective components that disadvantage women. Women faculty are paid less, are promoted more slowly, receive fewer honors, and hold fewer leadership positions than men. These discrepancies do not appear to be based on productivity, the significance of their work, or any other measure of performance. Progress in academic careers depends on evaluation of accomplishments by more senior scientists, a process widely believed to be objective. Yet measures of success underlying the current "meritocratic" system are often arbitrary and applied in a biased manner (usually unintentionally). Characteristics that are often selected for and are believed, on the basis of little evidence, to relate to scientific creativity—namely assertiveness and single-mindedness—are given greater weight than other characteristics such as flexibility, diplomacy, curiosity, motivation, and dedication, which may be more vital to success in science and engineering. At the same time assertiveness and single-mindedness are stereotyped as socially unacceptable traits for women.

7. Academic organizational structures and rules contribute significantly to the underuse of women in academic science and engineering. Rules that appear quite neutral may function in a way that leads to differential treatment or produces differential outcomes for men and women. Structural constraints and expectations built into academic institutions assume that faculty members have substantial spousal support. The evidence demonstrates that anyone lacking the work and family support traditionally provided by a "wife" is at a serious disadvantage in academe. However, the majority of faculty no longer have such support. About 90% of the spouses of women science and engineering faculty are employed full-time; close to half the spouses of male faculty also work full-time.

8. The consequences of *not* acting will be detrimental to the nation's competitiveness. Women and minority-group members make up an increasing proportion of the labor force. They also are an increasing proportion of postsecondary students. To capture and capitalize on this talent will require revising policies adopted when the workplace was more homogeneous and creating new organizational structures that manage a diverse workforce effectively. Effective programs have three key components: commitment to take corrective action, analysis and utilization of data for organizational change, and a campus framework for monitoring progress.

To facilitate clear, evidence-based discussion of the issues, the committee compiled a list of commonly held beliefs concerning women in science and engineering (Table S-1). Each is discussed and analyzed in detail in the text of the report.

CONCLUSIONS

The United States can no longer afford the underperformance of our academic institutions in attracting the best and brightest minds to the science and engineering enterprise. Nor can it afford to devalue the contributions of some members of that workforce through gender inequities and discrimination. It is essential that our academic institutions promote the educational and professional success of all people without regard for sex, race, or ethnicity. So that our scientists and engineers can realize their greatest potential, our academic institutions must be held accountable and provide evidence that women and men receive equitable opportunities, resources, and support. Institutional policies and practices must move from

TABLE S-1 Evidence Refuting Commonly Held Beliefs About Women in Science and Engineering

Belief	Evidence	Where Discussed
(1) Women are not as good in mathematics as men.	Female performance in high school mathematics now matches that of males.	Chapter 2
(2) The matter of "under-representation" on faculties is only a matter of time; it is a function of how many women are qualified to enter these positions.	Women's representation decreases with each step up the tenure-track and academic leadership hierarchy, even in fields that have had a large proportion of women doctorates for 30 years.	Chapter 3
(3) Women are not as competitive as men. Women don't want jobs in academe.	Similar proportions of men and women science and engineering doctorates plan to enter postdoctoral study or academic employment.	Chapter 3
(4) Behavioral research is qualitative; why pay attention to the data in this report?	The data are from multiple sources, were obtained using well-recognized techniques, and have been replicated in several settings.	Chapters 2-5
(5) Women and minorities are recipients of favoritism through affirmative-action programs.	Affirmative action is meant to broaden searches to include more women and minority-group members, but not to select candidates on the basis of race or sex, which is illegal.	Chapter 4
(6) Academe is a meritocracy.	Although scientists like to believe that they "choose the best" based on objective criteria, decisions are influenced by factors—including biases about race, sex, geographic location of a university, and age—that have nothing to do with the quality of the person or work being evaluated.	Chapter 4
(7) Changing the rules means that standards of excellence will be deleteriously affected.	Throughout a scientific career, advancement depends upon judgments of one's performance by more senior scientists and engineers. This process does not optimally select and advance the best scientists and engineers, because of implicit bias and disproportionate weighting of qualities that are stereotypically male. Reducing these sources of bias will foster excellence in science and engineering fields.	Chapter 4

continued

TABLE S-1 Continued

Belief	Evidence	Where Discussed
(8) Women faculty are less productive than men.	The publication productivity of women science and engineering faculty has increased over the last 30 years and is now comparable to men's. The critical factor affecting publication productivity is access to institutional resources; marriage, children, and elder care responsibilities have minimal effects.	Chapter 4
(9) Women are more interested in family than in careers.	Many women scientists and engineers persist in their pursuit of academic careers despite severe conflicts between their roles as parents and as scientists and engineers. These efforts, however, are often not recognized as representing the high level of dedication to their careers they represent.	Chapter 5
(10) Women take more time off due to childbearing, so they are a bad investment.	On the average, women take more time off during their early careers to meet their caregiving responsibilities, which fall disproportionately to women. But, by middle age, a man is likely to take more sick leave than a woman.	Chapter 5
(11) The system as currently configured has worked well in producing great science; why change it?	The global competitive balance has changed in ways that undermine America's traditional science and engineering advantages. Career impediments based on gender or racial or ethnic bias deprive the nation of talented and accomplished researchers.	Chapter 6

the traditional model to an inclusive model with provisions for equitable and unbiased evaluation of accomplishment, equitable allocations of support and resources, pay equity, and gender-equal family leave policies. Otherwise, a large number of the people trained in and capable of doing the very best science and engineering will not participate as they should in scientific and engineering professions.

RECOMMENDATIONS

Career impediments for women deprive the nation of an important source of talented and accomplished scientists and engineers who could contribute to our nation's competitiveness. Transforming institutional structures and procedures to eliminate gender bias is a major national task that will require strong leadership and continuous attention, evaluation, and accountability. Because those obstacles are both substantial and systemic, there are no easy fixes; however, many practices developed in the last decade by universities and funding agencies have proven effective in increasing both the participation of women on faculties and their appointment to leadership positions. In part, the challenge is to use such strategies more widely and evaluate them more broadly to ensure we are accessing the entire talent pool to find truly the best people for our faculties. We need to think creatively about opportunities for substantial and overarching reform of the academic enterprise—its structure, incentives, and accountability—to change outcomes and achieve equity.

The committee's recommendations are large-scale and interdependent, requiring the interaction of university leaders and faculties, scientific and professional societies, funding agencies, federal agencies, and Congress.

A. Universities

A1. ***Trustees, university presidents, and provosts*** should provide clear leadership in changing the culture and structure of their institutions to recruit, retain, and promote women—including minority women—into faculty and leadership positions.

(a) University leaders should *incorporate into campus strategic plans goals of counteracting bias against women in hiring, promotion, and treatment*. This includes working with an inter-institution monitoring organization (see below) to perform annual reviews of the composition of their student body and faculty ranks, publicizing progress toward the goals annually, and providing a detailed annual briefing to the board of trustees.

(b) University leaders should *take action immediately to remedy inequities in hiring, promotion, and treatment.*

(c) University leaders should as part of their *mandatory overall management efforts hold leadership workshops for deans, department heads, search committee chairs, and other faculty with personnel management responsibilities that include an integrated component on diversity and strategies to overcome bias and gender schemas* and strategies for encouraging fair treatment of all people. It is crucial that these workshops are integrated into the fabric of the management of universities and departments.

(d) University leaders should *require evidence of a fair, broad, and aggressive search before approving appointments and hold departments accountable for the equity of their search process and outcomes* even if it means canceling a search or withholding a faculty position.

(e) University leaders should *develop and implement hiring, tenure, and promotion policies that take into account the flexibility that faculty need* across the life course, allowing integration of family, work, and community responsibilities. They should provide uniform policies and central funding for faculty and staff on leave and should visibly and vigorously support campus programs that help faculty with children or other caregiving responsibilities to maintain productive careers. These programs should, at a minimum, include provisions for paid parental leave for faculty, staff, postdoctoral scholars, and graduate students; facilities and subsidies for on-site and community-based child care; dissertation defense and tenure clock extensions; and family-friendly scheduling of critical meetings.

A2. ***Deans and department chairs and their tenured faculty*** should take responsibility for creating a productive environment and immediately implement programs and strategies shown to be successful in minimizing the effect of biases in recruiting, hiring, promotion, and tenure.

(a) Faculties and their senates should initiate a *full faculty discussion of climate issues*.

(b) Deans, department chairs, and their tenured faculty should *develop and implement programs that educate all faculty members and students in their departments on unexamined bias and effective evaluation*; these programs should be *integrated into* departmental meetings and retreats, and professional development and teacher-training courses. For example, such programs can be incorporated into research ethics and laboratory management courses for graduate students, postdoctoral scholars, and research staff; and can be part of management leadership workshops for faculty, deans, and department chairs.

(c) Deans, department chairs and their tenured faculty should *expand their faculty recruitment efforts* to ensure that they reach adequately and proactively into the existing and ever-increasing pool of women candidates.

(d) Faculties and their senates should immediately *review their tenure processes and timelines* to ensure that hiring, tenure, and promotion policies take into account the flexibility that faculty need across the life course and do not sacrifice quality in the process of meeting rigid timelines.

A3. ***University leaders should work with their faculties and department chairs*** to *examine evaluation practices* to focus on the quality of contributions and their impact.

B. Professional societies and higher education organizations have a responsibility to play a leading role in promoting equal treatment of women and men and to demonstrate a commitment to it in their practices.

B1. Together, ***higher education organizations*** should *consider forming an inter-institution monitoring organization*. This body could act as an intermediary between academic institutions and federal agencies in recommending norms and measures, in collecting data, and in cross-institution tracking of compliance and accountability. Just as the opening of athletics programs to girls and women required strong and consistent inter-institutional cooperation, eliminating gender bias in faculty recruitment, retention, and promotion processes requires continuous inter-institutional cooperation, including data-gathering and analysis, and oversight and evaluation of progress.

(a) As an initial step, the committee recommends that the American Council on Education, an umbrella organization encompassing all of higher education, convene national higher education organizations, including the Association of American Universities, the National Association of State Universities and Land Grant Colleges, and others to consider the creation of a cross-university monitoring body.

(b) A primary focus of the discussion should be on defining the scope and structure of data collection. The committee recommends that data be collected at the department level by sex and race or ethnicity and include the numbers of students majoring in science and engineering disciplines; the numbers of students graduating with bachelor's or master's degrees in science and engineering fields; post-graduation plans; first salary; graduate school enrollment, attrition, and completion; postdoctoral plans; numbers of postdoctoral scholars; and data on faculty recruitment, hiring, tenure, promotion, attrition, salary, and allocation of institutional resources. The committee has developed a scorecard that can be used for this purpose (Chapter 6).

B2. ***Scientific and professional societies*** should

(a) *Serve in helping to set professional and equity standards,* collect and disseminate field-wide education and workforce data, and provide professional development training for members that includes a component on bias in evaluation.

(b) Develop and enforce guidelines to *ensure that keynote and other invited speakers* at *society-sponsored events reflect the diverse membership of the society*.
(c) Ensure *reasonable representation of women on editorial boards and in other significant leadership positions*.
(d) Work to ensure that women are recognized for their contributions to the nation's scientific and engineering enterprise through *nominations for awards and leadership* positions.
(e) Provide *child-care and elder-care grants or subsidies* so that their members can attend work-related conferences and meetings.

B3. ***Honorary societies*** should *review their nomination and election processes* to address the underrepresentation of women in their memberships.

B4. ***Journals*** should *examine their entire review process,* including the mechanisms by which decisions are made to send a submission to review, and take steps to minimize gender bias, such as blinded reviews.

C. Federal funding agencies and foundations should ensure that their practices—including rules and regulations—support the full participation of women and do not reinforce a culture that fundamentally discriminates against women. All research funding agencies should

C1. *Provide workshops to minimize gender bias.* Federal funding agencies and foundations should work with scientific and professional societies to host mandatory national meetings that educate members of review panels, university department chairs, and agency program officers about methods that minimize the effects of gender bias in evaluation. The meetings should be held every 2 years for each major discipline and should include data and research presentations on subtle biases and discrimination, department climate surveys, and interactive discussions or role-modeling. Program effectiveness should be evaluated on an ongoing basis.

C2. *Collect, store, and publish composite information* on demographics, field, award type and budget request, review score, and funding outcome for all funding applications.

C3. *Make it possible to use grant monies for dependent care expenses* necessary to engage in off-site or after-hours research-related activities or to attend work-related conferences and meetings.

C4. *Create additional funding mechanisms* to provide for interim technical or administrative support during a leave of absence related to caregiving.

C5. *Establish policies for extending grant support* for researchers who take a leave of absence due to caregiving responsibilities.

C6. *Expand support for research* on the efficacy of organizational programs designed to reduce gender bias, and for research on bias, prejudice, and stereotype threat, and the role of leadership in achieving gender equity.

D. Federal agencies should lay out clear guidelines, leverage their resources, and rigorously enforce existing laws to increase the science and engineering talent developed in this country.

D1. Even without additional resources, federal agencies should *move immediately to enforce the federal anti-discrimination laws* at universities and other higher education institutions through regular compliance reviews and prompt and thorough investigation of discrimination complaints.[1] Federal enforcement agencies should ensure that the range of their enforcement efforts covers the full scope of activities involving science and engineering that are governed by the anti-discrimination laws. If violations are found, the full range of remedies for violation of the anti-discrimination laws should be sought.

D2. Federal enforcement efforts should *evaluate whether universities have engaged in any of the types of discrimination* banned under the anti-discrimination laws, including: intentional discrimination, sexual harassment, retaliation, disparate impact discrimination, and failure to maintain required policies and procedures.

D3. Federal compliance review efforts should *encompass a sufficiently broad number and range of institutions* of higher education to secure a substantial change in policies and practices nationwide. Types of institutions that should be included in compliance reviews include 2-year and 4-year institutions; institutions of undergraduate education; institutions that grant graduate degrees; state universities; private colleges; and educational enterprises, including national laboratories and independent research institutes, which may not be affiliated with universities.

D4. Federal enforcement agencies, including the Equal Employment Opportunity Commission, the Department of Justice, the Department of La-

[1] Applicable laws include Title VI, Title VII, and Title IX of the Civil Rights Act; Executive Order 11246; the Equal Protection clause of the Constitution; the Equal Pay Act; the Pregnancy Discrimination Act; and the Family Medical Leave Act. Each of these statutes is discussed in detail in Chapter 5.

bor, the Department of Education, and individual federal granting agencies' Offices of Civil Rights should *encourage and provide technical assistance* on how to achieve diversity in university programs and employment. Possible activities include providing technical assistance to educational institutions to help them to comply with the anti-discrimination laws, creating a clearinghouse for dissemination of strategies that have been proven effective, and providing awards and recognition for model university programs.

E. Congress should take steps necessary to encourage adequate enforcement of anti-discrimination laws, including *regular oversight hearings* to investigate the enforcement activities of the Department of Education, the Equal Employment Opportunity Commission, the Department of Labor, and the science granting agencies—including the National Institutes of Health, the National Science Foundation, the Department of Defense, the Department of Agriculture, the Department of Energy, the National Institute of Standards and Technology, and the National Aeronautics and Space Administration.

CALL TO ACTION

The fact that women are capable of contributing to the nation's scientific and engineering enterprise but are impeded in doing so because of gender and racial/ethnic bias and outmoded "rules" governing academic success is deeply troubling and embarrassing. It is also a *call to action*. Faculty, university leaders, professional and scientific societies, federal agencies, and the federal government must unite to ensure that all our nation's people are welcomed and encouraged to excel in science and engineering in our research universities. Our nation's future depends on it.

1

Introduction

Science and engineering education and research are increasingly global endeavors. As described in the recent National Academies report *Rising Above the Gathering Storm*, globalization has already begun to challenge the longstanding scientific pre-eminence of the United States and, therefore, its economic leadership. Identifying the best, brightest, and most innovative science and engineering talent will be crucial if the nation's industries and the nation itself are to maintain their competitive edge.

> Major American businesses have made clear that the skills needed in today's increasingly global marketplace can only be developed through exposure to widely diverse people, cultures, ideas, and viewpoints.
>
> —Sandra Day O'Connor[1]

In the last 30 years, the numbers and proportion of women obtaining science and engineering bachelor's, master's, and doctoral degrees have increased dramatically. Women's presence has grown across the sciences (Figure 1-1). In the life sciences, women outnumber men in both under-

[1] *Opinion of the court*. Grutter v. Bollinger 539 US 306, 2003. *http://www.law.cornell.edu/supct/pdf/02-241P.ZO*.

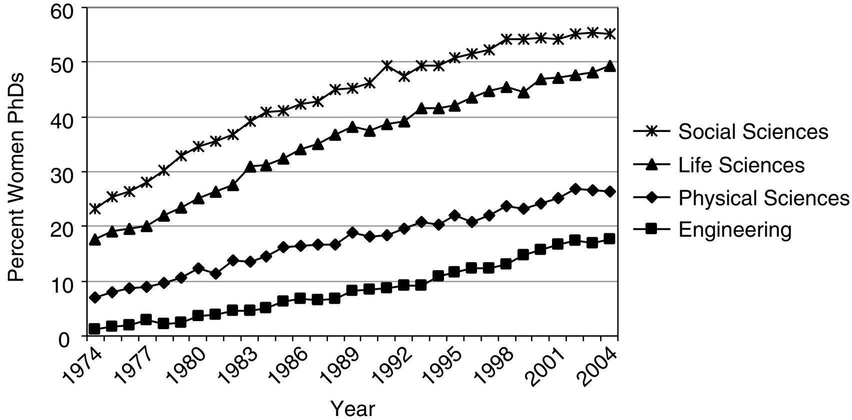


FIGURE 1-1 Percentage of science and engineering PhDs awarded to women, 1974-2004.

SOURCE: National Science Foundation (2006). Survey of Earned Doctorates, 1974-2004. Arlington, VA.

graduate and graduate programs.[2] Women now earn one-third of the PhDs granted by the 50 leading departments in chemistry, 27% in mathematics and statistics, and one-fourth in physics and astronomy. Even in engineering, historically the field with the fewest female participants, women now constitute one-fifth of undergraduate and graduate students.[3] In the top 50 engineering departments, women earn one-fourth of the PhDs granted in chemical engineering and 15% in engineering overall.[4]

In counterpoint to that dramatic educational progress, women, who constitute about half of the total workforce in the United States and half of the degree recipients in a number of scientific fields, still make up only one-fifth of the nation's scientific and technical workers. As shown in Chapter 3, at every academic career milestone the proportion of women in science and engineering declines. These declines are evident even in 2003, the most recent year for which data are available. In examining the transition into academic positions (Figure 1-2), the declines are greatest in fields requiring

[2]Government Accountability Office (2004). *Gender Issues: Women's Participation in the Sciences Has Increased, but Agencies Need to Do More to Ensure Compliance with Title IX* (GAO-04-639). Washington, DC: US Government Accountability Office.

[3]GAO (2004), ibid.

[4]Handelsman J, N Cantor, M Carnes, D Denton, E Fine, B Grosz, V Hinshaw, C Marrett, S Rosser, D Shalala, and J Sheridan (2005). More women in science. *Science* 309:1190-1191 *http://www.sciencemag.org/cgi/content/full/309/5738/1190*.

a period of postdoctoral study, namely life sciences, chemistry, and mathematics. It is interesting that in psychology, which like life sciences and chemistry is a field with a high proportion of women undergraduate and graduate students, there is a substantial decline in the proportion of women with increasing faculty rank. In comparison, in fields with a low proportion of women undergraduate and graduate students such as computer science and physical sciences, these proportions remain fairly constant with increasing faculty rank (Figure 1-2).

The situation is especially severe for minority-group women in sciences and engineering,[5] who are subject to dual discrimination and are required to overcome more barriers to achieve success. The bottom line is that minority-group women doctorates are less likely to be in tenure positions than men of any racial group or white women. The data on women faculty of color are discouraging (Box 1-1).

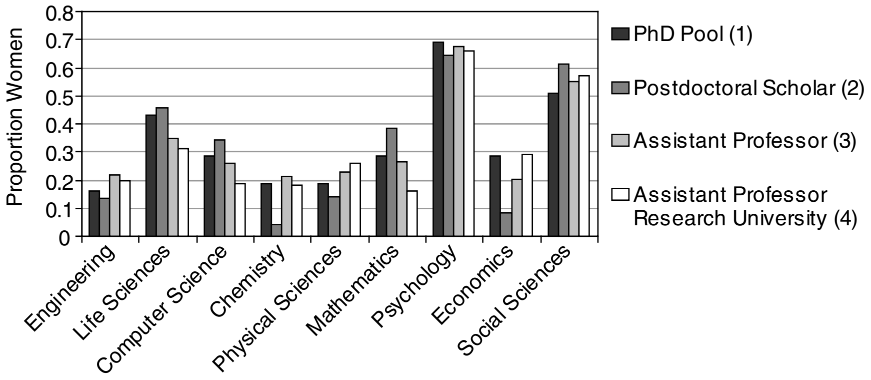
RECOGNIZING OBSTACLES

Women continue to face impediments to academic careers that do not confront men of comparable ability and training. Those barriers cause substantial waste of scientific and engineering talent and training. Several reports issued in the last 3 years have examined the barriers that women interested in science and engineering encounter at various stages of their career development. Some reports, including those by the Congressional Commission on the Advancement of Women and Minorities in Science, Engineering, and Technology (CAWMSET) and the Building Engineering and Science Talent (BEST) Initiative (Box 1-2) have focused on broad pipeline issues. Others, including RAND's *Gender Differences in Major Federal External Grant Programs* and the Government Accountability Office's *Women's Participation in the Sciences Has Increased, but Agencies Need to Do More to Ensure Compliance with Title IX*, have focused on the role of funding agencies. A number of university task forces have also issued reports on the institutional climate for women faculty,[6] including Harvard

[5]Ethnic and racial minority groups are defined using the current nomenclature of the US Census Bureau: African American, Hispanic, Native American (which includes Alaskan Natives and American Indians), and Asian American and Pacific Islanders. While the definition of underrepresented minorities varies by federal agency and between grant programs within agencies, by university, and between scientific and engineering disciplines, in this report by underrepresented minority we mean African American, Hispanic American, and Native American.

[6]For a listing of University reports, see the National Academies' Committee on Women in Science and Engineering Web page, *Gender Faculty Studies at Research I Institutions*, *http://www7.nationalacademies.org/cwse/gender_faculty_links.html*.

A: Postdoctoral Scholars and Assistant Professors



B: Associate Professors

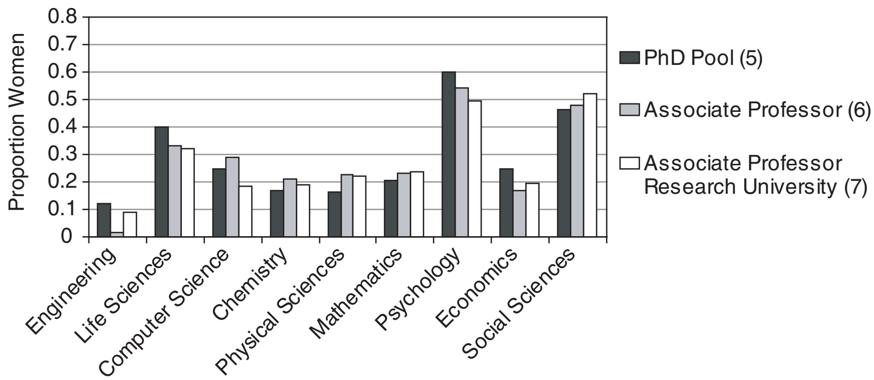


FIGURE 1-2 Comparison of the proportion of women in PhD pools with those in tenure-track or tenured professor positions in 2003, by field.

C: Full Professors

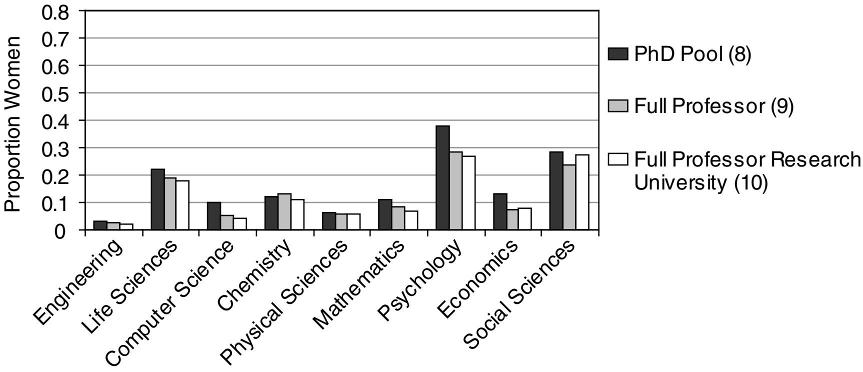


FIGURE 1-2 Continued.

NOTES: The Survey of Doctoral Recipients includes only those who earned doctorates in the United States and may underrepresent the actual number of postdoctoral scholars and tenure-track and tenured professors, particularly in those fields such as life sciences where there are a substantial number of international postdoctoral scholars and engineering where there are substantial number of international professors.[7] *Engineering* includes aeronautics, civil, electrical, environmental, industrial, mechanical, and other engineering fields; *Life Sciences* includes agricultural and biological sciences; *Chemistry* includes chemical engineering and chemistry fields; *Physical Sciences* includes geosciences, physics, and other physical science fields; *Social Sciences* includes political science, sociology and anthropology, and other social science fields. (1) The PhD pool for assistant professors was derived from a sum of all PhDs earned 0-6 years before 2003. (2) Includes those in postdoctoral positions who earned doctorate 0-6 years before 2003. (3) Includes those in assistant professor positions who earned doctorate 0-6 years before 2003. (4) Includes those in assistant professor positions at research universities who earned doctorate 0-6 years before 2003. Research Universities include those with undergraduate and graduate programs, as denoted by the former Carnegie classifications Doctorate 1 and 2 and Research 1 and 2. (5) The PhD pool for associate professors was derived from a sum of all PhDs earned 7-15 years before 2003. (6) Includes those in associate professor positions who earned doctorate 7-15 years before 2003. (7) See note 4. (8) The PhD pool for full professors was derived from a sum of all PhDs earned 16 or more years before 2003. (9) Includes those in full professor positions who earned doctorate 16 or more years before 2003. (10) See note 4.

SOURCE: National Science Foundation (2006). Survey of Doctoral Recipients, 2003. Arlington, VA: National Science Foundation.

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[7]See NAS/NAE/IOM (2005). *Policy Implications of International Graduate Students and Postdoctoral Scholars in the United States*. Washington, DC: The National Academies Press.

DEFINING THE ISSUES

BOX 1-1 Diversity among Women

Discrimination in the post-Civil Rights era is less a function of conscious antipathy and increasingly a byproduct of longstanding social structures, interaction patterns, and unexamined stereotypes that systematically disadvantage minority groups.[a] These may include negative stereotypes of a group's scientific or academic ability, the lack of influential mentors, and exclusion from social networks that facilitate career advancement.[b]

The historical experiences and cultural practices and values of America's various ethnic communities differ widely from one another as well as from American culture at large. So do the stereotypes that the culture at large imposes on them. Because of the diversity of cultural patterns, the experience and expectations of women vary by race and ethnicity.[c] The additional challenges that girls and women in ethnic and racial minority groups face in attaining scientific and engineering careers thus merit specific attention. Underrepresentation of this group of women is especially acute; Donna Nelson reports that "underrepresented minority women faculty are almost nonexistent in science and engineering departments at research universities."[d]

In December 1975, an American Association for the Advancement of Science conference on minority women in science found that both minority-group members (male and female) and women (minority and majority) faced considerable barriers to participation. Being both a woman and a minority-group member meant facing the barriers of both groups—a "double bind."[e]

Thirty years later seemingly little has changed. Cathy Trower and Richard Chait note that "despite earning doctorates in ever increasing numbers, many women and persons of color are eschewing academic careers altogether or exiting the academy prior to the tenure decision because both groups experience social isolation, a chilly environment, bias, and hostility."[f] The situation is worse if one is both a woman and a minority-group member. The numbers paint a bleak picture for minority women:

- Most African Americans who earn science and engineering doctorates are women, and yet, these women are less represented in academic faculties than are African American men.[g]

University's task forces on *Women Faculty* and *Women in Science and Engineering* (Box 1-2).

The National Academies, under the oversight of the Committee on Science, Engineering, and Public Policy, formed the Committee on Maximizing the Potential of Women in Academic Science and Engineering to provide a synthesis of the existing reports and basic research and to examine the implicit and explicit obstacles to educational and academic career advancement of women scientists and engineers, and the effects of race and sex in academic science and engineering careers.

- The proportion of tenured minority-group women declined from 1989 to 1997.[h]
- In 2002, there were no African American, Hispanic, or Native American women in tenured or tenure-track faculty positions in the nation's "top 50" computer science departments.[i]
- In 2002, Native American women held no full professor positions in physical sciences or engineering; there was only one African American woman full professor in the "top 50" physical sciences and engineering departments.[j]

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[a]WT Bielby (2000). Minimizing workplace gender and racial bias. *Contemporary Sociology* (29) 12-129; B Reskin (2000). The proximate causes of employment discrimination. *Contemporary Sociology* 29:319-328; S Strum (2001). Second generation employment discrimination: A structural approach. *Columbia Law Review* 101(3):458-568.

[b]CM Steele (1997). A threat in the air: How stereotypes shape intellectual identity and performance. *American Psychologist* 52:613-629; J Lach (1999). Minority women hit concrete ceiling. *American Demographics* 21(9):18-19.

[c]DS Davenport and JM Yurich (1991). Multicultural gender issues. *Journal of Counseling and Development* 70(1):64-71; SA Hill (2002). Teaching and doing gender in African American families. *Sex Roles* 47(11-12):493-506; GM Combs (2003). The duality of race and gender for managerial African American women: Implications of informal social networks on career advancement.

[d]DJ Nelson (2005). *A National Analysis of Diversity in Science and Engineering Faculties at Research Universities.* http://cheminfo.chem.ou.edu/~djn/diversity/briefings/Diversity%20Report%20Final.pdf.

[e]S Malcom, P Hall, and J Brown (1976). *The Double Bind: The Price of Being a Minority Woman in Science.* (AAAS Publication 76-R-S). Washington, DC: American Association for the Advancement of Science.

[f]C Trower and R Chait (2002). Faculty diversity: Too little for too long. *Harvard Magazine* (March-April).

[g]SL Myers and CS Turner (2004). The effects of PhD supply on minority faculty representation. *The American Economic Review* 94(2):296-301.

[h]Trower and Chait (2002), ibid.

[i]Nelson (2005), ibid.

[j]Nelson (2005), ibid.

The committee was aided in fulfilling its charge by the National Academies' Committee on Women in Science and Engineering, which during the same time was working on two reports on related subjects, *To Recruit and Advance Women Students and Faculty in US Science and Engineering*, and *Gender Differences in the Careers of Science, Engineering, and Mathematics Faculty* (Box 1-3). The Committee on Maximizing the Potential of Women in Academic Science and Engineering also benefited from the expertise of the outside panelists and other participants in its convocation, held on December 9, 2005, in Washington, DC. A workshop report, *Bio-*

DEFINING THE ISSUES

BOX 1-2 Building Engineering and Science Talent: The CAWMSET and BEST Projects

The innovation economy is a major factor in job growth in the United States; jobs in this economy require some technical or scientific knowledge. Women, African-Americans, Hispanics, Native Americans, and persons with disabilities make up two-thirds of the overall workforce but hold only about one-fourth of the scientific and technical jobs.[a]

The **Congressional Commission on the Advancement of Women and Minorities in Science, Engineering, and Technology (CAWMSET) Development** was established in 1998 to examine the "barriers that exist for women, underrepresented minorities and persons with disabilities at different stages of the science, engineering, and technology (SET) pipeline."[b] In September 2000 the Commission issued its report, *Land of Plenty: Diversity as America's Competitive Edge in Science, Engineering, and Technology*.

Finding	***Recommendation***
• Inadequacies in precollege education prevent access to high-quality science and mathematics education for minorities. A lack of role models and well-qualified teachers acts to discourage interest in SET careers.	• Develop, implement, and adopt high-quality state-level math and science curricula and teacher-quality standards.
• There are significant problems of access to higher education for underrepresented groups. These include lack of preparation, lack of encouragement, cost of attendance, and poor integration between 2- and 4-year colleges.	• Develop aggressive intervention programs focused on the transition from high school to college. • Expand federal and state financial investment in the undergraduate and graduate education of under-represented groups.
• The US workplace culture does not value underrepresented groups.	• Hold employers accountable for the career development and advancement of all employees, including members of underrepresented groups.
• The public image of scientists and engineers is inaccurate and derogatory. Women in particular do not receive adequate and accurate portrayal.	• Establish a body to coordinate actions to transform the public image of SET careers.

To build upon the recommendations of CAWMSET, the **Building Engineering and Science Talent (BEST) Initiative** was launched in September 2001. The objective of BEST was to "convene the nation's respected practitioners, researchers and policy makers, and identify what's working across the country to develop the technical talent of under-represented groups in pre-K through 12, higher education, and the workplace."[c] BEST produced three reports:

- What it Takes: Pre-K-12 Design Principles to Broaden Participation in Science, Technology, Engineering and Mathematics[d]
- A Bridge for All: Higher Education Design Principles to Broaden Participation in Science, Technology, Engineering and Mathematics[e]
- The Talent Imperative: Diversifying America's Science and Engineering Workforce[f]

The BEST report, *The Talent Imperative: Diversifying America's Science and Engineering Workforce*, focused on identifying principles and factors that underlie effective programs "developed to broaden the participation of women, underrepresented minorities and persons with disabilities in science, engineering, and technology." It identifies several principles and best practices in K-12 education, higher education, and the workforce, including:

Higher Education

- Institutional leadership. *Leadership matters in creating successful programs. A commitment by administration and senior faculty helps to ensure that increasing participation is an essential part of successful higher education programs.*
- Targeted recruitment. *Establishing and sustaining a feeder system can play an important role in increasing participation of underrepresented groups.*
- Engaged faculty. *Faculty members should be engaged in diversifying student talent. Successful student outcomes are a measure of faculty performance.*
- Bridging to the next level. *Successful programs build the relationships and skills needed for students to move through the educational system and on to career achievements.*
- Continuous evaluation. *Successful programs continually evaluate their processes and outcomes.*

Workforce

- Sustained commitment to change. *Successful workforce programs seek lasting change in organizations through comprehensive efforts at all levels.*
- Integrated organizational strategy. *Stand-alone activities do not succeed. Successful programs are able to make diversity initiatives a seamless part of the organization's operation.*
- Managerial accountability. *Successful programs hold managers at all levels accountable for achieving diversity goals.*
- Continuous improvement. *Successful programs include metrics to identify what is working and what is not working.*

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[a]Congressional Commission on the Advancement of Women and Minorities in Science, Engineering, and Technology Development (CAWMSET) (2000). *Land of Plenty: Diversity as America's Competitive Edge in Science, Engineering, and Technology*, *http://www.nsf.gov/pubs/2000/cawmset0409/cawmset_0409.pdf.*
[b]CAWMSET (2000), ibid.
[c]The BEST Initiative. *http://www.bestworkforce.org/.*
[d]Part 1: *http://www.bestworkforce.org/PDFdocs/BESTPre-K-12Rep_part1_Apr2004.pdf;* Part 2: *http://www.bestworkforce.org/PDFdocs/BESTPre-K-12Rep_part2_Apr2004.pdf.*
[e]*http://www.bestworkforce.org/PDFdocs/BEST_BridgeforAll_HighEdFINAL.pdf.*
[f]*http://www.bestworkforce.org/PDFdocs/BESTTalentImperativeFINAL.pdf.*

FOCUS ON RESEARCH

BOX 1-3 Committee on Women in Science and Engineering: *Gender Differences in the Careers of Science, Engineering, and Mathematics Faculty*

In response to a formal mandate from Congress, the Committee on Women in Science and Engineering (CWSE) and the Committee on National Statistics of the National Research Council conducted a study to assess sex differences in the careers of science, engineering, and mathematics faculty, focusing on major research institutions. The study builds on the previous work by CWSE and examines such issues as faculty hiring, promotion, tenure, and allocation of institutional resources including laboratory space.

The study committee performed departmental surveys and faculty surveys at the 89 Research I institutions.[a] CWSE surveyed 6 fields: biology, chemistry, civil engineering, electrical engineering, mathematics, and physics. In total, they distributed the survey to 492 departments with an 85% response rate, and about 1800 faculty with a 77% response rate. The departmental survey asked questions about department size, recent tenure-track hires, and applications, interviews, and first offers for those positions. It also asked about tenure and promotion. The faculty survey collected demographic information and asked about career milestones, productivity, professional activities, and institutional resources. In addition, the committee has collected and posted information on faculty and climate surveys performed at academic institutions across the United States.[b]

Because of timing, the Committee on Maximizing the Potential of Women in Academic Science and Engineering did not have an opportunity to review these survey results. Footnotes have been added in the text of this report to indicate where the forthcoming CWSE report may shed additional light on issues discussed.

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[a] *Research I (R1) university* was a category formerly used by the Carnegie Classification of Institutions of Higher Education to indicate those universities in the United States that received the highest amounts of federal science research funding. The category is, since 2000, obsolete, but the term is still widely used.

[b] See *http://www7.nationalacademies.org/cwse/gender_faculty_links.html.*

logical, Social, and Organizational Components of Success for Women in Academic Science and Engineering (*http://books.nap.edu/catalog/11766.html*), published by the National Academies Press, details the proceedings of that event.

DEFINING THE ISSUES

This report is organized according to the major themes of the committee's charge. **Chapter 2** examines the research on learning and performance to answer the question of whether cognitive differences between men and women exist and, if so, whether they form a basis for the differential success of men and women in science and engineering careers. **Chapter 3** follows the education and career trajectory of scientists and engineers and examines the persistence and attrition of men and women from high school graduation through hiring to tenure as science and engineering faculty members. **Chapter 4** examines how success is defined and evaluated in science and engineering and how gender schemas and discriminatory practices can affect evaluation of success. **Chapter 5** examines academic institutions and how apparently gender-neutral policies interact with systematic constraints to disproportionately hinder the career progression of women scientists and engineers. **Chapter 6** draws together the findings and shows why and what action should be taken to improve the career progression of women in science and engineering and concludes with a call to action.

Throughout the report, quotations, figures, tables, and boxes provide vignettes and additional data to illustrate the main points. Where possible, the committee broke out data by sex and by race or ethnicity. The boxes are organized into five categories: *Controversies, Defining the Issues, Experiments and Strategies*, *Focus on Research,* and *Tracking and Evaluation.* To assist universities in their efforts to remove the barriers that limit women's participation in academic science and engineering, the committee has developed a scorecard that universities can use to evaluate their progress. It appears as a box in Chapter 6. Appendixes provide information on the committee and its charge and reprint a chapter discussing theories of discrimination from a 2005 National Academies report entitled *Measuring Racial Discrimination*.

As the committee's deliberations progressed, it became increasingly clear that various cultural stereotypes and commonly held but unproven beliefs play major, frequently unacknowledged roles in the perception and treatment of women and their work in the scientific and engineering community. Those beliefs have often been cited as arguments against taking steps to improve the position of women in science and engineering or as reasons why such efforts are unnecessary, futile, or even harmful. To facilitate clear, evidence-based discussion of the issues, the committee compiled a list of commonly-held beliefs concerning women in science and engineering (Table S-1). Each is discussed and analyzed in detail in the text of the report.

The committee hopes that each of the actors involved in determining institutional culture and implementing relevant policies—universities, professional societies and higher education organizations, journals, federal funding agencies and foundations, federal agencies, and Congress—will give careful consideration to the extensive evidence supporting its findings and recommendations.

2

Learning and Performance

CHAPTER HIGHLIGHTS

Do cognitive differences between the sexes influence their differential success in science and engineering? A large body of research has probed the existence and nature of cognitive sex differences. Attempts to marshal the findings to answer that question have been hampered by three features of the public discussion of women in science.

First, the discussion has drawn on research in a highly selective way, emphasizing a small number of measures that show sex differences and de-emphasizing both the overlap between men and women on the measures and the large number of measures by which sex differences are small or nonexistent.[1] *Second, most studies of sex differences in average abilities for mathematics and science focus on measures that were designed to predict academic success in high school or college mathematics or science, such as the quantitative portion of the Scholastic Aptitude Test (SAT-M). Because the academic success of girls now equals or exceeds that of boys at the high school and college levels, however, there is no*

[1] JS Hyde (2005). The gender similarities hypothesis. *American Psychologist* 60:581-592; ES Spelke (2005). Sex differences in intrinsic aptitude for mathematics and science? A critical review. *American Psychologist* 60(9):950-958.

longer a gender gap for the studies to explain. Third, most studies of cognitive sex differences at the highest levels of mathematical and scientific ability also focus on measures that predict success in high school and college. These measures, however, have not proved to be predictive of success in later science careers.[2] *Thus, we cannot look to cognitive sex differences to explain the differential success of men and women scientists and engineers.*

FINDINGS

2-1. A large body of research has probed the existence and nature of cognitive sex differences.

2-2. Most discussions of cognitive sex differences emphasize a small number of measures showing sex differences and de-emphasize the overlap between men and women on those measures as well as the large number of measures by which sex differences are small, nonexistent, or favor women.

2-3. Studies of brain structure and function, of hormonal modulation of performance, of human cognitive development, and of human evolution have not revealed significant biological differences between men and women in performing science and mathematics that can account for the lower representation of women in these fields.

2-4. The academic success of girls now equals or exceeds that of boys at the high school and college levels, rendering moot all discussions of the biological and social factors that once produced sex differences in achievement at these levels.

2-5. Measures of aptitude for high school and college science have not proved to be predictive of success in later science and engineering careers. Notably, it is not just the top SAT scorers who continue on to successful careers; of the college-educated professional workforce in mathematics, science, and engineering, fewer than one-third of the men had SAT-M scores above 650, the lower end of the threshold typically presumed to be required for success in these fields.

2-6. The differing social pressures and influences on boys and girls appear to have more influence than their underlying abilities on their motivations and preferences.

[2] Y Xie and KA Shauman (2003). *Women in Science: Career Processes and Outcomes*. Cambridge, MA: Harvard University Press.

2-7. Activation of negative stereotypes can have a detrimental effect on women's interest and performance in domains relevant to success in academic science and engineering.

2-8. The present situation of women in scientific and engineering professions clearly results from the interplay of many individual, institutional, social, and cultural factors. If systematic differences between male and female scientific and mathematical aptitude and ability do exist, it is clear that they cannot account for women's underrepresentation in academic science and engineering.

RECOMMENDATION

2-1. Continued research is needed in elucidating the role of sex and gender in performance, including research on motivation, stereotype threat, and educational programs for improving performance in science and engineering fields.

RESEARCH APPROACHES

Researchers in a variety of disciplines and with a variety of perspectives—including neuroscience, cognitive psychology, evolutionary biology, and developmental and educational psychology—have sought to explore, measure, and explain whether boys and girls, and the men and women they become, differ from or resemble one another in various aptitudes, skills, behaviors, and decisions. Studies have examined such features as brain organization, hormonal influences on cognitive performance, genetics, and gender roles and socialization. In addition, researchers have performed meta-analyses of various bodies of research; this technique combines data from a number of studies to increase statistical power and give a clearer picture of results (Box 2-1).

> Scientists are people of very dissimilar temperaments doing different things in very different ways. Among scientists are collectors, classifiers, and compulsive tidiers-up; many are detectives by temperament and many are explorers; some are artists and others artisans. There are poet-scientists and philosopher-scientists and even a few mystics. What sort of mind or temperament can all these people be supposed to have in common? Obligative scientists must be very rare, and most people who are in fact scientists could easily have been something else instead.
>
> —Peter Medewar, The Art of the Soluble (1967)

FOCUS ON RESEARCH

BOX 2-1 Meta-analysis

Hundreds of studies examine gender differences in performance. Rather than conduct an additional study, one can synthesize the existing studies to find an overall outcome. *Meta-analysis* refers simply to the application of quantitative or statistical methods to combine evidence from numerous studies. Meta-analysis can tell us, when we aggregate over all the available studies, whether there really is a gender difference in mathematical ability. It can tell us the direction of the difference: do males score higher on average or do females? And it can also tell us the magnitude of any gender difference.

The *d* statistic, or effect size, is used to measure the gender difference. To obtain *d*, the mean score of females is subtracted from the mean score of males in a particular study, and the result is divided by the pooled within-gender standard deviation. Essentially, *d* tells us how far apart the means for males and females are in standardized units. *d* can have positive or negative values. A positive value means that males score higher, and a negative value means that females score higher. To give a tangible example, the gender difference in throwing distance is + 1.98.

In a meta-analysis, *d* is computed for each study, and then *d*s are averaged across all studies. Because meta-analysis aggregates over numerous studies, a meta-analysis typically represents the testing of tens of thousands, sometimes even millions of participants. Thus, the results should be far more reliable than those from any individual study.

How do we know when a *d*, an effect size, is small or large? The statistician Jacob Cohen provided the guideline that a *d* of 0.20 is small, 0.50 is moderate, and 0.80 is large.[a]

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[a] J Cohen (1988). *Statistical Power Analysis for the Behavioral Sciences*. 2nd ed., Hillsdale, NJ: Erlbaum.

Average differences in ability or performance on various intellectual or cognitive tasks have appeared in many studies. That statistically significant differences among groups can be identified, however, does not indicate that they have practical consequences. A generation ago, boys tended to outperform girls in high school and college mathematics and science, and the findings of these studies were invoked to explain differential representation in math and science professions. Now this gender gap in school achievement has disappeared and the relevance of average sex differences as predictors of success in real-world academic science and engineering is debatable.

In cognitive studies comparing boys and men with girls and women, the overlap between the sexes is generally large—usually much larger than the purported differences. Moreover, systematic sex differences do not exist in most cognitive functions.[3] For the variables that do show statistically significant sex differences, some observers argue that small effect sizes indicate that the variable is not important for future success. Means drawn from comparing large groups may provide little insight into the abilities and choices of the relatively small number of people who pursue advanced studies in science or engineering and seek academic careers in those fields. Others argue, however, that small sex differences can accumulate over time and lead to substantial differences in career success (Box 6-1).[4]

That differences exist in abilities, skills, or brain organization does not indicate that they are immutable, nor that they are related to the under-representation of women in science and engineering. Biological, social, and psychological factors interact.[5] Genetics and sex hormones are known to influence performance in a number of ways, but experience also influences brain function in both children and adults. Research over the past 25 years indicates that complex interactions, between biological and sociocultural influences, together with the purely personal happenstance of individual lives, explain the constellation of abilities that any particular person possesses.

COGNITION

A great deal of research has centered on comparing male and female cognitive abilities in domains presumed to be related to success in science and engineering. Broadly speaking, *cognition* refers to the mental processes that underlie information processing, including object perception, learning, memory, language acquisition, and problem solving.[6] Research into sex differences in scientific and engineering ability has emphasized comparisons of mathematical, spatial, and verbal abilities.

Cognitive studies use a number of strategies. Some examine the performance of large numbers of people—from elementary school children through adult college students—on standardized pencil-and-paper tests such as the SAT or the National Assessment of Educational Progress (NAEP). Others use controlled laboratory experiments to measure performance on such tasks as solving mathematical problems, performing spatial rotations, or comprehending or reproducing linguistic passages. Some research probes

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[3]JS Hyde (2005). The gender similarities hypothesis. *American Psychologist* 60(6):581-592.

[4]R Rosenthal, RL Rosnow, and DB Rubin (2000). *Contrasts and Effect Sizes in Behavioral Research: A Correlational Approach*. Cambridge, UK: Cambridge University Press.

[5]DF Halpern and U Tan (2001). Stereotypes and steroids: Using a psychobiosocial model to understand cognitive sex differences. *Brain and Cognition* 45:392-414.

[6]MRW Dawson and DA Medler (1999). *Dictionary of Cognitive Science, http://www.bcp.psych. ualberta.ca/~mike/Pearl_Street/Dictionary/contents/C/cognitive_psychology.html*.

the neurobiological correlates of cognition, using such techniques as functional magnetic resonance imaging while subjects carry out various mental tasks. Some compare levels of sex hormones with performance on a variety of tests. Meta-analyses combine the data from multiple studies to obtain increased statistical power.

> Some researchers object to the study of sex differences because they fear that it promotes false stereotypes and prejudice. There is nothing inherently sexist in a list of cognitive sex differences; prejudice is not intrinsic in data, but can be seen in the way people misuse data to promote a particular viewpoint or agenda. Prejudice also exists in the absence of data. Research is the only way to separate myth from empirically supported findings.
>
> —Diane F Halpern, Professor of Psychology and Director of the Berger Institute for Work, Family, and Children, Claremont McKenna College (2006)[7]

Mathematical and Spatial Performance

Mathematics plays such a central role in science that the question of whether there are sex differences in mathematical aptitude or ability has been a major focus of research.[8] Evidence shows that boys' and girls' aptitude is similar in early childhood, as are the developmental stages at which they integrate various components of mathematics ability.[9] Girls do as well as if not better than boys in high school mathematics and science classes,[10] and by 1998, girls were as likely as boys to take advanced mathematics and science classes.[11]

From 1990-2003, scores on the NAEP revealed no performance gap

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[7]DF Halpern (2006). Biopsychosocial contributions to cognitive performance. In: *Biological, Social, and Organizational Contributions to Science and Engineering Success*. Washington, DC: The National Academies Press.

[8]DF Halpern (2005). Sex, brains, hands: Gender differences in cognitive abilities. *Limbic Nutrition*, *http://www.limbicnutrition.com/blog/archives/028860.html*; S Pinker (2005). The science of gender and science: A debate. *Edge: The Third Culture*, *http://www.edge.org/3rd_culture/debate05/debate05_index.html*.

[9]ES Spelke (2005). Sex differences in intrinsic aptitude for mathematics and science? A critical review. *American Psychologist* 60(9):950-958.

[10]National Center for Education Statistics (2004). *Trends in Educational Equity of Girls and Women: 2004* (NCES 2005-016). Washington, DC: US Department of Education; B Bridgeman and C Wendler (1991). Gender differences in predictors of college mathematics performance and in college mathematics course grades. *Journal of Educational Psychology* 83(2):275-284; Y Xie and KA Shauman (2003). *Women in Science: Career Processes and*

between boys and girls among 4th, 8th, and 12th grade students.[12] Scores on the SAT-M show a somewhat different picture, however, with the average score for boys consistently above that for girls.[13] Because SAT-M scores underpredict the mathematics performance of college women relative to men,[14] the relevance of the difference is not clear. Many studies suggest that differences in spatial ability may underlie differential mathematics performance. Some spatial tasks show sex differences favoring girls, others show differences favoring boys, and disagreement exists on the relevance and predictive power of each set of tasks.[15] Sex differences favoring boys are concentrated in particular tasks, specifically those requiring visuospatial transformation and unconventional mathematical knowledge.[16] Girls, in contrast, excel in mathematical tasks that involve language processing.[17] Men appear to use spatial strategies more often than women, and such strategic choices may account for a male advantage among high

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Outcomes. Cambridge, MA: Harvard University Press; AM Gallagher and JC Kaufman (2005). *Gender Differences in Mathematics*. New York: Cambridge University Press.

[11]National Science Board (2004). *Science and Engineering Indicators, 2004* (NSB 04-01). Arlington, VA: National Science Foundation, Chapter 1.

[12]National Center for Education Statistics (2004), ibid.

[13]JS Hyde, E Fennema, and JS Lamon (1990). Gender differences in mathematics performance: A meta-analysis. *Psychological Bulletin* 107(2):139-155; MB Casey, RL Nuttall, E Pezaris, and CP Benbow (1995). The influence of spatial ability differences in mathematics college entrance scores across diverse samples. *Developmental Psychology* 31(4):697-705; LV Hedges and A Nowell (1995). Sex differences in mental test scores, variability, and numbers of high-scoring individuals. *Science* 269:41-45.

[14]Gallagher and Kaufman (2005), ibid.

[15]MB Casey, RL Nuttall, E Pezaris, and CP Benbow (1995), ibid; MB Casey, RL Nuttall, and E Pezaris (1997). Mediators of gender differences in mathematics college entrance test scores: A comparison of spatial skills with internalized beliefs and anxieties. *Developmental Psychology* 33(4):669-680; DC Geary, SJ Saults, F Liu, and MK Hoard (2000), ibid; MC Linn and AC Petersen (1985). Emergence and characterization of sex differences in spatial ability: A meta-analysis. *Child Development* 56:1479-1498; D Voyer, S Voyer, and MP Bryden (1995). Magnitude of sex differences in spatial abilities: A meta-analysis and consideration of critical variables. *Psychological Bulletin* 117(2):250-270.

[16]DF Halpern (2000). *Sex Differences in Cognitive Abilities (3rd ed.)*. Mahway, NJ: Erlbaum; E Spelke (2005), ibid; A Gallagher, JY Levin, and C Cahalan (2002). *Cognitive Patterns of Gender Differences on Mathematics Admissions Tests* (GRE Board Professional Report No. 96-17P). Washington, DC: Educational Testing Service; DC Geary, SJ Saults, F Liu, and MK Hoard (2000). Sex differences in spatial cognition, computational fluency, and arithmetical reasoning. *Journal of Experimental Child Psychology* 77:337-353; Linn and Petersen (1985), ibid; Voyer, Voyer, and Bryden (1995), ibid; DC Geary (2001). Sex differences in spatial abilities among adults from the United States and China: Implications for evolutionary theory. *Evolution and Cognition* 7(2):172-177; DW Collins and D Kimura (1997). A large sex difference on a two-dimensional mental rotation task. *Behavioral Neuroscience* 111(4):845-849.

[17]A Gallagher, JY Levin, and C Cahalan (2002), ibid; Pinker (2005), ibid; Spelke (2005), ibid.

performers on tests of mathematical reasoning.[18] When all students are encouraged to use spatial strategies, the gender gap in performance narrows.[19] If sex differences on speeded tests result from strategy choices rather than ability differences, the equal performance of men and women in college mathematics courses may be more significant than the small differences between their average scores on speeded tests such as the SAT-M.

One of the most robust cognitive sex differences concerns the ability to imagine an object at different orientations in space (the "mental rotation" task).[20] Boys and men perform consistently faster and more accurately on this task, and some argue that this difference gives them an advantage in science, mathematics, and technology.[21] Evidence indicates that the difference between men and women on this task may be largely due to stereotype threat (Box 2-4).[22] Furthermore, mental rotation and similar measures of spatial ability have been found to be less effective than verbal skills in predicting achievement in mathematics and science.[23] People with strong spatial skills are less likely than those with high verbal skills or high overall intelligence to have earned credentials at every academic level and more likely to work in blue-collar occupations that do not require advanced education.[24]

Another sex difference has to do with variability: there are more men at both the high and low ends of many cognitive performance distributions.[25]

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[18]DC Geary (1996). Sexual selection and sex differences in mathematical abilities. *Behavioral and Brain Sciences* 19:229-284; A Gallagher, JY Levin, and C Cahalan (2002), ibid; A Gallagher, R De Lisi, PC Holst, AV McGillicuddy-De Lisi, M Morely, and C Cahalan (2000) Gender differences in advanced mathematical problem solving. *Journal of Experimental Child Psychology* 75:165-190.

[19]Geary (1996), ibid.

[20]RN Shepard and J Metzler (1971). Mental rotation of three-dimensional objects. *Science* 171(972):701-703; see review by J Huttenlocher, S Levine, and J Vevea (1998). Environmental input and cognitive growth: A study using time-period comparisons. *Child Development* 69:1012-1029.

[21]S Pinker (2002). *The Blank Slate: The Modern Denial of Human Nature*. New York: Viking; DC Geary (1996). Sexual selection and sex differences in mathematical abilities. *Behavioral and Brain Sciences* 19:229-284.

[22]MS McGlone and J Aronson (2006). Stereotype threat, identity salience, and spatial reasoning. *Journal of Applied Developmental Psychology* (in press).

[23]AM Gallagher and JC Kaufman (2005). *Gender Differences in Mathematics*. New York: Cambridge University Press.

[24]LG Humphreys, D Lubinski, and G Yao (1993). Utility of predicting group membership and the role of spatial visualization in becoming an engineer, physical scientist, or artist. *Journal of Applied Psychology* 78(2):250-261.

[25]CP Benbow and JC Stanley (1980). Sex differences in mathematical ability: fact or artifact? *Science* 210:1262-1264; CP Benbow and JC Stanley (1988). Sex differences in mathematical reasoning ability: more facts. *Science* 222:1029-1031; LV Hedges and A Nowell (1995). Sex differences in mental test scores, variability, and numbers of high-scoring individuals. *Science* 269:41-45.

Some argue that variability differences may be more important than average differences in accounting for the preponderance of men scientists; however, this is based on the assumption that only those in the extreme upper tail of the performance distribution go on to successful careers in science and engineering. Recent data bring this assumption into question: the differences in sex distribution at the tails is decreasing,[26] and scientists and engineers may be drawn from a wider range of the distribution, not just the tails (Box 2-2).

Verbal and Written Performance

The data on verbal skills generally show women outperforming men. Although one early meta-analysis found the effect sizes too small to have practical meaning,[27] a variety of tests done over several decades have found girls outscoring boys, on the average, in a number of tasks involving reading, writing, vocabulary, and spelling.[28] In particular, girls and women perform better on tasks involving writing and comprehending complex prose; rapid access to and use of phonological, semantic, and episodic information in long term memory;[29] and speech articulation and fine motor tasks.[30] In 1988-1996, the US Department of Education reports that girls consistently and substantially outperformed boys in writing achievement at the 4th, 8th, and 11th grade levels.[31] Researchers and the mass

[25]Benbow and Stanley (1980), ibid; Benbow and Stanley (1983), ibid; LV Hedges and A Nowell (1995). Sex differences in mental test scores, variability, and numbers of high-scoring individuals. *Science* 269:41-45.

[26]LE Brody and CJ Mills (2005). Talent search research: What have we learned? *High Ability Studies* 16(1):97-111.

[27]Hyde and Linn (1988), ibid.

[28]A Feingold (1988), ibid; Nowell A and LV Hedges (1998). Trends in gender differences in academic achievement from 1960 to 1994: an analysis of differences in mean, variance and extreme scores, *Sex Roles: A Journal of Research* (39):21-43; Campbell, Hombo, and Mazzeo (2000), ibid; National Center for Education Statistics (2004), ibid; EM Weiss, G Kemmler, EA Deisenhammer, W Fleischhacker, and M Delazer (2003). Sex differences in cognitive functions. *Personality and Individual Differences* 35(4):863-875; Halpern (2005), ibid.

[29]A Herlitz, L-G Nilsson, and L Baeckman (1997). Gender differences in episodic memory. *Memory and Cognition* 25:801-811; LJ Levy, RS Astur, and KM Frick (2005). Men and women differ in object memory but not performance of a virtual radial maze. *Behavioral Neuroscience* 119:853-862.

[30]For example, see MW O'Boyle, EJ Hoff, and HS Gill (1995). The influence of mirror reversals on male and female performance in spatial tasks: A componential look. *Personality and Individual Differences* 18:693-699.

[31]National Center for Education Statistics (2000). *Trends in Educational Equity of Girls and Women: 2000* (NCES 2000-030). Washington, DC: US Department of Education.

media alike have called the sex difference in writing so large as to be "alarming" or a "crisis."[32] A more recent study shows consistent improvement among boys, and stresses that the predominant issues are race and class, not sex.[33] The female advantage in writing may be one reason why girls get higher grades in school, on average. Any assessment that relies on writing provides an advantage to women and girls.

Researchers have asked whether cognitive differences have changed over the years, especially as gender roles and expectations in society have changed in recent decades. Meta-analyses and examinations of data from several national standardized tests have found the gap in mathematical performance narrowing[34] while gaps in verbal performance, visuospatial rotation, and SAT-M scores have held steady.[35] Perhaps more salient are international comparisons. Most countries participating in the Programme for International Student Assessment (PISA)[36] showed significantly higher scores for girls than boys in reading literacy. Another international test found no sex difference among 8th-graders in science scores and a small but significant sex difference in mathematics favoring boys.[37] Perhaps most interesting is that girls in Taiwan and Japan dramatically outscore US boys in mathematics—a finding that supports the idea that the cultural values attached to mathematics, in particular attitudes about the importance of ability as opposed to effort, can substantially affect performance.[38]

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[32]Hedges and Nowell (1995), ibid; P Tyre (2006). The trouble with boys. *Newsweek* 147(5):44-52 (January 30).

[33]Education Sector (2006). *The Truth About Boys and Girls*. Washington, DC: Education Sector.

[34]JS Hyde, E Fennema, and JS Lammon (1990), ibid; Feingold (1988), ibid; JR Campbell, CM Hombo, and J Mazzeo (2000), ibid.

[35]Feingold (1988), ibid; Hedges and Nowell (1995), ibid; Masters MS and Sanders B (1993). Is the gender difference in mental rotation disappearing? *Behavior Genetics* 23: 337-341.

[36]PISA is run by the Organisation for Economic Co-operation and Development. It performs a survey every 3 years of 15-year-olds in the principal industrialized countries to assess mathematics, science, and reading skills. See *http://www.pisa.oecd.org/*.

[37]National Center for Education Statistics (1997). *The Third International Mathematics and Science Study*. Washington, DC: US Department of Education.

[38]M Lummis and HW Stevenson (1990). Gender differences in beliefs and achievement: A cross-cultural study. *Developmental Psychology* 26(2):254-263. Note that researchers using those parts of the SAT-M that produced the largest differencies for US boys and firls, found no gender differences in performance among Chinese or Japanese students. JP Byrnes, H Li, and X Xhaoging (1997). Gender differences on the math subset of the scholastic aptitude test may be culture specific. *Educational Studies in Mathematics* 34:49-66.

DEFINING THE ISSUES

BOX 2-2 The Variability Hypothesis

Mean differences between men and women in scores on mathematics and science achievement tests are not especially large, and mean scores have been converging. Many believe that these trends are largely irrelevant, however, because people who go on to research careers in science, mathematics, and engineering are not drawn from areas near the midpoint of science and mathematics abilities, or the fat part of the bell curve. Instead, the assumption is often made that those who end up in research careers in science, engineering, and mathematics (SEM) are drawn from the top 1-5% of the distribution in mathematics and science talent.[a]

It is precisely at this extreme tail of science and mathematics abilities that sex differences are most evident. For example, in a study of close to 10,000 talented 12- and 14-year-olds who had taken the SAT, the male:female ratio was 2:1 for those with SAT-M scores of at least 500; it was about 12:1 for those with scores of at least 700.[b] Such findings are often viewed as part of a pattern of greater variability in ability and achievement among men than among women. As Steven Pinker has so succinctly stated, when it comes to male abilities and achievement there are "more prodigies, more idiots."[c]

The variability hypothesis has a great deal of face validity and appeal. College-educated SEM professionals make up only 2-3% of the US workforce, so shouldn't they be those in the top 2-3% in science and mathematics abilities? Interestingly, the answer to that question, often assumed, has not been examined until recently. And the answer appears to be no. A recent economic analysis by Weinberger examined characteristics of the college-educated SEM workforce and found that fewer than one-third of the white males had SAT-M scores above 650, which is at the low end of the threshold for ability in mathematics typically presumed to be required for success in these fields.[d] In both samples of adolescents followed in the analysis, about one-fourth of the college-educated men and women in the SEM workforce had SAT-M scores below the 75th percentile, and more than half the men (and almost half the women) had scores below the 85th percentile—much closer to the fat part of the curve than anyone had imagined.

Those findings cast serious doubt on the variability hypothesis as the cause for the large discrepancy between the numbers of men and women who go on to SEM careers. It should be noted that the Weinberger study included SEM workforce participants holding bachelors degrees and above, and did not address the subset of those who obtain SEM doctorates.

A further argument against the variability hypothesis stems from its malleability over time. Although the upper tail male:female ratio was about 12:1 in the 1970s, it has declined to 3:1 in more recent samples.[e] This difference obviously cannot be explained by biological factors and suggests that social and cultural changes in the education of men and women have influenced test scores.

Further evidence against the hypothesis that men are biologically predisposed to achievement in mathematics at the highest levels comes from studies of stereotype threat (Box 2-4). Although women and men tend to perform equivalently well on less demanding mathematical material, women tend to underperform when given high-pressure tests with highly demanding problems. Research reveals that cultural factors mediate this drop in women's performance. Because the conditions that favor stereotype threat are just those required for highest performance on the SAT, it is not surprising that among the highest scorers, SAT scores underpredict the academic performance of women relative to men.

Even after controlling for mathematics test scores, less than half as many women as men were found to pursue SEM careers, both among a pool of all college graduates[f] and among a large sample of mathematically gifted youth.[g] Most notably, among youth scoring in the top 1% of mathematics ability as adolescents, men were almost twice as likely as women to obtain degrees in the physical sciences and engineering. Lack of innate mathematics ability could not explain this difference.

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[a]C Benbow and O Arjmand (1990). Predictors of high academic achievement in mathematically talented students: A longitudinal study. *Journal of Educational Psychology* 82:430-441; LV Hedges and A Nowell (1995). Sex differences in mental test scores, variability, and numbers of high-scoring individuals. *Science* 270:364-365; M Paglin and AM Rufolo (1990). Heterogeneous human capital, occupational choice, and male-female earnings differences. *Journal of Labor Economics* 8(1):123-144; S Pinker (2005). The science of difference: Sex ed. *The New Republic,* February 14.

[b]CP Benbow (1988). Sex differences in mathematical reasoning ability in intellectually talented preadolescents: Their nature, effects, and possible causes. *Behavioral and Brain Sciences* 11:169-232.

[c]Pinker (2005), ibid.

[d]CJ Weinberger (2005). *Is the Science and Engineering Workforce Drawn from the Far Upper Tail of the Math Ability Distribution?* Working Paper. Institute for Social, Behavioral and Economic Research and Department of Economics, University of California at Santa Barbara.

[e]LE Brody and CJ Mills (2005). Talent search research: What have we learned? *High Ability Studies* 16(1):97-111.

[f]CJ Weinberger (2005), ibid.

[g]CP Benbow, D Lubinski, DL Shea, and H Eftekhari-Sanjani (2000). Sex differences in mathematical reasoning ability at age 13: Their status 20 years later. *Psychological Science* 11(6):474-480.

TABLE 2-1 The Magnitude ("*d*") of Sex Differences in Mathematics Performance, by Age and Test Cognitive Level

	Cognitive Level		
Age Group	Computation	Concepts	Problem Solving
5-10	–0.20	–0.02	0.00
11-14	–0.22	–0.06	–0.02
15-18	0.00	0.07	0.29
19-25	N/A	N/A	0.32

NOTES: Ages were grouped roughly into elementary school (ages 5-10 years), middle school (11-14), high school (15-18), and college age (19-25). Cognitive level of the test was coded as assessing either simple computation (requires the use of only memorized mathematics facts, such as $7 \times 8 = 56$), conceptual (involves analysis or comprehension of mathematical ideas), problem solving (involves extending knowledge or applying it to new situations), or mixed. Conventionally, a negative number indicates a female advantage, and a positive number a male advantage. N/A = not available.

SOURCE: JS Hyde, E Fennema, and SJ Lamon (1990). Gender differences in mathematics performance: A meta-analysis. *Psychological Bulletin* 107:139-155.

Longitudinal Manifestation of Cognitive Differences

This broad assessment of the magnitude of sex differences is probably less useful than an analysis by both age and cognitive level. Meta-analyses show that sex differences in verbal performance do not change much with age.[39] However, some aspects of mathematics performance show striking age dependence (Table 2-1). Elementary and middle school girls outperform boys by a small margin in computation; there is no sex difference in high school. For understanding of mathematical concepts, there is no sex difference at any age level. For problem solving there is no sex difference in elementary or middle school, but one favoring boys and men emerges in high school and the college years. Problem solving performance deserves attention because problem solving is essential to success in science and engineering occupations.

Hyde suggests that differences in problem solving may result from course choice, that is, the tendency of girls and boys to select optional advanced mathematics and science courses in high school.[40] As described

[39]LV Hedges and A Nowell (1995). Sex differences in mental test scores, variability, and numbers of high-scoring individuals. *Science* 269:41-45; JS Hyde and MC Linn (1988). Gender differences in verbal ability: A meta-analysis. *Psychological Bulletin* 104:53-69.

[40]JS Hyde (2005). The gender similarities hypothesis. *American Psychologist* 60:581-592.

in Chapter 3, differences in mathematics course taking has narrowed over the last decade, so that by 1998 girls were as likely as boys to have taken advanced mathematics courses. Girls also are as likely as boys to take advanced biology, but they are less likely to take advanced chemistry and physics classes.[41] If problem solving is related to course choice, then it is possible that these differences have substantially narrowed during the last 15 years.

BIOLOGY

Four types of studies have been used to suggest a biological basis for the differing career outcomes of men and women: brain structure and function, hormonal influences on cognitive performance, psychological development in infancy, and evolutionary psychology.

Brain Structure and Function

The brains of human men and women show highly similar structure and organization at all points in development. Indeed, human brains are so similar that the explosively growing field of human functional brain imaging uses a single template to map the structures and functions of the brains of both sexes. Despite the overall similarity, however, a body of research has found sex differences in aspects of brain organization and the size and activity level during relevant tasks of different regions of the cerebral cortex.[42] The onset, symptomology, and prevalence of psychiatric disorders show marked sex differences. Lateralization of language functions (e.g., the extent to which functions appear primarily in one side of the brain instead of being represented in both hemispheres) may or may not be correlated with sex.[43] A relationship between handedness (preference for using the right or left hand) and cognitive abilities provides a useful avenue for

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[41] National Science Board (2004). *Science and Engineering Indicators, 2004* (NSF 04-01). Arlington, VA: National Science Foundation.

[42] SF Witelson (1991). Neural sexual mosaicism: Sexual differentiation of the human temporo-parietal region for function asymmetry. *Psychoneuroendocrinology* 16(1-3):131-153; SF Witelson, II Glezer, and DL Kigaar (1995). Women have greater density of neurons in the posterior temporal cortex. *The Journal of Neuroscience* 15(5):3418-3428.

[43] BA Shaywitz, SE Shaywitz, KR Pugh, RT Constable, P Skudlarski, RK Fulbright, RA Bronen, JM Fletcher, DP Shankweler, L Katz, and JC Gore (1995). Sex differences in the functional organization of the brain for language. *Nature* 373:607-609; JA Frost, JR Binder, JA Springer, TA Hammeke, PSF Bellgowan, SM Rao, and RB Cox (1999). Language processing is strongly lateralized in both sexes. *Brain* 122(2):199-208; IEC Sommer, A Aleman, A Bouma, and RS Kahn (2004). Do women really have more bilateral language representation than men? A meta-analysis of functional imaging studies. *Brain* 127(8):1845-1852.

investigating neurological differences.[44] In right-handed people and half of left-handers, the brain's left hemisphere dominates in verbal tasks, and the right hemisphere dominates in nonlinguistic spatial tasks. The remaining left-handers show either the reverse pattern or equal representation of tasks between the hemispheres. Left-handed men are more likely to show mathematical talent but also to suffer from dyslexia, stuttering, and mental retardation. Left-handed women have been found to exceed men in spatial tasks.

Hormonal Influences on Cognitive Performance

Hormones have received considerable attention as a possible source of sex differences in cognition and behavior. The findings are complex because of failure to replicate numerous reported effects and because hormones can influence both cognitive abilities and their manifestation in performance. The influences can be either direct or indirect. Influences on the neural substrates of cognition are direct. The individual preferences that lead to culture-specific experiences that enhance particular abilities are indirect.[45]

The presumed masculinizing effect of androgens on spatial ability and personal preferences has attracted particular interest.[46] Studies have cited androgen effects on brain development including a greater preference for male-typical toys, as well as superior spatial ability and lower interest in language tasks; these findings are based on research in girls affected by congenital adrenal hyperplasia, a condition resulting in overproduction of testosterone during fetal development.[47] That the condition causes girls to have masculinized genitalia raises the possibility that differences in preference or behavior may have a societal component resulting from the belief, by the girls themselves or their parents, that they are more masculine or less

[44]Halpern (2005), ibid.

[45]D Geary (1996). Sexual selection and sex differences in mathematical abilities. *Behavioral and Brain Sciences* 19:229-284.

[46]CCC Cohen-Bendahan, C van de Beek, and SA Berenbaum (2005). Prenatal sex hormone effects on child and adult sex-typed behavior: Methods and findings. *Neuroscience and Biobehavioral Reviews* 29:353-384.

[47]VL Pasterski, ME Geffner, C Brain, P Hindmarsh, B Charles, and M Hines (2005). Prenatal hormones and postnatal socialization by parents as determinants of male-typical toy-play in girls with congenital adrenal hyperplasia. *Child Development* 76:264-278; M Hines, BA Fane, VL Pasterski, GA Mathews, GS Conway, and C Brook (2003). Spatial abilities following prenatal androgen abnormality: Targeting and mental rotations performance in individuals with congenital adrenal hyperplasia. *Psychoneuroendocrinology* 28:1010-1026; SM Resnick, SA Berenbaum, II Gottesman, and TJ Bouchard (1986). Early hormonal influences on cognitive functioning in congenital adrenal hyperplasia. *Developmental Psychology* 22(2):191-198; Hines et al. (2003), ibid; Resnick et al. (1986), ibid.

feminine than other girls. That might encourage them to act in less stereotypically feminine ways.[48]

Research into the relationship between variations in fetal hormones in normal children and later behaviors considered typical of one sex or the other has produced mixed results. The amount of eye contact that boys make with their parents, for example, appears to correlate negatively with measures of fetal testosterone, possibly suggesting a role of the hormone in social development.[49] In addition, one study indicated that levels of fetal testosterone appear to be correlated positively with girls' ability to do mental rotation tasks.[50] Another study has found testosterone levels to be correlated negatively with counting and number facts. Levels of sex hormones are correlated with spatial ability in adults, some evidence shows. According to one study, testosterone strongly improved the ability of women, and impaired that of men, to do mental rotation, and estradiol impaired women's mental rotation ability.[51] Another study, however, found sex differences in spatial and verbal abilities but showed that different levels of testosterone, estradiol, or progesterone had no effect.[52] Where impairments are found, their sources could be either cognitive or motivational and social. Motivational and social influences on cognitive test performance are discussed below.

Psychological Development in Infancy

The last 30 years have brought an explosion of research on the cognitive abilities of human infants. In the vast majority of studies, male and female infants have shown equal abilities to perceive and represent objects, space, and number.[53] When sex differences in those abilities are found,

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[48]M Hines (2003). Sex steroids and human behavior: Prenatal androgen exposure and sex-typical play behavior in children. *Annals of the New York Academy of Sciences* 1007:272-282; CCC Cohen-Bendahan et al. (2005), ibid; Pasterski et al. (2005), ibid.

[49]S Luchtmaya, S Baron-Cohen, and P Raggatt (2002). Foetal testosterone and eye contact in 12-month-old human infants. *Infant Behavior and Development* 25:327-335.

[50]Luchtmaya et al. (2002), ibid.

[51]M Hausmann, D Slabbekoorn, SHM Van Goozen, PT Cohen-Kettenis, and O Güntürkün (2000). Sex hormones affect spatial abilities during the menstrual cycle. *Behavioral Neuroscience* 114(6):1245-1250.

[52]R Halari, M Hines, V Kumari, R Mehrotra, M Wheeler, V Ng, and T Sharma (2005). Sex differences in individual differences in cognitive performance and their relationship to endogenous gonadal hormones and gonadatropins. *Behavioral Neuroscience* 119(1):104-117.

[53]ES Spelke (2005). Sex differences in intrinsic aptitude for mathematics and science? A critical review. *American Psychologist* 60(9):950-958; DC Geary (1996). Sexual selection and sex differences in mathematical abilities. *Behavioral and Brain Sciences* 19:229-284.

they tend to favor girls and to be transitory;[54] such results are consistent with findings that girl infants develop somewhat more rapidly than boys across the board.

Some investigators have proposed that sex differences in mathematics and science abilities stem from innate predispositions to learn about different things, with infant boys more oriented to objects and infant girls to people.[55] With the exception of one study whose methods have been criticized for inadequate controls,[56] a large body of research fails to support that hypothesis, showing instead that infant girls and boys show equally strong interests in people and in objects.[57] Along similar lines, some researchers cite children's preferences for stereotypically masculine or feminine toys—trucks and blocks vs. dolls, for example—as evidence of innate biological differences in the preferences of the two sexes.[58] Children do not begin to show such toy preferences until the age of 18 months, however, and such differences are inconsistent even later in development.[59] Moreover, the basis of those sex differences has not been investigated. It is possible that features of the toys that are irrelevant to their representational significance, such as color, may account for the observed preferences. It is consistent with the latter interpretation that vervet monkeys have been reported to show the same sex differences in toy preferences as human children, even though monkeys fail to engage in the "cultural learning" that

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[54] R Baillargeon, L Kotovksy, and A Needham (1995). The acquisition of physical knowledge in infancy. In eds. D Sperber and D Premack, *Causal Cognition: A Multidisciplinary Debate* (pp. 79-116). New York: Clarendon Press. Oxford University Press; K van Marle (2004). *Infants' understanding of number: The relationship between discrete and continuous quantity*. Doctoral dissertation, Yale University.

[55] S Baron-Cohen (2002). *The Essential Difference: The Truth about the Male and the Female Brain*. New York: Basic Books; KR Browne (2002). *Biology at Work*. New Brunswick, NJ: Rutgers University Press.

[56] J Connellan, S Baron-Cohen, S Wheelwright, A Batki, and J Ahluwalia (2000). Sex differences in human neonatal social perception. *Infant Behavior and Development* 23:113-118.

[57] EE Maccoby and CN Jacklin (1974). *Psychology of Sex Differences*. Stanford, CA: Stanford University Press; ES Spelke (2005). Sex differences in intrinsic aptitude for mathematics and science? A critical review. *American Psychologist* 60(9):950-958.

[58] A Nordenström, A Servin, G Bohlin, A Larsson, and A Wedell (2002). Sex-typed toy play behavior correlates with the degree of prenatal androgen exposure assessed by CYP 21 genotype in girls with congenital adrenal hyperplasia. *Journal of Clinical Endocrinology and Metabolism* 87(11):5119-5124; VL Pasterski, ME Geffner, C Brain, P Hindmarsh, B Charles, and M Hines (2005). Prenatal hormones and post-natal socialization by parents as determinants of male-typical toy play in girls with congenital adrenal hyperplasia. *Child Development* 76(1):264-278.

[59] LA Serbin, D Poulin-Dubois, KA Colburne, MG Sen, and JA Y Eichstedt (2001). Gender stereotyping in infancy: Visual preferences for and knowledge of gender stereotyped toys in the second year. *International Journal of Behavioral Development* 25:7-15.

leads human children to treat toys as representations of real objects.[60] The existence of equivalent sex differences in the object preferences of male and female children and monkeys suggests that the preferences are not mediated by differences in cognitive interests or abilities.

Evolutionary Psychology

If biologically based differences in mathematics, science, or related abilities do separate the sexes, some scholars argue they probably have origins in human evolution.[61] Such explanations are exceedingly difficult to evaluate, because humans' paleolithic ancestors did not practice science or formal mathematics. Some investigators argue that humans and their ancestors were hunter-gatherers for countless generations and that natural selection would have favored men who had strong spatial skills useful in traveling long distances to locate game and then felling it with spears or arrows. Others argue that because both global and local spatial cues are important for navigation, women, whose food gathering required detailed geographic knowledge and possibly extensive travel, would also have needed to have good spatial ability to find and remember good food sources.[62] Some call into question whether hunting and gathering were sex-typed activities.[63] In addition to sex differences in cognition, some researchers argue that motivation has clear evolutionary links (Box 2-3).

In summary, studies of brain structure and function, of hormonal influences on cognitive performance, of psychological development in infancy, and of human evolution provide no clear evidence that men are biologically advantaged in learning and performing mathematics and science. That makes sense in light of the fact that most of the studies focus on average abilities and on structures and functions that are ingredients to success in

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[60]M Tomasello and J Call (1997). *Primate Cognition*. New York: Oxford University Press.

[61]DC Geary (1998). *Male, Female: The Evolution of Human Sex Differences*. Washington, DC: American Psychological Association; S Baron-Cohen (2002). *The Essential Difference: The Truth about the Male and Female Brain*. New York: Basic Books; S Pinker (2002). *The Blank Slate: The Modern Denial of Human Nature*. New York: Viking; KR Browne (2002). *Biology at Work: Rethinking Sexual Equality*. New Brunswick, NJ: Rutgers University Press.

[62]D Geary (1996). Sexual selection and sex differences in mathematical abilities. *Behavioral and Brain Sciences*, 19:229-284; S Hrdy (1997). Raising Darwin's consciousness: Female sexuality and the prehominid origins of patriarchy. *Human Nature* 8(1):1-49; K Cheng (2005). Reflections on geometry and navigation. *Connection Science* 17(1-2):5-21; NS Newcombe and J Huttenlocher (2006). Development of spatial cognition. In *Handbook of Child Psychology: Vol. 2. Cognition, Perception, and Language* (6th ed.). Eds. D Kuhn and R.S Siegler, New York: Wiley.

[63]Hrdy (1997), ibid.

CONTROVERSIES

BOX 2-3 The Evolution of Motivation

The main evolutionary psychology argument focuses not on a cognitive difference but rather on a motivational one: men are said to be more competitive, and competitiveness is said to be good for science and engineering. The claim that men are more competitive is controversial: some researchers argue that women are just as competitive but express their competitiveness in different ways. And, it is far from clear that greater competitiveness makes for more effective science. A mistake that is often made in considering the aptitude of a minority group for a given discipline is to conclude, from the fact that the characteristics of the majority group predominate in the discipline, that the majority traits are required for success in the discipline. Examples of that error are easy to see when one looks to the past. In the 1930s to 1950s, there were no Jews in academic psychology. EG Boring, one of the fathers of experimental psychology, argued that Jews were unfit to be experimental psychologists because of the "defects of their race." Specifically, he argued that all the successful psychologists had qualities of Christian temperance. Today, we would say that Christianity was a typical characteristic of the experimental psychologists of Boring's day for social reasons, not because it gave a biological advantage for successful science. Similarly, today's scientists and engineers have a whole array of typically male characteristics that may or may not enhance the quality of their science.

high school and college mathematics and science. Because men and women do not differ in their average abilities and because they have now achieved equal academic success in science through the college level, there is no sex performance difference for the biological studies and theories to explain.

SOCIETY AND CULTURE

As members of a highly social species, humans do not exist solely as biological entities. We live within complex interpersonal networks and cultural frameworks that strongly mold our development, behavior, opportunities, and choices. The abilities that people exhibit and the skills that they possess therefore result not only from their biological endowment but also from the social and cultural influences that begin at the moment of their birth and continue to the end of their lives. Those influences and their results can vary markedly among cultures. In Iceland, for example, adolescent girls outscore boys in mathematical reasoning;[64] in the United States,

[64] US Department of Education (2004). *International Outcomes of Learning in Mathematics Literacy and Problem Solving: PISA 2003 Results from the US Perspective: Highlights* (NCES 2005–003). Washington, DC: US Department of Education.

a higher proportion of African American women than white women pursue degrees in science and engineering (Table 3-2).[65]

Socialization of Infants and Children

Societies have quite specific stereotypes about male and female characteristics and behaviors and generally begin applying them in earliest infancy. Evidence indicates that parents and others interpret baby boys' and girls' characteristics and behavior—even when they are identical—as reflecting qualities consistent with traditional gender roles.[66] During childhood, many parents encourage sex differences in behavior and experience—and therefore possibly in neurobiology—by treating boys and girls differently, and also by estimating their abilities differently, again in line with gender stereotypes.[67]

Such treatment can powerfully affect children's own concepts of gender and influence their view of their own talents, especially regarding gender stereotyped endeavors, such as social relations, sports, mathematics, and science, the last of which, according to one study, parents believe boys find easier and more interesting than do girls.[68] However, another study found that children with less traditional views of gender roles expressed stronger interest in mathematics. According to a meta-analysis, the effect sizes of the influence of parents' gender beliefs diminished after the mid-1980s, possibly indicating a decrease in gender stereotyping.[69] Moreover, the equal

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[65]National Science Foundation (2004). *Women, Minorities and Persons with Disabilities in Science and Engineering 2004*. Arlington, VA: National Science Foundation.

[66]SM Condry and JC Condry (1976). Sex differences: A study of the eye of the beholder. *Child Development* 47:812-819; SM Condry, JC Condry, and LW Pogatshnik (1983). Sex differences: A study of the ear of the beholder. *Sex Roles: A Journal of Research* 9(6):697-705.

[67]Geary (1996), ibid; Valian (1998), ibid; JE Jacobs and JS Eccles (1992). The impact of mothers' gender-role stereotypic beliefs on mothers' and children's ability perceptions. *Journal of Personality and Social Psychology* 63(6):932-944.

[68]Jacobs and Eccles (1992), ibid; HR Tenenbaum and C Leaper (2003a). Are parents' gender schemas related to their children's gender-related cognitions? A meta-analysis. *Developmental Psychology* 38(4):615-630; JE Jacobs, P Davis-Kean, M Bleeker, JS Eccles, and O Malanchuk (2005). "I can, but I don't want to": The impact of parents, interests, and activities on gender differences in math. In *Gender Differences in Mathematics: An Integrative Psychological Approach*., eds. AM Gallagher and JC Kaufman, New York: Cambridge University Press (pp. 246-263); HR Tenenbaum and C Leaper (2003b). Parent-child conversations about science: The socialization of gender inequities. *Developmental Psychology* 39(1): 34-47; K Crowley, MA Callanan, HR Tenenbaum, and E Allen (2001). Parents explain more often to boys than to girls during shared scientific thinking. *Psychological Science* 12(3):258-261.

[69]C Leaper, KJ Anderson, and P Sanders (1998). Moderators of gender effects on parents' talk to their children: A meta-analysis. *Developmental Psychology* 34(1):3-27.

performance of boys and girls in high school and college mathematics suggests either that the gender stereotypes have waned or that they are not powerful enough to prevent girls' academic success.

Education

Throughout the school years many parents respond differently to their sons and daughters as they study science and mathematics, generally engaging more with and showing more encouragement to the boys. Some data indicate that parents' interest and engagement in these subjects predicts the grades that children earn later in school careers.[70] Other studies, however, found more mixed effects.[71] Still, negative gender stereotyping of abilities can do more than deprive people of encouragement to pursue a field or of the expectation that they can succeed. In addition to parents, teachers and their stereotypes also strongly influence children's conceptions of what they can achieve.[72]

As children progress through school and begin to consider possible adult careers, studies have shown the ambitions of boys and girls begin to diverge. Girls tend to show more interest in languages, literature, music, and drama than equally bright boys, who are likelier to focus on physical science and mathematics and history.[73] Other studies found little difference between college men's and women's attitudes toward mathematics, but a lower likelihood that women would have mathematics-related career goals.[74] Many of the data showing those preferences date from the 1970s and 1980s, but more recent work finds the same tendencies among students in the 21st century. Neither the subjects that individuals studied nor their levels of mathematics achievement accounted for these differences inasmuch as girls not only took as many mathematics and science courses as boys, but earned better grades.[75]

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[70] Tenenbaum and Leaper (2003b), ibid; Crowley et al. (2001), ibid; Jacobs and Eccles (1992), ibid.

[71] H Lytton and DM Romney (1991). Parents' differential socialization of boys and girls: A meta-analysis. *Psychological Bulletin* 109(2):267-296.

[72] CM Steele (1997). A threat in the air: How stereotypes shape intellectual identity and performance. *American Psychologist* 52(6):613-629.

[73] JS Eccles (1994). Women's educational and occupational choices. *Psychology of Women Quarterly* 18:585-609.

[74] JS Hyde, E Fennema, M Ryan, LA Frost, and C Hopp (1990). Gender comparisons of mathematics attitudes and affect: A meta-analysis. *Psychology of Women Quarterly* 14:299-324; JM Singer and JE Stake (1986). Mathematics and self-esteem: Implications for women's career choice. *Psychology of Women Quarterly* 10:339-352.

[75] ME Evans, H Schweingruber, and HW Stevenson (2002). Gender differences in interest and knowledge acquisition: The United States, Taiwan, and Japan. *Sex Roles: A Journal of*

In summary, the different social pressures on boys and girls appear to have more influence on their motivations and preferences than their underlying abilities. Some of that influence may stem from misconceptions of the nature of work in SEM, including the idea that it is suited to isolated, asocial people. Some of the influence may stem from mistaking the characteristics that are *typical* of current scientists, engineers, and mathematicians for characteristics that are necessary ingredients of success in SEM careers. Because most current scientists, engineers, and mathematicians are male, the typical characteristics of "success" more likely resemble those of male rather than of female students. This may deter some young women from viewing SEM careers as appropriate. To the extent that these forces account for the underlying sex difference in students' expressed interests in SEM, they may wane as the numbers of women in graduate school and in postdoctoral and faculty positions continue to rise.

> Minority students must be freed from lowered expectations that dampen drive and achievement as well as from exalted expectations of those few who earn advanced degrees. As is true for all populations, from a large pool the elite stars will emerge. The challenge to all of us, then, is to create an environment… in which the intellectual talents of all Americans can be developed and applied. There are no simple formulas or clever insights to do this—just hard, committed work and support.
>
> -Carlos Guiterrez, Professor of Chemistry,
> California State University, Los Angeles (2001)[76]

Social Effects on Women's Cognitive Performance

If men and women have equal average capacity for science, why do they perform differently on some speeded tests of mathematical and scientific reasoning? In addition to sex differences in the use of spatial and linguistic problem solving strategies discussed above, research in social psychology provides evidence that women's awareness of negative stereotypes of women in science can undermine their performance in high-stakes, speeded tests of scientific and mathematics aptitude. *Stereotype threat* re-

Research 47(3-4):153-167; C Morgan, JD Isaac, and C Sansone (2001). The role of interest in understanding the career choices of female and male college students. *Sex Roles: A Journal of Research* 44(5-6):295-320; Y Xie and KA Shauman (2003). *Women in Science: Career Processes and Outcomes*. Cambridge, MA: Harvard University Press.

[76]C Gutierrez (2001). Who will do chemistry? *Chemical and Engineering News* 79(21):5.

FOCUS ON RESEARCH

BOX 2-4 Stereotype Threat

In 1995, Claude Steele and Josh Aronson published an influential article in which they demonstrated a phenomenon they called *stereotype threat*.[a] Stereotype threat occurs when people feel that they might be judged in terms of a negative stereotype or that they might do something that might inadvertently confirm a stereotype of their group.

When any of us find ourselves in a difficult performance situation, especially one that has time pressure involved, we might recognize that if we do poorly, others could think badly about our own individual abilities. But if you are a woman or minority-group student trying to excel in science or engineering, there is the added worry that poor performance could be taken as confirmation that group stereotypes are valid.

Stereotype threat has been shown to apply to women performing a difficult mathematics test. Women tend to do more poorly than men, not on the average questions, but only on the high-level questions and only when their gender has been commented upon.[b] When stereotype threat is at work, fewer women will have high scores, and their scores will under-predict their achievement.

A series of studies by Toni Schmader and colleagues suggests that women's performance can be improved by acknowledging stereotype threat, as shown in Figure B2-4. In one condition, one group of men and women was given a set of word problems and told that it was a problem-solving exercise, with no mention of a test, mathematics, or ability. In this condition ("Problem Solving"), women's performance on the test was not different from that of their male peers, regardless of whether differences in SAT were controlled for. In a second condition, a different group of men and women was given the same set of word problems and told that their task would yield a diagnostic measure of mathematics ability that would be used to compare men's and women's scores; in this condition ("Math Test"), there was a gender gap similar to that seen in SAT-M scores.

In a third condition, a third group of men and women was told that the test they were taking—the same set of word problems as used in condition one and two—was a diagnostic measure of mathematics ability, and that their performance would be used to compare men's and women's scores. These are the same conditions that led to performance decrements in the second group. However, they were also informed about stereotype threat and reminded that if they were feeling anxious while taking the test, it might be a result of external stereotypes and not a

fers to the "experience of being in a situation where one faces judgment based on societal stereotypes about one's group" (Box 2-4).[77] For example, women perform worse than men on difficult but not easy math tests if gender stereotypes are made salient or if they are told that the tests have sex differences in performance. But, when women are told that there are no sex

[77] SJ Spencer, CM Steele, and DM Quinn (1999). Stereotype threat and women's math performance. *Journal of Experimental and Social Psychology* 35:4-28.

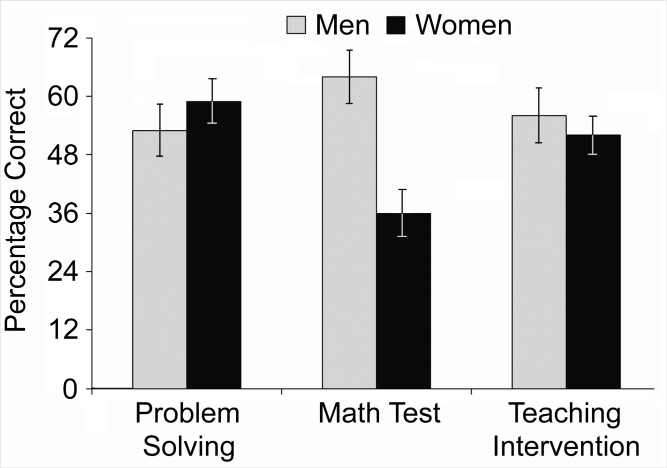

FIGURE B2-4 Teaching about stereotype threat inoculates against its effects.
ADAPTED FROM: M Johns, T Schmader, and A Martens (2005). Knowing is half the battle: Teaching stereotype threat as a means of improving women's math performance. *Psychological Science* 16:175-179.

reflection of their ability to do well. Under those conditions ("Teaching Intervention"), women's performance was significantly increased and not significantly different from that of their male peers.[c]

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[a]CM Steele and J Aronson (1995). Stereotype threat and the intellectual test performance of African Americans. *Journal of Personality and Social Psychology* 69:797-811.

[b]SJ Spencer, CM Steele, and DQ Quinn (1999). Stereotype threat and women's math performance. *Journal of Experimental Social Psychology* 35:4-28.

[c]Similar targeted interventions have been proven to improve performance among minority-group middle-school students (GL Cohen, J Garcia, N Apfel, and A Master (2006). Reducing the racial acheivement gap: A social-psychological intervention. *Science* 313:1307-1310) and women college students (MS McGlone and J Aronson (2006). Stereotype threat, identity salience, and spatial reasoning. *Journal of Applied Developmental Psychology* (in press).

differences in test performance[78] or that tests are not diagnostic of ability[79] they perform just as well as men. That effect has been replicated in highly selected and less-highly selected samples of women.[80]

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[78]Spencer, Steele, and Quinn (1999), ibid.

[79]PG Davies, SJ Spencer, DM Quinn, and R Gerhardstein (2002). Consuming images: How television commercials that elicit stereotype threat can restrain women academically and professionally. *Personality and Social Psychology Bulletin* 28(12):1615-1628.

[80]Spencer, Steele, and Quinn (1999), ibid.

Making sex salient can further degrade women's performance on speeded tests of mathematics. For example, women's mathematics performance decreases as the number of men present during testing increases.[81] Schmader shows that linking sex to math performance has a negative effect on performance only for women who have a high level of gender identity and only if test performance is linked to sex.[82] Additionally, women with stronger gender identities, including those who have selected mathematics-intensive majors, hold more negative attitudes toward mathematics and identify less with mathematics.[83] Notably, Asian women performed better on a mathematics test when their Asian identity was made salient but worse when their female identity was made salient.[84]

Quinn and Spencer find that stereotype threat exerts its effects on women's mathematics performance by diminishing their ability to formulate problem solving strategies.[85] As evidence, women underperformed compared to men on mathematics word problems but not when the problems were converted to their numerical equivalents. An analysis of the problem-solving strategies of women in high and low stereotype threat conditions revealed that women in the high-threat condition formulated fewer problem-solving strategies than women in the low-threat condition. Moreover, women in the high-threat condition were less likely than men to be able to strategize.

Davies and colleagues found that television commercials that evoked gender stereotypes caused women to underperform compared with men.[86] The effect was more pronounced in women for whom the commercials resulted in greater activation of the stereotype. It is important that exposure to gender stereotypic commercials also caused women to avoid answering mathematics questions in favor of verbal questions on a subsequent aptitude test. A control group of women exposed to gender-neutral commercials, like men, attempted to answer more mathematics than verbal questions.

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[81] M Inzlicht and T Ben-Zeev (2000). A threatening intellectual environment: Why females are susceptible to experiencing problem-solving deficits in the presence of males. *Psychological Science* 11(5):365-371.

[82] T Schmader (2002). Gender identification moderates stereotype threat effects on women's math performance. *Journal of Experimental Social Psychology* 38:194-201.

[83] Nosek, BA, MR Banaji, and AG Greenwald (2002). Math = Male, Me = Female, Therefore Math ≠ Me. *Journal of Personality and Social Psychology* 83:44-59.

[84] M Shih, TL Pittinsky, and N Ambady (1999). Stereotype susceptibility: Identity salience and shifts in quantitative performance. *Psychological Science* 10(1):80-83.

[85] DM Quinn and SJ Spencer (2001). The interference of stereotype threat with women's generation of mathematical problem-solving strategies. *Journal of Social Issues* 57(1):55-71.

[86] Davies, Spencer, Quinn, and Gerhardstein (2002), ibid.

The negative effect of stereotype threat on women is not limited to mathematics performance. Women exposed to gender stereotypic commercials expressed less interest in academic and vocational domains in which they risked being negatively stereotyped, such as mathematics and engineering; they expressed more interest in neutral domains, such as creative writing and linguistics. Kray and colleagues showed that women's ability to negotiate was undermined by stereotype threat.[87] When participants were told that a test was diagnostic of negotiating ability, men expected to perform better and made more extreme opening offers than women. When traits that are stereotypical of men were experimentally linked to effective negotiators and traits that are stereotypical of women were linked to ineffective negotiators, men performed better than women in negotiations. Taken together, the findings show that activation of negative stereotypes can have a detrimental effect on women's interest and performance in domains relevant to success in academic science and engineering.

CONCLUSION

The present situation of women in scientific and engineering professions clearly results from the interplay of many individual, institutional, social, and cultural factors. Research shows that the measured cognitive and performance differences between men and women are small and in many cases nonexistent. There is no demonstrated connection between these small differences and performance or success in science and engineering professions. Furthermore, measurements of mathematics- and science-related skills are strongly affected by cultural factors, and the effects of these factors can be eliminated by appropriate mitigation strategies, such as those used to reduce the effects of stereotype threat.

Because sex differences in cognitive and neurological functions do not account for women's underrepresentation in academic science and engineering, efforts to maximize the potential of the best scientists and engineers should focus on understanding and mitigating cultural biases and institutional structures that affect the participation of women. These issues and successful strategies to enhance the recruitment and retention of women in science and engineering are discussed in the following chapters.

[87] LJ Kray, L Thompson, and A Galinsky (2001). Battle of the sexes: Gender stereotype confirmation and reactance in negotiations. *Journal of Personality and Social Psychology* 80(6):942-958.

3

Examining Persistence and Attrition

CHAPTER HIGHLIGHTS

Women who start out on the path toward a career in academic science and engineering leave it for other fields at higher rates than their male counterparts. While there are field differences in pattern of attrition, more women than men leave at nearly every stage of the career trajectory. Fewer high school senior girls than boys state a desire to major in science or engineering in college. Girls who state such an intention are likelier than comparable boys to change their plans before arriving at college. Once in college, women and men show a similar persistence to degree, but women science and engineering majors are less likely than men to enter graduate school.

Women who enter graduate school in science and engineering are as likely as men to earn doctorates, but give a poorer rating to faculty-student interactions and publish fewer research papers than men. Many women graduate students report feelings of isolation. More women than men report plans to seek postdoctoral positions. Among postdoctoral scholars, women report lower satisfaction with the experience, and women are proportionately underrepresented in the applicant pools for tenure-track faculty positions.

It appears that women and men faculty in most fields who are reviewed receive tenure at similar rates. There is substantial faculty mobility prior to the tenure case, when some tenure-track ladder faculty move between institutions and others leave academe. Mo-

bility patterns differ between women and men; men who move prior to tenure tend to leave academe, while women tend to enter adjunct positions. For women faculty members, feelings of isolation, lack of respect of colleagues, and difficulty in integrating family and professional responsibilities are major factors in attrition from university careers. For universities, faculty attrition presents a serious loss both economically and in morale.

FINDINGS

3-1. There is substantial attrition of both men and women along the science and engineering educational pathway to first academic position. The major differences between the patterns of attrition are at the transition points: fewer high school girls intend to major in science and engineering fields, more alter their intentions to major in science and engineering between high school and college, fewer women science and engineering graduates continue on to graduate school, and fewer women science and engineering PhDs are recruited into the applicant pools for tenure-track faculty positions.

3-2. Productivity does not differ between men and women science and engineering faculty, but it does between men and women graduate students and postdoctoral scholars. Differences in numbers of papers published, meetings attended, and grants written reflect the quality of faculty-student interactions.

3-3. There is substantial faculty mobility between initial appointment and tenure case. Faculty at Research I universities are half as likely as the overall population of faculty to move to other types of academic institutions. Men and women hired into tenure-track positions had a similar likelihood of changing jobs, but men were twice as likely to move from academia to other employment sectors (15.3% of men and 8.5% of women) and women were 40% more likely to move to an adjunct position (9.2% of men and 12.7% of women).

3-4. Overall, men and women science and engineering faculty who come up for tenure appear to receive it at similar rates. Differences in the rate at which men and women receive tenure vary substantially by field and by race or ethnicity. For example, in social sciences women are about 10% less likely than men to be awarded tenure. African American women science and engineering faculty were 10% less likely than men of all ethnicities to be awarded tenure.

3-5. As faculty move up in rank, differences between men and women become apparent in promotions, awards, and salary.

3-6. No organization addresses the concerns of minority-group women; scientific and professional society committees address either women or minorities; most data are collected and analyzed by sex *or* by race or ethnicity.

3-7 Policy analyses of the education, training, and employment of scientists and engineers are hampered by data collection inadequacies, including lack of data, inability to compare data among surveys, difficulty in constructing longitudinal cohorts, difficulty in examining sex *and* race or ethnicity, and lags in the reporting of data.

RECOMMENDATIONS

3-1. Efforts to increase the number of women in science and engineering should be focused on both recruiting and retention. Professional societies should work to recruit high school students to science and engineering careers. Colleges and universities should work to recruit women and minority students to science and engineering majors, to graduate school, and to faculty positions. University leaders and faculties need to work together to identify and remedy issues that address faculty retention.

3-2. Recruiting for faculty positions needs to be an active process that consciously develops and reaches out to women and minority-group scientists. Deans and department chairs and their tenured faculty should expand their faculty recruitment efforts to ensure that they reach adequately and proactively into the existing and ever-increasing pool of women candidates.

3-3. We need to understand more about faculty turnover. Universities should collect department data and scientific and professional societies should track discipline-wide turnover; the data should be collected annually and shared so that turnover dynamics can be understood and appropriate policies can be developed to retain faculty.

3-4. Changes should be made in the type of data that are collected on minority-group women and efforts should be made to ensure that the data are comparable across surveys and studies. Specifically, the National Science Foundation (NSF) *Survey of Doctorate Recipients* needs to be made more robust to allow for analysis of the small numbers of women of color. Other national surveys must collect data in a way that permits multiple demographic comparisons. Federal agencies and pro-

fessional societies must report data so that the particular experiences of minority-group women can be understood and tracked and appropriate policies can be developed.

3-5. Universities should collect data annually on education and employment of scientists and engineers by sex and race or ethnicity using a standard scorecard format (Box 6-8). Data should include the number of students majoring in science and engineering disciplines; the number of students graduating with a bachelor's or master's degree in science and engineering fields; postgraduation plans; graduate school enrollment, attrition, and completion; postdoctoral plans; number of postdoctoral scholars; and data on faculty recruitment, hiring, turnover, tenure, promotion, salary, and allocation of institutional resources. The data should be made publicly available.

3-6. Scientific and professional societies should collect and disseminate field-wide education and workforce data with a similar scorecard.

Women who start on the path toward a career in academic science leave that path in favor of other fields at a higher rate than their male colleagues. In this chapter, we will analyze sex differences in science and engineering education and career trajectories and rates of departure from the academic science track in favor of careers in other sectors. The decision to pursue a particular career path is a choice, but certainly not an arbitrary one. Forces other than individual preference or scholastic aptitude and preparation affect choices about career paths and appear to be driving women into careers outside of academic research.

Not everyone who pursues a scientific education wants to be an academic scientist; 59% of science and mathematics, 55% of social science, and 28% of engineering graduate students say that they are preparing to become college or university faculty members or to seek postdoctoral research or academic appointments.[1] In the United States, fewer than half of all people with PhDs in science and engineering are employed in the academic sector (Figure 3-1).

As discussed in Chapter 2, social expectations and stereotypes regarding what it means to be a scientist or engineer influence career choices. Men benefit from a series of accumulated advantages: the implicit assumption that men can be academic scientists and engineers, the encouragement they

[1]MT Nettles and CM Millett (2006). *Three Magic Letters: Getting to PhD*. Baltimore, MD: Johns Hopkins University Press. This study followed a sample of 9,036 graduate students from 21 of the major US doctorate-producing institutions from 1996 to 2001.

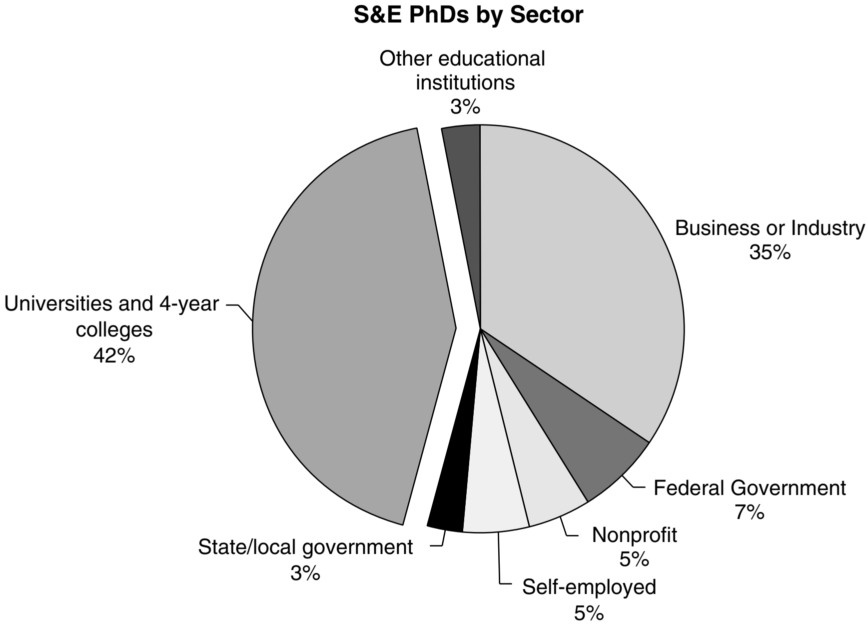

FIGURE 3-1 Occupations of science and engineering PhDs by sector, 2002.

SOURCE: National Science Foundation (2004). *Women, Minorities, and Persons with Disabilities in Science and Engineering, 2004*. Arlington, VA: National Science Foundation.

receive to pursue academic careers, and role models provided by men who have successful academic careers. Women often suffer from a series of accumulated disadvantages, so when they make career choices, they choose from a set of options different from that of their male counterparts.[2] Research shows that the more ways in which a person differs from the norm, the more social interactions affect choices; thus, the interlocking effects of

[2]V Valian (1998). *Why So Slow? The Advancement of Women*. Cambridge, MA: MIT Press; MA Mason and M Goulden (2004). Marriage and baby blues: Redefining gender equity in the academy. *Annals of the American Academy of Political and Social Science* 596 (1):86-103; D Ginther (2006). The economics of gender differences in employment outcomes in academia. In *Biological, Social, and Organizational Components of Success for Women in Academic Science and Engineering*. Washington, DC: The National Academies Press.

sex and race can further restrict career options.[3] An analysis by the Education Trust[4] found that 93 of every 100 white kindergartners would graduate from high school, 65 would complete some college, and 33 would obtain a bachelor's degree. The corresponding numbers for black kindergartners were 87, 50, and 18, respectively. Of 100 Hispanic and Native American kindergartners, only 11 and 7, respectively, would earn a bachelor's degree.

> There is no linear path to a degree. The default 'pipeline' metaphor . . . is wholly inadequate to describe student behavior [which] moves in starts and stops, sideways, down one path to another and perhaps circling back. Liquids move in pipes; people don't.
>
> —Cliff Adelman, in The Toolbox Revisited: Paths to Degree Completion From High School Through College (2006)[5]

The question is where are differences in decision making manifested between men and women? The cohort of high school graduates who are now of an age to be assistant professors (assuming a direct educational path and no stop-outs) would have been seniors in the mid-1980s (Box 3-1 for a description of lagged cohort analysis). For this cohort, specific differences exist between the rates at which men and women chose and persevered in science and engineering education and careers.[6] In 1982, high school senior girls were half as likely as boys to plan a science or engineering major in college. This difference was compounded by girls' rate—2.4 times higher than that of boys—of attrition from the science and engineering educational trajectory during the transition from high school to college. During college, women and men showed similar perseverance to degrees in science and engineering fields. The other substantial difference in education and career attrition or perseverance between men and women in the cohort occurred during the transition from graduate school to tenure-track positions (Figure 1-2).

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[3]CSV Turner (2002). Women of color in academe: Living with multiple marginality. *Journal of Higher* Education 73(1):74-93.

[4]Education Trust, Inc. (2002). *The Condition of Education, 2002*. Data were from surveys conducted by the US Department of Education and the US Department of Commerce Bureau of the Census, March Current Population Surveys, 1971-2001.

[5]Available from the US Department of Education at *http://www.ed.gov/rschstat/research/pubs/toolboxrevisit/toolbox.pdf*.

[6]Y Xie and KA Shauman (2003). *Women in Science: Career Processes and Outcomes*. Cambridge, MA: Harvard University Press.

CONTROVERSIES

BOX 3-1 Models of Faculty Representation

Most analyses of career trajectories of women scientists and engineers use a pipeline analogy, positing that women are underrepresented at senior levels of academe because they are disproportionately "lost" along the journey from interested high school student to tenured faculty. However, analyses must take into account the number of years it takes for a person to progress from a newly attained PhD to a tenured faculty position. There is a lag between earning a degree and advancing to the next level and "without considering lag time, we are left with erroneous conclusions about what the distribution of women faculty *should* be without enough information about what the available pool of women is."[a]

Senior-level academics attained their PhDs a number of years before reaching the level of full professor. One study reports that in 2002 the middle 50% of full professors in physics earned their doctorates in 1967-1980.[b] Therefore, in considering the representation of women in this faculty rank, it is most appropriate to consider that representation in terms of the cohort of PhDs granted in 1967-1980. Similarly for associate professors the appropriate cohort (again using the example of physics) is 1984-1991 and for assistant professors (the "entry level" of the professoriate) it is 1991-1997. That is what is meant by considering "lag time." Although the specific length of the lag time may vary from field to field (based on such factors as number of postdoctoral fellowships required before receiving a faculty appointment), the general principle applies in fields other than physics.

When lag time is considered, one notices that when the current cohort of senior faculty received their doctorates there were fewer women in the pool than there are now. In some fields, that almost completely explains the low numbers of women in senior faculty positions. For instance in physics, in 2005 5% of full professors were women; in 1967-1980 (when the current cohort of full physics professors would have attained their PhDs) an average of 4% of PhDs were awarded to women. At the associate professor level, 11% were women in 2005; and in 1984-1991 (the appropriate year range for this cadre) 9% of PhDs went to women. At the assistant professor level, 16% were women in 2005; and in 1991-1997 (the appropriate year range for this cadre) 12% of PhDs went to women.[c] Similar findings are not confined to the discipline of physics. Using a similar type of analysis a National Research Council panel reported, in a general non-discipline-specific finding, that "much, but not all, of the difference in men and women in their success in becoming faculty is due to differences in the stage of their career."[d] The panel predicted, in the coming decades, increases in the percentages of female faculty.

However, other work presents an alternative view. Nelson, in a study of faculty representation at "top 50" science and engineering schools, reports that "in most science disciplines studied, the percentage of women among recent PhD recipi-

[a] R Ivie and KN Ray (2005). *Women in Physics and Astronomy, 2005.* College Park, MD: American Institute of Physics, *http://www.aip.org/statistics/trends/reports/women05.pdf.*

[b] Ivie and Ray (2005), ibid.

[c] Ivie and Ray (2005), ibid.

[d] National Research Council (2001). *From Scarcity to Visibility: Gender Differences in the Careers of Doctoral Scientists and Engineers.* Washington, DC: National Academy Press.

ents is much higher than their percentage among assistant professors, the typical rank of recently hired faculty."[e] Nelson finds further, that even in fields where women earn more PhDs than men (such as biology), "white males maintain their hold on the vast majority of assistant professor positions."[f] Similar findings were reported by Myers and Turner, who found the disparity between the number of female PhD recipients and the number of female assistant professors to be especially acute for underrepresented minority groups.[g] Such findings indicate that qualified female candidates exist, but in many fields they are not being recruited into the tenure-track applicant pool in proportion to their presence in the PhD pool and suggest that the lag model is insufficient to account for the current underrepresentation of female faculty.

The usefulness of the lag model discussed above depends on the validity of the pipeline model itself, a validity that has been questioned by some. The traditional pipeline model assumes a one-way flow in career progression, suggesting that once a person leaves science it is not possible to return. Work by Xie and Shauman challenges this paradigm, arguing that "exit, entry and reentry are real possibilities. Many persons, especially women, become scientists through complicated processes rather than by just staying in the pipeline."[h] Others, including the Building Engineering and Science Talent (BEST) Initiative (Box 1-2) and the Human Frontier Science Program, have developed new paradigms for education, training, and career paths in the natural sciences.[i] Women may be more likely to pursue career paths that are not accounted for in traditional models of representation. Efforts should be made to be cognizant and supportive of those different career paths, and, in considering faculty representation, it is important to consider pathways beyond the pipeline paradigm. Xie and Shauman argue that the underrepresentation of women in science and engineering is "a complex social phenomenon that defies any attempt at simplistic explanation." They note the "complex and multifaceted nature of women scientists' career processes and outcomes" and suggest that increasing "women's representation in science/engineering requires many social, cultural and economic changes that are large-scale and independent." Clearly the pipeline model is important but, by itself, it is not sufficient to address underrepresentation.

A National Research Council panel[j] found that, "while the most important

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[e]DJ Nelson (2005). *A National Analysis of Diversity in Science and Engineering Faculties at Research Universities.* Available at: *http://cheminfo.chem.ou.edu/%7Edjn/diversity/briefings/Diversity%20Report%20Final.pdf.*

[f]Nelson (2005), ibid.

[g]SL Myers and CS Turner (2004). The effects of PhD supply on minority faculty representation. *American Economic Review* 94(2):296-301.

[h]Xie and Shauman (2003). *Women in Science*: *Career Processes and Outcomes*. Cambridge: Harvard University Press.

[i]The BEST Initiative (2004). *The Talent Imperative: Diversifying America's Science and Engineering Workforce.* Available at *http://www.bestworkforce.org/PDFdocs/BESTTalentImperativeFINAL.pdf*, European Science Foundation (2002). Towards a new paradigm for education, training, and career paths in the natural sciences. *European Science Foundation Policy Briefing* 16, *http://www.esf.org/publication/139/ESPB16.pdf#search=%22Torsten%20Wiesel%20training%20paradigm%22*.

[j]National Research Council (2001), ibid.

continued

BOX 3-1 Continued

factor affecting gender differences in faculty status is the age of a scientist or engineer, there are important differences related to field, type of institution, and other variables." A study by Kuck and colleagues highlights one of the other factors: the significance of the institution from which a person received their PhD as a factor in women's likelihood of attaining a tenure-track position in chemistry. Kuck and colleagues examined hiring patterns in the 50 top-rated chemistry departments. They found that among the 50 departments, 10 schools supplied 60% of the younger faculty members, while only 32% of the faculty came from the other 40 schools.[k] The 10 top faculty-supplying schools were, with a few exceptions, also the top-rated graduate schools. In other words, "a small group of schools contributed a disproportionate number of younger faculty." Postdoctoral placements also play a role in attaining tenure-track positions. Kuck and colleagues report that hiring of chemistry faculty by the top 50 universities is tracking the growth of women in postdoctoral appointments. Those who hold appointments at the top five suppliers of faculty are more likely to be preferentially hired by a top-50 department.

Such findings demonstrate the influence of the PhD or postdoctoral institution on future career prospects and suggest that, when looking at faculty representation, it may be important to look at the pool of doctorates and postdoctorates from only a select subset of research universities.

[k]VJ Kuck et al. (2004). Analysis by gender of the doctoral and postdoctoral institutions of faculty members at the top-fifty ranked chemistry departments. *Journal of Chemical Education* 81(3):356-363.

That type of analysis is useful for broad-brush policy development, but very specific differences by field must be acknowledged. Over the past decade, there have been significant changes, including increases in the numbers and proportion of girls taking high-level science and mathematics classes in high school and increases in graduate school enrollments and degrees. Research on underrepresentation in science and engineering focuses on the two categories of sex and race or ethnicity in large part because the data are collected by sex or race or ethnicity. As a consequence, minority-group women tend to disappear in analyses.[7] Where possible, in the analysis of persistence and attrition in science and engineering education

[7]See, for example, CB Leggon (2006). Women in science: Racial and ethnic differences and the differences they make. *Journal of Technology Transfer* 31:325-333.

and academic careers, this report includes data on minority-group women broken out by race and ethnicity.[8]

COURSE SELECTION IN HIGH SCHOOL

Rigorous study in high school is the best predictor of persistence to a degree in college.[9] Advanced mathematics study appears to be an additional important factor in preparing students for college and can substantially narrow differences between racial and ethnic groups.[10] The gender gap in science and mathematics courses taken in high school has narrowed over the last decade (Table 3-1). Since 1994, girls have been as likely as boys to complete advanced mathematics courses, including Advanced Placement or International Baccalaureate calculus.[11] Also since 1994, girls have been more likely than boys to take advanced biology and chemistry. Physics is the only advanced science subject in which boys continue to complete courses at higher rates than girls, although the difference is small. African Americans and Hispanics were less likely than whites to complete advanced mathematics and science courses in high school.

In an analysis of the National Educational Longitudinal Survey, Hanson found variability in attitudes toward science among women.[12] For ex-

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[8]The committee acknowledges that there are different experiences within racial and ethnic groups. These are addressed in more detail in the National Science Foundation's Women, Minorities, and Persons with Disabilities in S&E reports, *http://www.nsf.gov/statistics/wmpd/*; BEST reports, *http://www.bestworkforce.org*; NAS/NAE/IOM (2006). *Biological, Social, and Organizational Components of Success for Women in Academic Science and Engineering*. Washington, DC: The National Academies Press; G Campbell, R Denes, and C Morrison (1999). *Access Denied: Race, Ethnicity and the Scientific Enterprise*, New York: Oxford University Press; National Research Council (1992). *Science and Engineering Programs: On Target for Women?* Washington, DC: National Academy Press; National Research Council (1991). *Women in Science and Engineering: Increasing Their Numbers in the 1990s: A Statement on Policy and Strategy*. Washington, DC: National Academy Press; National Research Council (1989). *Everybody Counts: A Report to the Nation on the Future of Mathematics Education*. Washington, DC: National Academy Press.

[9]LJ Horn and L Kojaku (2001). *High School Academic Curriculum and the Persistence Path Through College: Persistence and Transfer Behavior of Undergraduates 3 Years after Entering 4-Year Institutions* (NCES 2001-163). Washington, DC: US Department of Education.

[10]C Adelman (1999). *Answers in the Toolbox: Academic Intensity, Attendance Patterns, and Bachelor's Degree Attainment* (PLLI 1999-8021). Washington, DC: US Department of Education; G Orfield (2005). *Dropouts in America: Confronting the Graduation Rate Crisis.* Cambridge, MA: Harvard Education Press.

[11]National Science Board (2006). *Science and Engineering Indicators, 2006.* Arlington, VA: National Science Foundation, Appendix Table 1-17.

[12]SL Hanson (2004). African American women in science: Experiences from high school through the post-secondary years and beyond. *NWSA Journal* 16(1):96.

TABLE 3-1 Percentage of High School Graduates Completing Advanced Coursework in Mathematics and Science, by Sex and Year of Graduation

	1990		1994		1998		2000	
Subject	Men	Women	Men	Women	Men	Women	Men	Women
Mathematics								
• Trigonometry/Algebra III	20.6	20.9	23.0	24.9	19.4	22.5	17.9	21.1
• Precalculus/Analysis	14.4	13.0	16.3	18.4	23.1	22.9	25.4	27.9
• Statistics and probability	1.2	0.8	2.0	2.1	3.4	4.0	5.8	5.6
• Calculus	8.3	6.2	10.3	10.1	12.0	11.6	13.3	12.0
Science								
• Advanced biology	25.7	29.2	31.5	37.8	33.8	40.8	31.5	40.5
• Chemistry	43.8	46.1	47.5	53.3	53.3	59.2	58.1	66.8
• Physics	24.9	18.3	26.7	22.5	31.0	26.6	35.6	31.5

SOURCES: US Department of Education, National Center for Education Statistics, National Assessment of Educational Progress, 1990, 1994, 1998, and 2000 High School Transcript Studies. Based on Table 1-8 in National Science Board (2006). *Science and Engineering Indicators, 2006.* Arlington, VA: National Science Foundation.

ample, African American girls expressed a greater interest in science than did white girls in both the 8th and 10th grades.

COLLEGE-GOING AND MAJORS

In the mid-1980s, about half of high school graduates enrolled in college immediately on graduation. In 2003, 65% of high school graduates enrolled in college on graduation, with 43% at 4-year colleges and 22% at 2-year colleges. The proportion entering college was higher among white students than among African American or Hispanic students. In addition, the rate of increase was higher among women than men at both 4- and 2-year colleges.[13]

A larger proportion of women than men high school seniors indicate an expectation to attend and complete college, but men are about 60% more likely to indicate an expectation to major in a science and engineering field.[14] For at least 20 years, about one-third of all first-year college students have planned to study science and engineering.[15] The proportion is similar among most racial and ethnic groups and, similar to high school intentions, is higher among men than women in many fields (Table 3-2). It should be noted that the percentages of Asian, African American, and Hispanic first-year college students who intend to pursue a science or engineering major are higher than that of their white counterparts.

Undergraduate Persistence to Degree

Women undergraduates have outnumbered men since 1982, and in 2002 they earned 58% of all bachelor's degrees. The share and number of science and engineering bachelor's degrees awarded to women and minority-group members has increased over the last 20 years, and women have earned at least half of all bachelor's degrees in science and engineering since 2000.[16] Much of the increase among minorities was fueled by an increase in science and engineering degrees awarded to women. A recent study[17]

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[13]National Science Board (2006). *Science and Engineering Indicators, 2006*. Arlington, VA: National Science Foundation, Figures 1-28 and 1-29.

[14]Y Xie and KA Shauman (2003). *Women in Science: Career Processes and Outcomes*. Cambridge, MA: Harvard University Press, Chapter 2.

[15]HS Astin (2005). *Annual Survey of the American Freshman, National Norms*. Los Angeles, CA: Higher Education Research Institute.

[16]National Science Board (2006), ibid.

[17]C Goldin, LF Katz, and I Kuziemko (2006). *The Homecoming of American College Women: The Reversal of the College Gender Gap* (NBER Working Paper No. 12139). Cambridge, MA: National Bureau of Economic Research.

TABLE 3-2 Percentages of First-Year College Students Intending to Major in Science and Engineering, by Sex and Race or Ethnicity, 2004

	Overall		African American	
	Men	Women	Men	Women
Physical sciences	2.9	1.9	1.7	1.9
Life sciences	7.4	9.0	7.5	10.9
Mathematics	1.0	0.6	0.6	0.4
Computer sciences	4.1	0.4	6.2	1.5
Social and behavioral sciences	7.5	11.5	7.1	14.3
Engineering	17.9	2.9	15.1	2.9
Total	**40.8**	**26.3**	**38.2**	**31.9**

NOTES: *Physical sciences* include earth, atmospheric, and ocean sciences; *life sciences* include agricultural sciences and biological sciences; and *social and behavioral sciences* includes psychology. The *Hispanic American* category includes Latinos; *Native American* includes Alaskan Natives and American Indians; and *Asian American* includes Pacific Islanders. Students with unknown race or ethnicity and those who are temporary residents are not included.

suggests that those trends result from much longer term shifts in which women saw higher education as a way to gain entrance into the skilled labor market.

There are substantial variations in the demographics of degree recipients by field, sex, and race or ethnicity (Table 3-3). A larger proportion of Asian Americans earn science and engineering bachelor's degrees than that of any other racial or ethnic group. African American women earn more science bachelor's degrees than African American men. In all racial or ethnic categories, men earn more engineering bachelor's degrees than women. It is also interesting to note that, although one-third of all first-year college students plan to study science and engineering, only half that proportion graduate with degrees in science and engineering. The most important factor for completing a bachelor's degree for both men and women appears to be rigorous preparation in high school.[18]

[18] C Adelman (2006). *The Toolbox Revisited: Paths to Degree Completion from High School through College*. Washington, DC: US Department of Education, *http://www.ed.gov/rschstat/research/pubs/toolboxrevisit/toolbox.pdf*.

	Hispanic		Native American		Asian American		White	
	Men	Women	Men	Women	Men	Women	Men	Women
	2.1	1.3	3.2	2.1	2.6	2.0	3.0	1.9
	7.9	10.4	8.2	9.0	14.1	18.0	6.4	7.7
	0.8	0.7	0.7	0.5	1.0	0.8	1.0	0.7
	4.5	0.6	4.7	0.5	4.1	0.6	3.9	0.3
	8.7	15.6	8.7	14.4	6.7	10.6	7.4	10.6
	21.0	3.1	15.2	2.9	25.8	5.6	17.0	2.7
	45.0	**31.7**	**40.7**	**29.4**	**54.3**	**25.8**	**38.7**	**23.9**

SOURCE: National Science Board (2006). *Science and Engineering Indicators, 2006*. Arlington, VA: National Science Foundation, Appendix Table 2-6. Data compiled from HS Astin (2005). *Survey of the American Freshman: National Norms*. Higher Education Research Institute, University of California at Los Angeles.

Social Factors Influencing Undergraduate Attrition

Many students who enter college intending to obtain a science and engineering bachelor's degree abandon their goal along the way. As shown above and in numerous other studies, it is not poor high school preparation, ability, or effort, but rather the educational climate of science and engineering departments that correlates with the high proportion of undergraduates who opt out of science and engineering.[19] Although the gap between intention and attainment is large for all students, research shows that a lower proportion of women realize their high school intentions.[20] In

[19]E Seymour and NM Hewitt (1997). *Talking about Leaving*. Boulder, CO: Westview Press; S Laurich-McIntyre and SG Brainard (1995). Retaining Women Freshmen in Engineering and Science: A Success Story. *Women in Engineering Conference Proceedings: Is Systemic Change Happening?* Washington, DC, pp. 227-232; A Ginorio (1995). *Warming the Climate for Women in Academic Science*. Washington, DC: Association of American Colleges and Universities.

[20]SE Berryman (1983). *Who Will Do Science? Minority and Female Attainment of Science and Mathematics Degrees: Trends and Causes*. New York: Rockefeller Foundation; TL Hilton and VE Lee (1988). Student interest and persistence in science. *Journal of Higher Education*

TABLE 3-3 Number of Bachelor's Degrees in Science and Engineering, by Sex and Race or Ethnicity, 2001

	Overall		African American	
	Men	Women	Men	Women
Physical sciences	10,598	7,533	530	604
Life sciences	33,981	45,575	2,053	3,628
Mathematics	5,958	5,497	330	451
Computer sciences	31,284	11,900	1,628	1,989
Social and behavioral sciences	68,458	120,164	5,146	13,629
Engineering	47,344	11,914	3,054	1,026
Total	**197,623 (15.7)**	**202,583 (16.1)**	**12,741 (11.9)**	**21,327 (20.0)**

NOTES: The numbers in parentheses indicate the percent of total bachelor's degrees awarded represented by science and engineering degrees for that racial or ethnic category. For example, 15.7 of all bachelor's degrees awarded are in science and engineering fields; for African American women 20% of all bachelor's degrees awarded are in science and engineering fields. *Physical sciences* include earth, atmospheric, and ocean sciences; *life sciences* includes agricultural sciences and biological sciences; and *social and behavioral sciences* includes psychology. *Native American* includes Alaskan Natives and American Indians; and *Asian Ameri-*

addition, more men college students make the transition into science and engineering fields from other fields.[21]

Data indicate that these climate issues affect decision making early on; once students enroll in college, the probability of completing a science and engineering major is similar for men and women. Xie and Shauman report that, for students who declare a major in science and engineering, 60% of

59(5):510-526; J Oakes (1990). Opportunities, achievement, and choice: Women and minority students in science and mathematics. *Review of Research in Education* 16:153-222; Y Xie (1996). A demographic approach to studying the process of becoming a scientist/engineer. In: *Careers in Science and Technology: An International Perspective*. Washington, DC: National Academy Press; E Seymour and NM Hewitt (1997). *Talking about Leaving*. Boulder, CO: Westview Press.

[21]Xie and Shauman (2003), ibid.

Hispanic		Native American		Asian American		White	
Men	Women	Men	Women	Men	Women	Men	Women
448	497	59	59	730	700	8,046	5,202
1,493	3,101	312	334	3,356	4,536	24,868	31,407
357	295	28	23	482	434	4,245	3,928
2,302	726	193	78	4,280	2,046	19,043	5,448
5,505	9,999	534	930	4,786	8,023	47,272	79,622
1,858	962	192	64	5,341	1,684	31,710	7,057
11,963 (13.3)	**15,580 (17.3)**	**1,318 (15.2)**	**1,478 (17.1)**	**18,975 (25.1)**	**17,423 (23.0)**	**135,184 (15.2)**	**132,664 (14.9)**

can includes Pacific Islanders. Students with unknown race or ethnicity and those who are temporary residents are not included.

SOURCE: National Science Foundation, Division of Science Resource Statistics, special tabulations of US Department of Education, National Center for Education Statistics, Integrated Postsecondary Education Data System, Completions Survey. Arlington, VA: National Science Foundation. Data available at *http://www.nsf.gov/statistics/wmpd/tables/tabc-15.xls*.

women and 57% of men complete the major.[22] Students' expectations of their social roles strongly influence their educational and career goals. Applying Eagly and Karau's *role congruity theory* to women in science suggests an incongruity between stereotypical female characteristics and the attributes that are thought to be required for success in academic science and engineering.[23]

Women and men appear to enter science and engineering majors for different reasons. Seymour and Hewitt suggest that women were almost twice as likely as men to have chosen a science and engineering major through the active influence of someone important to them, such as a

[22]Xie and Shauman (2003), ibid.
[23]Eagly and Karau (2002), ibid.

relative, teacher, or close friend. In contrast, men were twice as likely as women to cite being good at mathematics or science in high school as a reason for declaring the major (whether or not they were actually better prepared than women).[24] That suggests that more young men than women had the confidence to take higher-level mathematics and science courses in college.

Women and men also appear to leave science and engineering majors for different reasons (Table 3-4). Similar proportions of men and women cited losing interest in science, engineering, and mathematics (SEM) majors, poor teaching, and shifting to more appealing career options. More women felt that they could get a better education in a non-SEM major, rejected SEM careers and lifestyles, and felt that advising was inadequate. Men more frequently cited course overload, loss of confidence, financial problems, and issues with competition. A study on the retention of science and engineering undergraduates at the University of Washington also indicates that advising and a supportive community are important factors in the retention of women in SEM majors.[25]

The University of Washington study looked only at women who entered college with an interest in pursuing a science or engineering major. The sequencing of science and engineering courses is often strict, so it can be difficult to enter a science or engineering major from a nonscience or nonengineering field. Even so, men are twice as likely as women to move from a nonscience field into a science field during their first 2 years.[26] Universities can institute programs to increase enrollment and reduce attrition (Box 3-2).

COLLEGE TO GRADUATE SCHOOL

A larger percentage of men than women who major in science and engineering enroll in graduate school in science and engineering fields (about 15% of men and 10% of women). An additional 8% of men and 12% of women enter graduate school in a nonscience or nonengineering field, and nearly 75% of those who earn science and engineering bachelor's degrees enter the workforce directly.[27]

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[24]Seymour and Hewitt (1997), ibid.

[25]SG Brainard and L Carlin (1997). *A Longitudinal Study of Undergraduate Women in Engineering and Science, http://fie.engrng.pitt.edu/fie97/papers/1252.pdf.*

[26]Xie and Shauman (2003). *Women in Science*: *Career Processes and Outcomes*. Cambridge, MA: Harvard University Press.

[27]Xie and Shauman (2003), ibid.

TABLE 3-4 Top Reasons for Leaving Science, Engineering, or Mathematics Undergraduate Degree Program, by Sex

	Women		Men	
Reason for Switching to Non-SEM Major	%	Rank	%	Rank
Non-SEM major offers better education	**46**	1	35	5
Lack/loss of interest in SEM	43	2	42	1
Rejection of SEM careers and associated lifestyles	**38**	3	20	11
Poor teaching by SEM faculty	33	4	39	3
Inadequate advising or help with academic problems	**29**	5	20	10
Curriculum overload	29	6	**42**	2
SEM career options not worth the effort	27	7	**36**	4
Shift to more appealing non-SEM career option	27	8	27	6
Loss of confidence due to low grades	19	9	**27**	7
Financial problems	11	14	**24**	9
Morale undermined by competition	4	19	**26**	8

NOTE: Percentages in bold face indicate where differences between men and women were significant.

SOURCE: E Seymour and NM Hewitt (1997). *Talking about Leaving*. Boulder, CO: Westview Press.

The proportion of women varies by field and personal factors:[28]

- Women bachelor's degree recipients in the physical sciences are more likely than men to attend graduate school in a non-science and engineering field (19% compared to 5%).
- Women with an undergraduate degree in engineering are more likely than men to attend graduate school in engineering (20% compared to 15%). In contrast with science fields, a bachelor's degree in engineering is

[28]Xie and Shauman (2003), ibid.

EXPERIMENTS AND STRATEGIES

BOX 3-2 Carnegie Mellon's Women in Computer Science Program

Carnegie Mellon University brought female enrollment in its undergraduate computer science program up from 7% to 40% from 1995 to 2000 and significantly reduced attrition.[a]

Here's what it did:

- **Created the Summer Institute for Advanced Placement Computer Science (CS) Teachers**. With a grant from the NSF, Carnegie Mellon trained 240 Advanced Placement (AP) CS teachers to teach C++ (a major component of the AP exam) and informed the teachers about the gender gap in CS and what they could do about it. *By 2000, 18% of female CS majors had a high school CS teacher who had attended the summer institute (up from 0% in 1995).*
- **Changed admissions criteria**. In addition to demonstrated academic competence, more weight is given to nonacademic factors such as leadership potential and commitment to give back to the community for both admission and financial aid. The admissions office also emphasizes "no prior programming experience necessary."
- **Built a supportive community**. The Women@SCS Advisory Council was created and holds weekly meetings to foster community, address the needs of women in CS, and organize outreach to women and girls with an interest in CS.

[a]It should be noted that the proportion of women enrolled in the computer science program at Carnegie Mellon University (CMU) decreased to between 25-30% since 2000, despite continued efforts by CMU. This is still higher than 15%, the average proportion of women in computer science programs at Research I universities.

often considered a terminal degree; many engineering graduates find satisfying and well-paying jobs in the private sector. To gain entry to these jobs, employers may require more credentials from women than men.[29]

- Married women and women with children are far less likely than married men and men with children to attend graduate school.

Graduate School

The number of science and engineering doctoral degrees awarded in the United States has remained fairly constant over the last two decades, fluctu-

[29]C Goldin (2002). A *Pollution Theory of Discrimination: Male and Female Differences in Occupations and Earnings* (Working Paper 8985). Cambridge, MA: National Bureau of Economics Research.

ating between 12,000 to 14,000 degrees awarded each year. The major change has been in the percentage of PhD recipients who have been temporary residents, which has risen from 23% in 1966 to 39% in 2003.[30] Among US citizens and permanent residents, the number of white men earning science and engineering PhDs has decreased from a peak of 11,000 in 1975 to about 7,000 in 2003. The number and proportion of science and engineering PhDs awarded to white women and to members of underrepresented minorities have increased over the past two decades; from 1983 to 2003, the number of science and engineering PhDs earned by African Americans, Hispanics, and Native Americans had more than doubled to 1,500, or 5% of all PhDs awarded (Table 3-5).

There are a few key differences in perseverance to degree by sex. In a recent longitudinal study of PhD completion, Nettles and Millett[31] followed a cohort of graduate students to determine the significant factors affecting time to degree and degree completion. They found women and men to have similar completion rates and time to degree. All students ostensibly had access to a faculty adviser, but only a subset of students (69%) indicated they had a mentor.[32]

Research productivity is of concern for women in SEM. When several background and experience factors were adjusted for, men graduate students showed a significant advantage in paper presentations, publishing research articles, and consequently total research productivity. Overall, the most consistent contributions to productivity measures were having a mentor and being supported by a research assistantship during the course of one's studies. Women were as likely as men to have mentors and assistantship support, so other factors besides the conventional departmental indicators underlie the sex differences in productivity. Nettles and Millett point to the sex difference in graduate students' rating of their interactions with faculty. The fact that women gave low ratings to their interactions with

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[30]R Freeman, E Jin, and C-Y Shen (2004). *Where Do New US-Trained Science-Engineering PhDs Come From?* (NBER Working Paper 10554). Cambridge, MA: National Bureau of Economic Research.

[31]MT Nettles and CM Millett (2006). *Three Magic Letters: Getting to PhD*. Baltimore, MD: Johns Hopkins Press. This study followed 9,036 students who completed their first year of graduate studies in 1996. Data are reported by sex or race or ethnicity; there are no specific data reported on minority women.

[32]In their questionnaire, Nettles and Millet defined mentor as "someone on the faculty to whom students turned for advice, to review a paper, or for general support and encouragement." This definition made it possible for the mentor and adviser to be the same person, but it did give the researchers a chance to examine mentorship separately from advising.

TABLE 3-5 Number of PhD Degrees Awarded In Science and Engineering, by Race or Ethnicity and Sex, 2003

	Overall		African American	
	Men	Women	Men	Women
Physical science	1,726	752	46	28
Life science	2,451	2,071	54	70
Mathematics	364	152	11	5
Computer science	343	97	12	5
Social and behavioral science	2,256	3,292	105	250
Engineering	1,726	437	57	18
Total	**8,866**	**6,801**	**285**	**376**

NOTES: *Physical science* includes earth, atmospheric, and ocean sciences; *life science* includes agricultural sciences and biological sciences; *mathematics* includes statistics; and *social and behavioral science* includes psychology. *Native American* includes Alaskan Natives and Ameri-

faculty may be a consequence of the predominance of male faculty in science and engineering fields.[33] Minority-group women face additional challenges in navigating student-faculty interactions in graduate school.[34]

[33]Nettles and Millett (2006), ibid; BR Sandler (1991). *The Campus Climate Revisited: Chilly Climate for Women Faculty, Administrators, and Graduate Students*. Washington, DC: Association of American Colleges.

[34]Y Moses (1989). *Black Women in Academe: Issues and Strategies*. Washington, DC: Association of American Colleges; B Books (2000). Black and female: Reflections on graduate school. In *Women in Higher Education*, eds. J Glazer-Raymo, EM Bensimon, and BK Townsend, 2nd Ed. Boston, MA: Pearson Publishing; S Nieves-Squires (1991). *Hispanic Women: Making their Presence on Campus Less Tenuous*. Washington, DC: Association of American Colleges.

Hispanic		Native American		Asian American		White	
Men	Women	Men	Women	Men	Women	Men	Women
58	31	2	2	125	81	1,406	575
110	87	6	9	283	261	1,875	1,574
9	7	1	1	27	24	297	110
6	4	2	0	62	17	240	64
113	209	14	24	112	173	1,798	2,494
80	23	9	2	259	80	1,256	300
376	**362**	**34**	**38**	**868**	**636**	**6,872**	**5,117**

can Indians; in 2003 *Asian American* does not include Pacific Islanders. Students with unknown race or ethnicity and those who are temporary residents are not included.

SOURCE: National Science Foundation (2003). *Survey of Earned Doctorates, 2003*. Arlington, VA: National Science Foundation.

> Overall, the finding that men rated student-faculty social interactions higher than women is the most troubling observation, because it implies the continuing existence of the "old boys club" and possible sex discrimination.
>
> —Michael Nettles and Catherine Millett (2006)[35]

For minority-group students, it appears that type of graduate funding support, although it does not impact time to degree, can have a significant effect on formation of peer connections, faculty interactions, and research productivity. In the sciences and mathematics, African Americans were more than three times less likely than whites to publish.[36] Science and engineering teaching assistants appear to have fewer opportunities to pub-

[35]Nettles and Millett (2006), ibid.
[36]Nettles and Millett (2006), ibid.

lish articles, and those supported on research assistantships reported higher publication rates. Nettles and Millett suggest that fellowship support of minority-group students may separate them from both research obligations and opportunities. Other research supports the finding that type of graduate research support can affect faculty interaction and career outcomes; students on fellowships were less likely to continue in academic science and engineering careers.[37]

It is notable that there are substantial differences by field, sex, and race or ethnicity in the types of graduate research support received (Table 3-6). Biological sciences have a very low proportion of students using personal funds (12.4%) compared with computer science (25.0%) and social and behavioral sciences (41.8%). Teaching assistantships are 2.5 times more prevalent in mathematics (52.5%) than in any other field. Research assistantships are prevalent in physical sciences (47.2%), engineering (43.2%), and biological sciences (35.7%). Engineering and computer science have a higher proportion of students receiving employer assistance than science fields (8.3%, 9.1%, and 2.3%, respectively). More women support their graduate work with personal funds and more men receive employee reimbursement. More African Americans and Hispanics receive fellowship support, more whites receive teaching assistantships, and more Asian Americans receive research assistantships.

Single women without children appear to be equally likely as all men to complete a science and engineering graduate degree.[38] Other research indicates that doctoral students who are married or who have children under the age of 18 years have experiences similar to those of their peers who are not married or do not have children. They report similar peer interactions, social and academic interactions with faculty, and levels of research productivity. The primary difference is that students with children were more likely to temporarily stop out of their graduate program, and, in engineering and social sciences (but not other sciences), students with children took longer to complete their PhDs.[39] In 2006, both Stanford University and Dartmouth College announced specific graduate student childbirth policies to facilitate the retention of women graduate students (Box 6-6).

As discussed in the chemistry case study, one's academic pedigree can affect the likelihood of landing a tenure-track position, particularly in a research university. Most men and women who earn science and engineer-

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[37]M Gaughan and S Robin (2004). National science training policy and early scientific careers in France and the United States. *Research Policy* 33:569-581.

[38]Xie and Shauman (2003), ibid.

[39]Nettles and Millett (2006), ibid.

TABLE 3-6 Primary Source of Support (Percent) for US Citizen and Permanent Resident Science and Engineering Doctorate Recipients, by Sex and Race or Ethnicity, 1999-2003

Primary Source of Support	All S&E	Men	Women	African American	Hispanic	Native American	Asian American	White
Personal/Family funds	22.9	19.4	27.7	25.1	23.8	30.4	12.6	24.2
Teaching assistantship	15.3	15.7	14.6	9.3	11.3	9.1	13.6	16.2
Research assistantship, traineeship, and internship	29.8	33.1	25.3	15.2	18.7	17.7	40.4	30.1
Fellowship, scholarship, or dissertation grant	23.5	22.4	24.9	40.5	34.4	29.9	24.8	21.7
Employer reimbursement	3.2	4.1	1.9	2.6	3.0	3.1	2.9	3.3

NOTE: Numbers do not add to 100%; the “other” category was not included in table.

SOURCE: National Science Foundation (1999-2003). *Survey of Earned Doctorates*. Arlington, VA: National Science Foundation.

TABLE 3-7 Top 10 US Baccalaureate Institutions of Science and Engineering Doctorate Recipients, 1999-2003

	Men	Women
Total S&E PhDs	80,516	46,432
1	University of California, Berkeley (957)	University of California, Berkeley (552)
2	Cornell University, all campuses (719)	Cornell University, all campuses (462)
3	University of Illinois, Urbana-Champaign (671)	University of Michigan, Ann Arbor (450)
4	Massachusetts Institute of Technology (650)	University of California, Los Angeles (379)
5	Pennsylvania State University, main campus (591)	University of Wisconsin, Madison (324)
6	Harvard University (558)	Harvard University (321)
7	University of Michigan, Ann Arbor (558)	University of Illinois, Urbana-Champaign (317)
8	Brigham Young University, main campus (524)	University of California, San Diego (311)
9	University of Wisconsin, Madison (510)	University of Texas, Austin (305)
10	University of Texas, Austin (501)	University of California, Davis (501)

SOURCE: National Science Foundation (1999-2003). *Survey of Earned Doctorates.* Arlington, VA: National Science Foundation.

ing doctorates earned their baccalaureate degrees at research universities (Table 3-7); Gaughan and Robin found that obtaining an undergraduate degree at one of the Research I universities is highly predictive of entry into an academic career.[40] There are differences by sex, race, and ethnicity in the baccalaureate origins of science and engineering doctorates.[41] For example, historically black colleges and universities and women's colleges

[40] Gaughan and Robin (2004), ibid.

[41] DG Solorzano (1994). The baccalaureate origins of Chicana and Chicano doctorates in the physical, life, and engineering sciences: 1980-1990. *Journal of Women and Minorities in Science and Engineering* 1(4):253-272; NR Sharpe and CH Fuller (1995). Baccalaureate origins of women physical science doctorates: Relationship to institutional gender and science discipline. *Journal of Women and Minorities in Science and Engineering* 2(1):1-15; T Lintner (1996). *The Forgotten Scholars: American Indian Doctorate Receipt, 1980-1990, http://eric.ed.gov/ERICDocs/data/ericdocs2/content_storage_01/0000000b/80/25/be/36.pdf*; CB Leggon and W Pearson (1997). The baccalaureate origins of African American female PhD scientists. *Journal of Women and Minorities in Science and Engineering* 3(4):213-224.

have played a larger role in producing women African American science PhD students: 75% of the African American women who earned PhDs in biology from 1975-1992 earned their baccalaureate degrees from either Spelman College or Bennett College.[42]

Graduate School Attrition

A number of researchers have examined the factors involved in graduate school attrition. Graduate Record Examination scores and undergraduate grade point averages are poor predictors of PhD attainment rates.[43] The social climate of graduate school plays a large role in whether a woman obtains a PhD in science or engineering.

While in graduate school, students face many challenges, not the least of which is maintaining self-confidence. Some have suggested that women are conditioned to measure the value of their achievements by the amount and nature of the feedback and attention they receive from others, but that men are taught to require little support from others.[44] Those social expectations would make women more vulnerable to losing their self-confidence in situations where little praise is given—a common occurrence in graduate school.[45] Other researchers reported that a loss in self-confidence adversely affected career plans and the determination to carry them out.[46] The integration of students into a community is associated with lower attrition rates.[47]

The isolation that women experience in graduate school has led to a number of adverse consequences, such as reduced opportunities to compare experiences with others, to seek help without the fear of being judged as inadequate or lacking in intelligence, to receive affirmation of their evaluations of situations, to obtain advice on ways of addressing a problem, to

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[42]CB Leggon and W Pearson (1997). The baccalaureate origins of African American female PhD scientists. *Journal of Women and Minorities in Science and Engineering* 3:213-224.

[43]National Research Council (1996). *The Path to the PhD*. Washington, DC: National Academy Press.

[44]VJ Kuck, CH Marzabadi, SA Nolan, and J Buckner (2004). Analysis by gender of the doctoral and postdoctoral institutions of faculty members at the top-fifty ranked chemistry departments. *Journal of Chemical Education* 81(3):356-363, *http://www.chem.indiana.edu/academics/ugrad/Courses/G307/documents/Genderanalysis.pdf*.

[45]CA Trower and JL Bleak (2004). *Study of New Scholars. Gender: Statistical Report* [Universities]. Cambridge, MA: Harvard Graduate School of Education, *http://www.gse.harvard.edu/~newscholars/newscholars/downloads/genderreport.pdf*.

[46]Kuck et al. (2004), ibid.

[47]BE Lovitts (2001). *Leaving the Ivory Tower: The Causes and Consequences of Departure from Doctoral Study*. Lanham, MD: Rowman and Littlefield.

TABLE 3-8 Location and Type of Planned Postgraduate Study for US Citizens and Permanent Resident Science and Engineering PhD Recipients, by Sex, 2003

Location and Type of Postgraduate Activity	All S&E PhD recipients	Women	Men
US PhD recipients	10,863	4,545	6,316
Based in United States	96.4%	96.7%	96.1%
Academic employment	24.0%	26.6%	22.2%
Industry employment	16.6%	11.7%	20.1%
Postdoctoral study	42.9%	45.3%	41.2%
Other[a]	12.8%	13.1%	12.6%
Based abroad	3.3%	3.1%	3.5%
Location unknown	0.3%	0.2%	0.4%

[a] Includes elementary and secondary schools, government, nonprofit, and other or unknown.

SOURCE. National Science Foundation, Division of Science Resource Statistics, *Survey of Earned Doctorates, 2003*. Arlington, VA: National Science Foundation.

gain peer support and encouragement, and to build a professional network. In group meetings, female students reported that often their remarks were barely recognized by other group members, while the comments of their male peers were met with enthusiasm and support. Other studies reiterate this finding—that women are indeed "left out of informal networks" of communication.[48]

POSTGRADUATE CAREER PLANS

A majority of students in the sciences and mathematics (59%) and the social sciences (55%), but only 28% of students in engineering, prepare to become postdoctoral scholars or college or university faculty. Among all science and engineering PhD recipients in 2003, more women than men reported plans to enter postdoctoral study, and substantially more men than women reported plans to enter industrial employment (Table 3-8).

[48] Kuck et al. (2004), ibid.

POSTDOCTORAL APPOINTMENTS

Postdoctoral research is virtually required in the life sciences, and is becoming increasingly common in the physical sciences and engineering. In the life sciences, men and women PhDs obtain postdoctoral appointments at similar rates (70.7% of women and 72.5% of men)—nearly 6,400 women and 10,500 men. In the physical sciences, 42.7% of women and 47.4% of men obtain postdoctoral appointments —1,000 women and 5,100 men.[49]

Professional Development and Productivity

In a recent national survey, Davis[50] reports that postdoctoral scholars with the highest levels of oversight and professional development are more satisfied, give their advisers higher ratings, report fewer conflicts with their advisers, and are more productive than those reporting the lowest levels of oversight. Although salaries and benefits were weakly linked to subjective success and positive adviser relations, higher salaries[51] and increased structured oversight appear to be linked to paper production, both for all peer-reviewed papers and first-author papers. Perhaps most interesting is the role of planning. Davis found that postdoctoral scholars who had crafted explicit plans with their adviser at the outset of their appointments were more satisfied with their experience than those who had not. In addition to subjective measures of success, postdoctoral scholars with written plans submitted papers to peer-reviewed journals at a 23% higher rate, first-author papers at a 30% higher rate, and grant proposals at a 25% higher rate than those without written plans.

Research on the post-PhD employment of scientists and engineers has shown that men employed in the academic sector express significantly greater job satisfaction than women; members of underrepresented minority groups are far less satisfied.[52] Similarly, Davis found that men postdoctoral scholars had higher levels of subjective success than women. Men had higher publication rates, although women submitted grant proposals at a higher rate; this suggests different resource allocation strategies. Underrepresented minority postdoctoral scholars submitted first-author papers at a lower rate than majority postdoctoral scholars. These data may

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[49]National Science Foundation (2004). *Graduate Students and Postdoctorates in Science and Engineering*. Arlington, VA: National Science Foundation.

[50]G Davis (2005). *Optimizing the Postdoctoral Experience: An Empirical Approach* (Working Paper). Research Triangle Park, NC: Sigma Xi, The Scientific Research Society.

[51]One standard deviation in each (for salary, a 19% difference, or roughly $7,600) corresponds to a 6.5-7% increase in the rate of paper production.

[52]P Moguerou (2002). *Job Satisfaction among US PhDs: The Effects of Gender and Employment Sectors* (Working Paper), *http://www.rennes.inra.fr/jma2002/pdf/moguerou.pdf*.

reflect what has been reported in mentoring studies of graduate students (see above) and junior faculty, where men and women report substantially different mentoring relationships. One institution found that women faculty were less likely than men to have mentors who actively fostered their careers and more likely than male faculty to report having mentors who used the women faculty's work for the mentor's own benefit (Box 6-3).

Funding Source

Overall, postdoctoral funding source does not appear to have a differential effect on career outcome. Certainly, being awarded a prestigious fellowship appears to have a favorable effect on one's chances of landing a tenure-track position,[53] but is not clear whether the fellowships select those who are already destined to land such positions or provide an additional advantage in being hired.

Recognizing that the age at which researchers receive their first independent award has been increasing over the last 20 years, the National Institutes of Health created the Pathway to Independence Award.[54] The award provides an opportunity for promising postdoctoral scientists to receive both mentored and independent research support from the same award. It remains to be seen how this award will affect the proportion of postdoctoral scholars who successfully transition to faculty positions or whether it will increase the proportion of women scientists who continue in academic careers.

Similarly, it is unclear whether there is a differential effect on career progression for women who receive a prestigious award such as the NSF Faculty Early Career Development (CAREER) award. Each year NSF selects nominees for the Presidential Early Career Awards for Scientists and Engineers (PECASE) from among the most meritorious new CAREER awardees. The PECASE program recognizes outstanding scientists and engineers who early in their careers show exceptional potential for leadership at the frontiers of knowledge. PECASE is the highest honor bestowed by the US government on scientists and engineers beginning their independent careers.[55] It is notable that the proportion of women CAREER and PECASE awardees in the last 10 years meets or exceeds the proportion of women in the PhD pool (Figure 3-2).

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[53] G Pion and M Ionescu-Pioggia (2003). Bridging postdoctoral training and a faculty position: Initial outcomes of the Burroughs Wellcome Fund Career Awards in the Biomedical Sciences. *Academic Medicine* 78(2):177-186.

[54] *http://grants.nih.gov/grants/new_investigators/pathway_independence.htm*.

[55] *http://www.nsf.gov/pubs/2002/nsf02111/nsf02111.htm*.

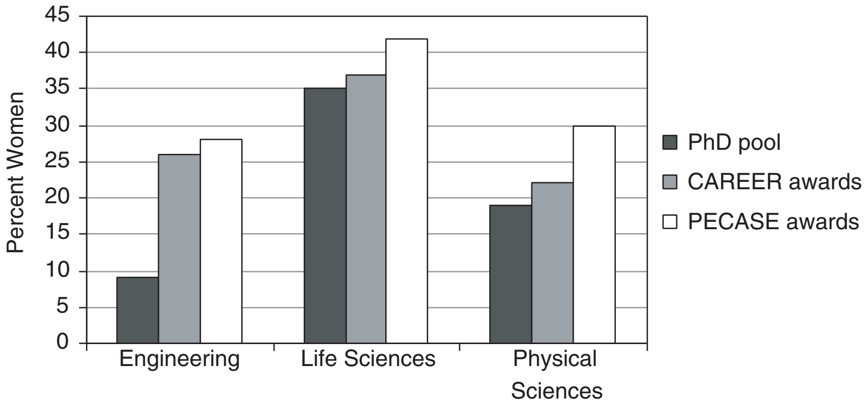

FIGURE 3-2 Proportion of women CAREER and PECASE awardees, 1995-2004.

NOTES: PhD pool was calculated as the average proportion of women earning PhDs in the 5-year period prior to the award. *Physical sciences* include mathematics and computer sciences.

SOURCE: *PhD Pool:* National Science Foundation, *Survey of Earned Doctorates, 1991-1999*; *CAREER awards* and *PECASE awards* are published by the National Science Foundation and available at *http://www.nsf.gov/awardsearch*. Engineering awards were those made by the ENG directorate, life sciences awards were those made by the BIO directorate, and physical sciences awards were those made by the CSE, GEO and MPS directorates.

FACULTY POSITIONS

Gains in women's representation among bachelor's and doctoral degree recipients have not translated into representation among college and university faculty (Figure 1-2 and Table 3-9). Four times as many men as women with science and engineering doctorates hold full-time faculty positions.[56] Data derived from the Association of American Medical Colleges Faculty Roster show that less than 5% of medical school faculty identify themselves as African American, Hispanic, or Native American.[57] Even though more African American women than African American men earn

[56]CPST (2002). *Professional Women and Minorities: A Total Human Resources Data Compendium*, 14th ed. Washington, DC: Commission on Professionals in Science and Technology.

[57]A Palepu, PL Carr, RH Friedman, H Amos, AS Ash, and MA Moskowitz (1998). Minority faculty in academic medicine. *JAMA* 280(9):767-771.

TABLE 3-9 Bachelor's Degree Recipients Compared with Faculty, by Sex and Field, 2002

	Percent Women		Percent Men	
	Students	Faculty	Students	Faculty
Biological sciences	58.4	20.2	41.6	79.8
Chemistry	47.3	12.1	52.7	87.9
Computer science	27.7	10.6	72.3	89.4
Physics	21.4	6.6	78.6	93.4

SOURCE: CB Leggon (2006). Women in science: Racial and ethnic differences and the differences they make. *Journal of Technology Transfer* 31:325-333.

science and engineering degrees, African American women make up less than half of the total African American full-time faculty in colleges and universities.[58] As discussed above, the underrepresentation of women on faculties can contribute to undergraduate and graduate students opting into career paths outside of academe.[59] It can also contribute to feelings of isolation among female faculty.

Hiring New Doctorates into Faculty Positions

No data are available on the total number of science and engineering tenure-track positions available each year. It is well known, however, that there are not nearly enough faculty positions to accommodate the new PhD pool. In physics in 2003, for example, there were 679 new faculty recruitments (including tenured, tenure-track, temporary, and non-tenure-track positions) and 1,197 new PhDs.[60] In mathematics in 2004, there were

[58]WB Harvey (2003). *20th Anniversary Minorities in Higher Education Annual Status Report*. Washington, DC: American Council on Education; K Hamilton (2002). The state of the African American professoriate. *Black Issues in Higher Education* 19(7):30-31.

[59]Discussed in ALW Sears (2003). Image problems deplete the number of women in academic applicant pools. *Journal of Women and Minorities in Science and Engineering* 9:169-181; MF Fox and PE Stephan (2001). Careers of young scientists: Preferences, prospects, and realities by gender and field. *Social Studies of Science* 31(1):109-122.

[60]R Ivie and KN Ray (2005). *Women in Physics and Astronomy, 2005* (AIP Publication Number R-430.02). College Park, MD: American Institute of Physics, *http://www.aip.org/statistics/trends/reports/women05.pdf*.

1,081 doctoral recipients and 232 reported hires in all faculty departments (126 were tenure-track at Research I universities).[61]

Fields vary in the proportion of female faculty relative to the available pool. In physics in 2004, a higher percentage of women were hired as junior faculty than are represented in the recent PhD pool: 18% of new physics hires and 13% of recent physics PhDs.[62] In mathematics in 2004, women made up 31% of doctoral recipients and 28.4% of new faculty hires.[63] Paradoxically, fields with higher proportions of women in the PhD pool have lower proportions of women in the applicant pool (Figure 1-2a, b, and c).[64] The same appears to be true in academic medicine (Box 3-3).

Usual department hiring processes often do not identify exceptional female candidates. That point is brought into sharp focus by a recent report from the Massachusetts Institute of Technology (MIT),[65] in which the number of women science faculty is plotted over time (Figure 3-3).

> The increases in the representation of women and minorities don't just "happen," but result from specific pressures, policies, and positive initiatives designed to increase the hiring of women or minorities; and that when these pressures abate or expire, hiring progress stops or even reverses.
>
> —Nancy Hopkins, Diversification of a University Faculty (2006)

In 2006, there were 36 female faculty and 240 male faculty in the School of Science at MIT. The total number of tenured and untenured women faculty in the MIT science departments rose steeply twice: between 1972 and 1976 and between 1997 and 2000. Those rises do not reflect contemporaneous increases in the size of the faculty. The number of male faculty actually decreased (from 259 to 229) during the rise in female faculty between 1997 and 2000 because of an early retirement program. Instead, the first sharp rise in the number of women science faculty beginning in 1972 was the result of pressures associated with the Civil Rights Act

[61]EE Kirkman, JW Maxwell, and CA Rose (2005). 2004 Annual Survey of the Mathematical Sciences. *Notices of the American Mathematical Society, http://www.ams.org/employment/2004Survey-Third-Report.pdf*.

[62]R Ivie and KN Ray (2005). *Women in Physics and Astronomy, 2005*. American Institute of Physics.

[63]Kirkman, Maxwell, and Rose (2005), ibid.

[64]Applications, interviews, and hiring decisions are discussed in the forthcoming report by the National Academies Committee on Women in Science and Engineering (Box 1-3).

[65]Hopkins (2006), ibid. Available at *http://web.mit.edu/fnl/volume/184/hopkins.html*.

DEFINING THE ISSUES

BOX 3-3 Academic Medicine

During the last 30 years the share of women graduating from medical colleges has nearly reached parity with the share of male graduates. However, as shown in Figure B3-1, while the share of women students and faculty members was similar before 1974, since then, increases in the proportion of women medical school graduates have not translated into similar increases in the proportion of women in faculty positions.

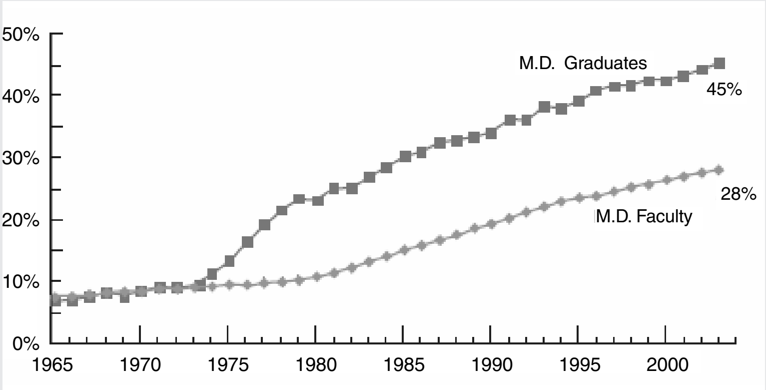

FIGURE B3-1 Representation of women MDs in academic medicine faculty positions, 1965-2004.

ADAPTED FROM: Association of American Medical Colleges (2005). The changing representation of men and women in academic medicine. *AAMC Analysis in Brief* 5(2):1-2, *http://www.aamc.org/data/aib/aibissues/aibvol5_no2.pdf.*

A Snapshot of the Current Situation for Female Faculty Members in Medicine[a]

- The growth trajectories of women students and women faculty are now similar, but the dramatic increase in women students in the years 1974-1980 was not matched by any change in the rate of growth of women faculty (Figure B3-1).
- The proportion of women in senior faculty positions in 2004 matched the proportion of women graduates in 1980 (Figure B3-2).
- Across all levels of seniority, women medical faculty earn significantly lower salaries than male faculty. Minority-group faculty earn less than white faculty.
- Women do not gain in academic rank at a rate that is proportional to their representation in medical school faculties.

[a]AS Ash, PL Carr, R Goldstein, and RH Friedman (2004). Compensation and advancement of women in academic medicine: Is there equity? *Annals of Internal Medicine* 141(3):205-212.

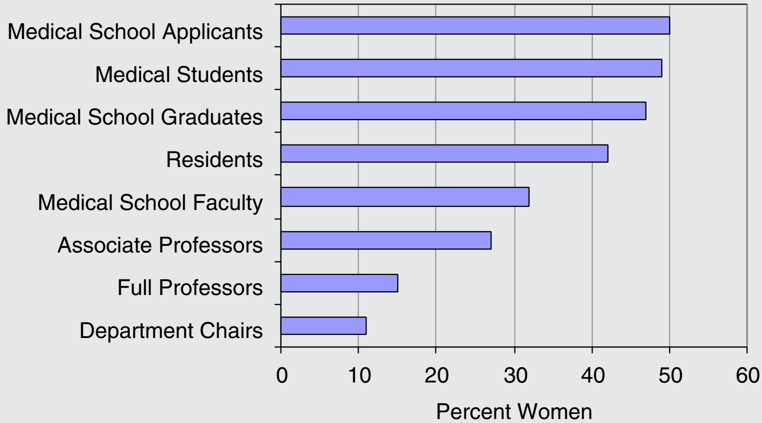

FIGURE B3-2 Proportion of women in academic medicine, by educational stage and rank.

ADAPTED FROM: Association of American Medical Colleges (2005). *Women in US Academic Medicine: Statistics and Medical School Benchmarking*, *http://www.aamc.org/members/wim/statistics/stats05/wimstats2005.pdf*.

Reasons for Differences

Brown and colleagues[b] note that a number of factors may contribute to women's slower advancement, but a pipeline problem is not among them. They conclude that the supply of women graduating from medical schools is adequate and that "the **culture of academic medicine**, not the numbers of available women, drives the lopsided numbers." Cultural issues include a lack of high-ranking female role models; gender stereotyping that works to limit opportunities; exclusion from career development opportunities; differences in workplace expectations for men and women; social and professional isolation; and gender differences in the amount of funding, space, and staff support provided. Those factors have been found to adversely affect female faculty members' career satisfaction and advancement. In addition, traditional constructs of reward and hierarchy within departments have been found to impede advancement of women faculty because they are inherently gender-biased. Bickel et al. point out "medicine tends to over-value heroic individualism" with the result that "women will not 'measure up' as easily as men do."[c]

[b]A Brown, W Swinyard, and J Ogle (2003). Women in academic medicine: A report of focus groups and questionnaires, with conjoint analysis. *Journal of Women's Health* 12(10):999-1008.

[c]J Bickel, D Wara, BF Atkinson, LS Cohen, M Dunn, S Hostler, TRB Johnson, P Morahan, AH Rubenstein, GF Sheldon, and E Stokes (2002). Increasing women's leadership in academic medicine: Report of the AAMC project implementation committee. *Academic Medicine* 77(10):1043-1061.

continued

BOX 3-3 Continued

A second difficulty is related to **tensions between professional and personal life** which seem to be especially acute for women in academic medicine. Brown et al. report that "the demands of career and personal life [are] each great enough to extract compromise from the other, and, further, that anticipated support from a partner, the community, and medical center was inadequate to make it possible to succeed in multiple roles at once." Bickel and colleagues note that academic medicine tends to "reward unrestricted availability to work (i.e., neglect of personal life)." Furthermore, as in other fields, the pressures of the tenure timeline in academic medicine often coincide with decisions (and associated pressures) to start a family.

Potential Policy Options

Potential policy actions to redress those problems focus on adjusting the institutional environment in a way that improves the experiences of both male and female faculty. Improving the quality of professional development programs for all faculty has proven effective in addressing culture and climate issues[d] (Chapter 4 and Box 6-3). Other suggestions are to:

- Improve department mentoring programs, including providing guidance to male faculty on how to be effective mentors for female faculty.
- Address the tensions between work and personal lives and obligations.
- Identify which institutional practices tend to favor men's over women's professional development and rebalance them to value the institution's goals in a gender-neutral way.
- Recognize models of career success based on quality rather than quantity, so that people can craft careers that both serve the institution's needs and harmonize with their own core values.
- Place more value on accomplishments accruing from collaborative work.
- Provide more flexibility for part-time work.
- Adjust tenure policies.
- Provide options for partner hiring programs and childcare.

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[d]LP Fried, CA Francomano, SM MacDonald, EM Wagner, EJ Stokes, KM Carbone, WB Bias, MM Newman, and JD Stobo (1996). Career development for women in academic medicine: Multiple interventions in a department of medicine. *Journal of the American Medical Association* 276(11):898-905; S Mark, H Link, PS Morahan, L Pololi, V Reznik, and S Tropez-Sims (2001). Innovative mentoring programs to promote gender equity in academic medicine. *Academic Medicine* 76:39-42.

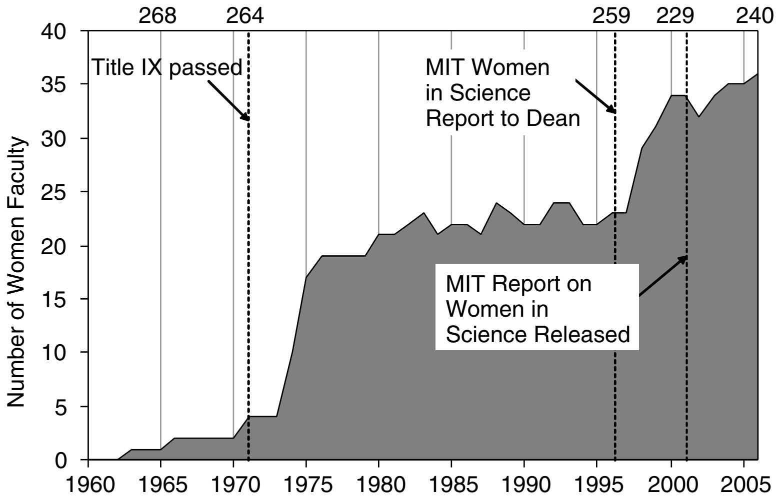

FIGURE 3-3 Number of women faculty in the School of Science at the Massachusetts Institute of Technology, 1963-2006.

NOTES: The numbers of male faculty in several relevant years are shown along the top of the graph.

ADAPTED FROM: N Hopkins (2006). Diversification of a university faculty: Observations on hiring women faculty in the schools of science and engineering at MIT. *MIT Faculty Newsletter* 18(4):1, 16-23. *http://web.mit.edu/fnl/volume/184/hopkins.html.*

and affirmative action regulations. In particular, Secretary of Labor George Schultz in 1971 ordered compliance reviews of hiring policies of women in universities. All institutions receiving federal funding were required to have such plans in effect as of that year. The second sharp rise between 1997 and 2000 resulted directly from the Dean of the School of Science's response to the 1996 MIT *Report on Women Faculty in the School of Science*.

The "Pool"

As discussed in Box 3-1, one of the current controversies is how to define the available pool of talent. Some base their figures on the proportion of women who have recently graduated with a PhD or MD; others suggest it should be based on the average over several years. In some fields where postdoctoral appointments are common, "recent" may be 5 years prior to a search. Others suggest the appropriate pool should be the proportion of women in the postdoctorate pool. Still others argue that the pool should be based on the proportion of women earning PhDs in top-tier institutions. As discussed in Box 3-1, there is currently no consensus on how to measure the "pool" of qualified candidates.

At the University of California, Berkeley, "doctoral pool" is defined in a two-step process. First, the average proportion of US residents earning PhDs in the relevant field in the 5 years prior is obtained from the National Science Foundation Survey of Earned Doctorates, which publishes these figures annually. Second, the pool is narrowed by considering only those PhDs awarded at the 35 institutions producing the most PhDs at top-quartile-rated doctoral programs, based on the National Research Council's *Research Doctorate Programs in the United States: Continuity and Change* report.[66] Indeed, research on hiring shows that faculty at Research I universities received their doctorate degrees from a very select group of institutions,[67] and that narrowing the institutional filter further may provide a more realistic picture of actual hiring practice. This issue is discussed in more detail later in this chapter in the *Chemistry Case Study* section. Perception of career opportunities is another factor affecting the sex distribution of the academic job applicant pool; some research indicates that women mathematics and science graduate students perceive academic careers more negatively than do men.[68]

Applicant data on biology and the health sciences at the University of California, Berkeley, in 2001-2004 show that women made up 47% of recent biology and health sciences doctorates from the top-quartile of graduate schools, but only 29% of applicants for tenure-track faculty positions (Figure 3-4). In physical science, mathematics, computer science, and engineering disciplines, women made up 21% of recent PhDs from those top schools and 15% of applicants (Figure 3-5). Minority-group women, in contrast with white women, are present in the University of California, Berkeley, applicant pool in the same proportion as in the PhD pool, but are not represented proportionately among assistant professors.

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[66] National Research Council (1995). *Research Doctorate Programs in the United States: Continuity and Change*. Washington, DC: National Academy Press.

[67] For example, see VJ Kuck, CH Marzabadi, SA Nolan, and J Buckner (2004). Analysis by gender of the doctoral and postdoctoral institutions of faculty members at the top-fifty ranked chemistry departments. *Journal of Chemical Education* 81(3):356-363.

[68] ALW Sears (2003). Image problems deplete the number of women in academic applicant pools. *Journal of Women and Minorities in Science and Engineering* 9:169-181; D Barbezat (1992). The market for new PhD economists. *Journal of Economic Education* 23:262-276.

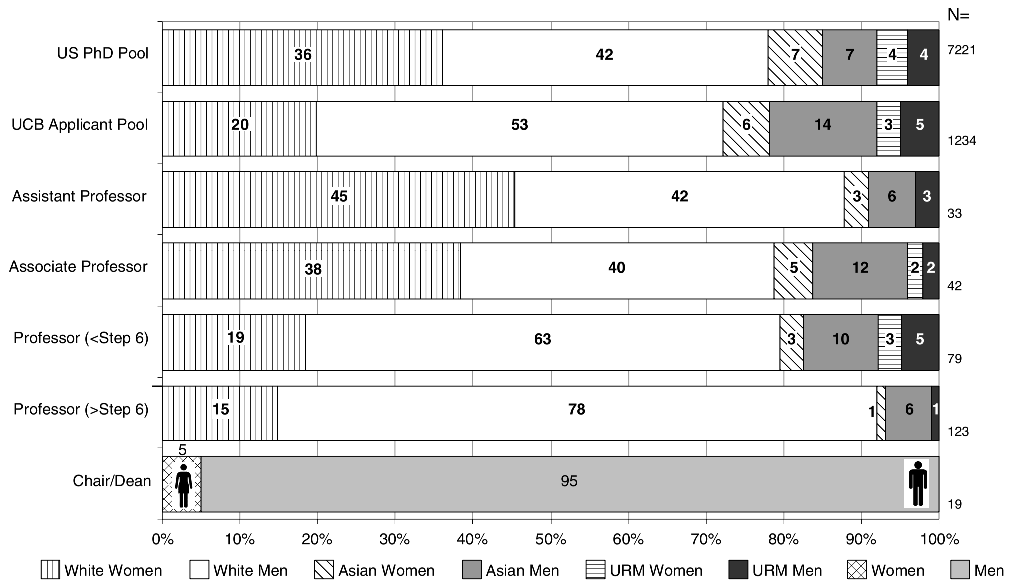

FIGURE 3-4 Biological and health sciences applicant pool and faculty positions at the University of California, Berkeley, 2001-2004.

NOTES: *Underrepresented minority (URM)* includes African American, Hispanic American, and Native American. *Chair/Dean* figures are broken down only by sex because of low counts. The PhD pool is based on PhDs granted to US residents, 1997-2001, at the 35 institutions producing the most PhDs at top-quartile-rated doctoral programs (National Research Council Reputational Ratings).

SOURCE: UC Berkeley Faculty Applicant Pool Database, 2001-2004; UC Berkeley Faculty Personnel Records, 2003; and National Science Foundation Survey of Earned Doctorates.