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

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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.

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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 aca-
demic 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 respon-
sibilities—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 sci-
ence and engineering departments.

This needless waste of the nation’s scientific talent must end. In addi-
tion 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 in-
  stitutions that contribute to and discourage talented individuals from real-
  izing 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
Committee on Maximizing the Potential of Women in Academic Science and Engineering
The Committee on Science, Engineering, and Public Policy (COSEPUP) appreciates the support of the standing National Academies Committee on Women in Science and Engineering (CWSE), which is represented on the guidance group, on the study committee, and on project staff.

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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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
Beyond Bias and Barriers: Fulfilling the Potential of Women in Academic Science and Engineering
http://www.nap.edu/catalog/11741.html

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

<table>
<thead>
<tr>
<th>Belief</th>
<th>Evidence</th>
<th>Where Discussed</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1) Women are not as good in mathematics as men.</td>
<td>Female performance in high school mathematics now matches that of males.</td>
<td>Chapter 2</td>
</tr>
<tr>
<td>(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.</td>
<td>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.</td>
<td>Chapter 3</td>
</tr>
<tr>
<td>(3) Women are not as competitive as men. Women don’t want jobs in academe.</td>
<td>Similar proportions of men and women science and engineering doctorates plan to enter postdoctoral study or academic employment.</td>
<td>Chapter 3</td>
</tr>
<tr>
<td>(4) Behavioral research is qualitative; why pay attention to the data in this report?</td>
<td>The data are from multiple sources, were obtained using well-recognized techniques, and have been replicated in several settings.</td>
<td>Chapters 2-5</td>
</tr>
<tr>
<td>(5) Women and minorities are recipients of favoritism through affirmative-action programs.</td>
<td>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.</td>
<td>Chapter 4</td>
</tr>
<tr>
<td>(6) Academe is a meritocracy.</td>
<td>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.</td>
<td>Chapter 4</td>
</tr>
<tr>
<td>(7) Changing the rules means that standards of excellence will be deleteriously affected.</td>
<td>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.</td>
<td>Chapter 4</td>
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continued
TABLE S-1 Continued

<table>
<thead>
<tr>
<th>Belief</th>
<th>Evidence</th>
<th>Where Discussed</th>
</tr>
</thead>
<tbody>
<tr>
<td>(8) Women faculty are less productive than men.</td>
<td>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.</td>
<td>Chapter 4</td>
</tr>
<tr>
<td>(9) Women are more interested in family than in careers.</td>
<td>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.</td>
<td>Chapter 5</td>
</tr>
<tr>
<td>(10) Women take more time off due to childbearing, so they are a bad investment.</td>
<td>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.</td>
<td>Chapter 5</td>
</tr>
<tr>
<td>(11) The system as currently configured has worked well in producing great science; why change it?</td>
<td>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.</td>
<td>Chapter 6</td>
</tr>
</tbody>
</table>

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.
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.

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. 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-

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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.
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

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-
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. In the top 50 engineering departments, women earn one-fourth of the PhDs granted in chemical engineering and 15% in engineering overall.

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

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3 GAO (2004), ibid.

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, 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, including Harvard

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5Ethnic 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.

6For 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/cwsel/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.
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. 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.


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.\textsuperscript{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.\textsuperscript{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.\textsuperscript{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.”\textsuperscript{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.”\textsuperscript{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.”\textsuperscript{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.\textsuperscript{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.\(^j\)

\(^h\)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-
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

<table>
<thead>
<tr>
<th>Finding</th>
<th>Recommendation</th>
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<tr>
<td>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.</td>
<td>Develop, implement, and adopt high-quality state-level math and science curricula and teacher-quality standards.</td>
</tr>
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<td>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.</td>
<td>Develop aggressive intervention programs focused on the transition from high school to college.</td>
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<td>The US workplace culture does not value underrepresented groups.</td>
<td>Expand federal and state financial investment in the undergraduate and graduate education of underrepresented groups.</td>
</tr>
<tr>
<td>The public image of scientists and engineers is inaccurate and derogatory. Women in particular do not receive adequate and accurate portrayal.</td>
<td>Hold employers accountable for the career development and advancement of all employees, including members of underrepresented groups.</td>
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<td></td>
<td>Establish a body to coordinate actions to transform the public image of SET careers.</td>
</tr>
</tbody>
</table>

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:
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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bCAWMSET (2000), ibid.


ehttp://www.bestworkforce.org/PDFdocs/BEST_BridgeforAll_HighEdFINAL.pdf.

fhttp://www.bestworkforce.org/PDFdocs/BESTTalentImperativeFINAL.pdf.
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 per-
formance 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.
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

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. 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.

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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).

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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)
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

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**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 *ds* 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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the purported differences. Moreover, systematic sex differences do not exist in most cognitive functions. 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).

That differences exist in abilities, skills, or brain organization does not indicate that they are immutable, nor that they are related to the underrepresentation of women in science and engineering. Biological, social, and psychological factors interact. 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. 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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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)

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. 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. Girls do as well as if not better than boys in high school mathematics and science classes, and by 1998, girls were as likely as boys to take advanced mathematics and science classes. From 1990-2003, scores on the NAEP revealed no performance gap

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between boys and girls among 4th, 8th, and 12th grade students. Scores on the SAT-M show a somewhat different picture, however, with the average score for boys consistently above that for girls. Because SAT-M scores underpredict the mathematics performance of college women relative to men, 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. Sex differences favoring boys are concentrated in particular tasks, specifically those requiring visuospatial transformation and unconventional mathematical knowledge. Girls, in contrast, excel in mathematical tasks that involve language processing. Men appear to use spatial strategies more often than women, and such strategic choices may account for a male advantage among high


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


17A Gallagher, JY Levin, and C Cahalan (2002), ibid; Pinker (2005), ibid; Spelke (2005), ibid.
performers on tests of mathematical reasoning. When all students are encouraged to use spatial strategies, the gender gap in performance narrows. 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). 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. Evidence indicates that the difference between men and women on this task may be largely due to stereotype threat (Box 2-4). 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. 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.

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

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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,\textsuperscript{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,\textsuperscript{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.\textsuperscript{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;\textsuperscript{29} and speech articulation and fine motor tasks.\textsuperscript{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.\textsuperscript{31} Researchers and the mass

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\textsuperscript{27}Hyde and Linn (1988), ibid.


media alike have called the sex difference in writing so large as to be “alarming” or a “crisis.” A more recent study shows consistent improvement among boys, and stresses that the predominant issues are race and class, not sex. 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 while gaps in verbal performance, visuospatial rotation, and SAT-M scores have held steady. Perhaps more salient are international comparisons. Most countries participating in the Programme for International Student Assessment (PISA) 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. 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.

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34 JS Hyde, E Fennema, and JS Lammon (1990), ibid; Feingold (1988), ibid; JR Campbell, CM Hombo, and J Mazzeo (2000), ibid.
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/.
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.¹

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 700.² 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.”³

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.⁴ 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 malleabil-
ity 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. 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 and among a large sample of mathematically gifted youth. 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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10CJ Weinberger (2005), ibid.

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. 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. As described

### Table 2-1

The Magnitude ("d") of Sex Differences in Mathematics Performance, by Age and Test Cognitive Level

<table>
<thead>
<tr>
<th>Age Group</th>
<th>Cognitive Level</th>
<th>Computation</th>
<th>Concepts</th>
<th>Problem Solving</th>
</tr>
</thead>
<tbody>
<tr>
<td>5-10</td>
<td></td>
<td>-0.20</td>
<td>-0.02</td>
<td>0.00</td>
</tr>
<tr>
<td>11-14</td>
<td></td>
<td>-0.22</td>
<td>-0.06</td>
<td>-0.02</td>
</tr>
<tr>
<td>15-18</td>
<td></td>
<td>0.00</td>
<td>0.07</td>
<td>0.29</td>
</tr>
<tr>
<td>19-25</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>0.32</td>
</tr>
</tbody>
</table>

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.

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.\textsuperscript{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.\textsuperscript{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.\textsuperscript{43} A relationship between handedness (preference for using the right or left hand) and cognitive abilities provides a useful avenue for


investigating neurological differences. 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.

The presumed masculinizing effect of androgens on spatial ability and personal preferences has attracted particular interest. 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. 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

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44Halpern (2005), ibid.
feminine than other girls. That might encourage them to act in less stereotypically feminine ways.\textsuperscript{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.\textsuperscript{49} In addition, one study indicated that levels of fetal testosterone appear to be correlated positively with girls’ ability to do mental rotation tasks.\textsuperscript{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.\textsuperscript{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.\textsuperscript{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.

\section*{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.\textsuperscript{53} When sex differences in those abilities are found,

\begin{itemize}
\item \[48\text{M Hines (2003). Sex steroids and human behavior: Prenatal androgen exposure and sex-typical play behavior in children. }\textit{Annals of the New York Academy of Sciences} 1007:272-282; CCC Cohen-Bendahan et al. (2005), ibid; Pasterski et al. (2005), ibid.\]
\item \[49\text{S Luchtmaya, S Baron-Cohen, and P Raggatt (2002). Foetal testosterone and eye contact in 12-month-old human infants. }\textit{Infant Behavior and Development} 25:327-335.\]
\item \[50\text{Luchtmaya et al. (2002), ibid.}\]
\item \[51\text{M Hausmann, D Slabbeekoor, SHM Van Goopen, PT Cohen-Kettenis, and O Güntürkün (2000). Sex hormones affect spatial abilities during the menstrual cycle. }\textit{Behavioral Neuroscience} 114(6):1245-1250.\]
\end{itemize}
they tend to favor girls and to be transitory;\textsuperscript{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.\textsuperscript{55} With the exception of one study whose methods have been criticized for inadequate controls,\textsuperscript{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.\textsuperscript{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.\textsuperscript{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.\textsuperscript{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


leads human children to treat toys as representations of real objects. 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. 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. Some call into question whether hunting and gathering were sex-typed activities. 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...
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,

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

### 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. 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.

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. 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. Moreover, the equal

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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. Other studies, however, found more mixed effects. 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.

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. 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. 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 as much as girls not only took as many mathematics and science courses as boys, but earned better grades.

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

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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.\(^8\) 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.\(^6\) 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

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

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.  


FIGURE B2-4 Teaching about stereotype threat inoculates against its effects.


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

78Spencer, Steele, and Quinn (1999), ibid.  
80Spencer, 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.


\(^{86}\) 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 stereotyped 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. 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.

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-
Professional 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. 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

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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

sex and race can further restrict career options. An analysis by the Education Trust 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)

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. 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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Most analyses of career trajectories of women scientists and engineers use a pipeline analogy, positing that women are underrepresented at senior levels of academia 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.”

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. 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. 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.” 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-

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\(^b\) Ivie and Ray (2005), ibid.

\(^c\) Ivie and Ray (2005), ibid.

ents is much higher than their percentage among assistant professors, the typical rank of recently hired faculty. 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.” 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. 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.” 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. 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 found that, “while the most important

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7Nelson (2005), ibid.
11National Research Council (2001), ibid.
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. 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.

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. Where possible, in the analysis of persistence and attrition in science and engineering education

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

**COURSE SELECTION IN HIGH SCHOOL**

Rigorous study in high school is the best predictor of persistence to a degree in college.  

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.  

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. 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. For ex-

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

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<tbody>
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<td>Mathematics</td>
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<tr>
<td>• Trigonometry/Algebra III</td>
<td>20.6</td>
<td>20.9</td>
<td>23.0</td>
<td>24.9</td>
<td>19.4</td>
<td>22.5</td>
<td>17.9</td>
<td>21.1</td>
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<tr>
<td>• Precalculus/Analysis</td>
<td>14.4</td>
<td>13.0</td>
<td>16.3</td>
<td>18.4</td>
<td>23.1</td>
<td>22.9</td>
<td>25.4</td>
<td>27.9</td>
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<tr>
<td>• Statistics and probability</td>
<td>1.2</td>
<td>0.8</td>
<td>2.0</td>
<td>2.1</td>
<td>3.4</td>
<td>4.0</td>
<td>5.8</td>
<td>5.6</td>
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<tr>
<td>• Calculus</td>
<td>8.3</td>
<td>6.2</td>
<td>10.3</td>
<td>10.1</td>
<td>12.0</td>
<td>11.6</td>
<td>13.3</td>
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<tr>
<td>Science</td>
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<tr>
<td>• Advanced biology</td>
<td>25.7</td>
<td>29.2</td>
<td>31.5</td>
<td>37.8</td>
<td>33.8</td>
<td>40.8</td>
<td>31.5</td>
<td>40.5</td>
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<tr>
<td>• Chemistry</td>
<td>43.8</td>
<td>46.1</td>
<td>47.5</td>
<td>53.3</td>
<td>53.3</td>
<td>59.2</td>
<td>58.1</td>
<td>66.8</td>
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<tr>
<td>• Physics</td>
<td>24.9</td>
<td>18.3</td>
<td>26.7</td>
<td>22.5</td>
<td>31.0</td>
<td>26.6</td>
<td>35.6</td>
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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 col-
lege 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.\textsuperscript{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.\textsuperscript{14} For at least 20 years, about one-third of all first-year college stu-
dents have planned to study science and engineering.\textsuperscript{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 engi-
neering 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 minor-
ity-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.\textsuperscript{16} Much of the increase among minorities was fueled by an increase
in science and engineering degrees awarded to women. A recent study\textsuperscript{17}

\textsuperscript{13}National Science Board (2006). \textit{Science and Engineering Indicators}, 2006. Arlington,
VA: National Science Foundation, Figures 1-28 and 1-29.
\textsuperscript{14}Y Xie and KA Shauman (2003). \textit{Women in Science: Career Processes and Outcomes}.
\textsuperscript{15}HS Astin (2005). \textit{Annual Survey of the American Freshman, National Norms}. Los Ange-
\textsuperscript{16}National Science Board (2006), ibid.
\textsuperscript{17}C Goldin, LF Katz, and I Kuziemko (2006). \textit{The Homecoming of American College
Women: The Reversal of the College Gender Gap} (NBER Working Paper No. 12139). Cam-
TABLE 3-2 Percentages of First-Year College Students Intending to Major in Science and Engineering, by Sex and Race or Ethnicity, 2004

<table>
<thead>
<tr>
<th>Field</th>
<th>Overall</th>
<th></th>
<th></th>
<th>African American</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Men</td>
<td>Women</td>
<td></td>
<td>Men</td>
<td>Women</td>
</tr>
<tr>
<td>Physical sciences</td>
<td>2.9</td>
<td>1.9</td>
<td></td>
<td>1.7</td>
<td>1.9</td>
</tr>
<tr>
<td>Life sciences</td>
<td>7.4</td>
<td>9.0</td>
<td></td>
<td>7.5</td>
<td>10.9</td>
</tr>
<tr>
<td>Mathematics</td>
<td>1.0</td>
<td>0.6</td>
<td></td>
<td>0.6</td>
<td>0.4</td>
</tr>
<tr>
<td>Computer sciences</td>
<td>4.1</td>
<td>0.4</td>
<td></td>
<td>6.2</td>
<td>1.5</td>
</tr>
<tr>
<td>Social and behavioral sciences</td>
<td>7.5</td>
<td>11.5</td>
<td></td>
<td>7.1</td>
<td>14.3</td>
</tr>
<tr>
<td>Engineering</td>
<td>17.9</td>
<td>2.9</td>
<td></td>
<td>15.1</td>
<td>2.9</td>
</tr>
<tr>
<td>Total</td>
<td>40.8</td>
<td>26.3</td>
<td></td>
<td>38.2</td>
<td>31.9</td>
</tr>
</tbody>
</table>

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.\(^\text{18}\)

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

<table>
<thead>
<tr>
<th>Hispanic</th>
<th>Native American</th>
<th>Asian American</th>
<th>White</th>
</tr>
</thead>
<tbody>
<tr>
<td>Men</td>
<td>Women</td>
<td>Men</td>
<td>Women</td>
</tr>
<tr>
<td>2.1</td>
<td>1.3</td>
<td>3.2</td>
<td>2.1</td>
</tr>
<tr>
<td>7.9</td>
<td>10.4</td>
<td>8.2</td>
<td>9.0</td>
</tr>
<tr>
<td>0.8</td>
<td>0.7</td>
<td>0.7</td>
<td>0.5</td>
</tr>
<tr>
<td>4.5</td>
<td>0.6</td>
<td>4.7</td>
<td>0.5</td>
</tr>
<tr>
<td>8.7</td>
<td>15.6</td>
<td>8.7</td>
<td>14.4</td>
</tr>
<tr>
<td>21.0</td>
<td>3.1</td>
<td>15.2</td>
<td>2.9</td>
</tr>
<tr>
<td>45.0</td>
<td>31.7</td>
<td>40.7</td>
<td>29.4</td>
</tr>
</tbody>
</table>

| Men      | Women           | Men            | Women |
| 2.6      | 2.0             | 14.1           | 18.0  |
| 1.0      | 0.8             | 1.0            | 0.7   |
| 4.1      | 0.6             | 3.9            | 0.3   |
| 6.7      | 10.6            | 7.4            | 10.6  |
| 25.8     | 5.6             | 17.0           | 2.7   |
| 54.3     | 25.8            | 38.7           | 23.9  |


---


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

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

<table>
<thead>
<tr>
<th></th>
<th>Overall</th>
<th>African American</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Men</td>
<td>Women</td>
</tr>
<tr>
<td>Physical sciences</td>
<td>10,598</td>
<td>7,533</td>
</tr>
<tr>
<td>Life sciences</td>
<td>33,981</td>
<td>45,575</td>
</tr>
<tr>
<td>Mathematics</td>
<td>5,958</td>
<td>5,497</td>
</tr>
<tr>
<td>Computer sciences</td>
<td>31,284</td>
<td>11,900</td>
</tr>
<tr>
<td>Social and behavioral sciences</td>
<td>68,458</td>
<td>120,164</td>
</tr>
<tr>
<td>Engineering</td>
<td>47,344</td>
<td>11,914</td>
</tr>
<tr>
<td>Total</td>
<td>197,623</td>
<td>202,583</td>
</tr>
</tbody>
</table>

(15.7) (16.1) (11.9) (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


21Xie and Shauman (2003), ibid.
women and 57% of men complete the major.\textsuperscript{22} Students’ expectations of their social roles strongly influence their educational and career goals. Applying Eagly and Karau’s \textit{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.\textsuperscript{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

\begin{table}
\centering
\begin{tabular}{cccccccc}
\hline
 & Hispanic & & Native American & & Asian American & & White & \\
 & Women & & Women & & Women & & Women & \\
\hline
Men & Women & Men & Women & Men & Women & Men & Women \\
448 & 497 & 59 & 59 & 730 & 700 & 8,046 & 5,202 \\
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 & 15,580 & 1,318 & 1,478 & 18,975 & 17,423 & 135,184 & 132,664 \\
(13.3) & (17.3) & (15.2) & (17.1) & (25.1) & (23.0) & (15.2) & (14.9) \\
\hline
\end{tabular}
\end{table}

\textsuperscript{22}Xie and Shauman (2003), ibid.
\textsuperscript{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). 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.

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. 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.

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24Seymour and Hewitt (1997), ibid.
27Xie and Shauman (2003), ibid.
The proportion of women varies by field and personal factors:

- 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

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28 Xie and Shauman (2003), ibid.
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-

Exchanging 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. 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 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.

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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31MT 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.

32In 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

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

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 Amer-

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


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)  

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. Science and engineering teaching assistants appear to have fewer opportunities to pub-

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35Nettles and Millett (2006), ibid.
36Nettles 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-

38Xie and Shauman (2003), ibid.
39Nettles 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

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

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

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.\textsuperscript{40} There are differences by sex, race, and ethnicity in the baccalaureate origins of science and engineering doctorates.\textsuperscript{41} For example, historically black colleges and universities and women’s colleges

\begin{table}[h]
\centering
\begin{tabular}{|c|c|c|}
\hline
 & Men & Women \\
\hline
Total S&E PhDs & 80,516 & 46,432 \\
\hline
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) \\
\hline
\end{tabular}
\caption{Top 10 US Baccalaureate Institutions of Science and Engineering Doctorate Recipients, 1999-2003}
\end{table}

\textsuperscript{40}Gaughan and Robin (2004), ibid.
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.\footnote{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.}

### 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.\footnote{National Research Council (1996). The Path to the PhD. Washington, DC: National Academy Press.} 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.\footnote{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.} 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.\footnote{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.} Other researchers reported that a loss in self-confidence adversely affected career plans and the determination to carry them out.\footnote{Kuck et al. (2004), ibid.} The integration of students into a community is associated with lower attrition rates.\footnote{BE Lovitts (2001). Leaving the Ivory Tower: The Causes and Consequences of Departure from Doctoral Study. Lanham, MD: Rowman and Littlefield.}

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

<table>
<thead>
<tr>
<th>Location and Type of Postgraduate Activity</th>
<th>All S&amp;E PhD recipients</th>
<th>Women</th>
<th>Men</th>
</tr>
</thead>
<tbody>
<tr>
<td>US PhD recipients</td>
<td>10,863</td>
<td>4,545</td>
<td>6,316</td>
</tr>
<tr>
<td>Based in United States</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Academic employment</td>
<td>96.4%</td>
<td>96.7%</td>
<td>96.1%</td>
</tr>
<tr>
<td>Industry employment</td>
<td>24.0%</td>
<td>26.6%</td>
<td>22.2%</td>
</tr>
<tr>
<td>Postdoctoral study</td>
<td>16.6%</td>
<td>11.7%</td>
<td>20.1%</td>
</tr>
<tr>
<td>Other*</td>
<td>42.9%</td>
<td>45.3%</td>
<td>41.2%</td>
</tr>
<tr>
<td>Based abroad</td>
<td>3.3%</td>
<td>3.1%</td>
<td>3.5%</td>
</tr>
<tr>
<td>Location unknown</td>
<td>0.3%</td>
<td>0.2%</td>
<td>0.4%</td>
</tr>
</tbody>
</table>

*Includes elementary and secondary schools, government, nonprofit, and other or unknown.


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).

48Kuck et al. (2004), ibid.
EXAMINING PERSISTENCE AND ATTRITION

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, Davis50 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 salaries51 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

51One 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.
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, 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. 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. 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).

---


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. 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. Even though more African American women than African American men earn PhDs in the 5-year period prior to the award, Physical sciences include mathematics and computer sciences.

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. 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. Even though more African American women than African American men earn

science and engineering degrees, African American women make up less than half of the total African American full-time faculty in colleges and universities.\textsuperscript{58} As discussed above, the underrepresentation of women on faculties can contribute to undergraduate and graduate students opting into career paths outside of academe.\textsuperscript{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.\textsuperscript{60} In mathematics in 2004, there were

<table>
<thead>
<tr>
<th>Percent Women</th>
<th>Percent Men</th>
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<tbody>
<tr>
<td>Students</td>
<td>Faculty</td>
</tr>
<tr>
<td>Biological sciences</td>
<td>58.4</td>
</tr>
<tr>
<td>Chemistry</td>
<td>47.3</td>
</tr>
<tr>
<td>Computer science</td>
<td>27.7</td>
</tr>
<tr>
<td>Physics</td>
<td>21.4</td>
</tr>
</tbody>
</table>


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1,081 doctoral recipients and 232 reported hires in all faculty departments (126 were tenure-track at Research I universities).\textsuperscript{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.\textsuperscript{62} In mathematics in 2004, women made up 31\% of doctoral recipients and 28.4\% of new faculty hires.\textsuperscript{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).\textsuperscript{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),\textsuperscript{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


\textsuperscript{63}Kirkman, Maxwell, and Rose (2005), ibid.

\textsuperscript{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).

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.

![Graph showing representation of women MDs in academic medicine faculty positions, 1965-2004.](http://www.aamc.org/data/aib/aibissues/aibvol5_no2.pdf)

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


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

- 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.

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Reasons for Differences

Brown and colleagues\textsuperscript{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 \textit{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.”\textsuperscript{c}


\textsuperscript{continued}

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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 (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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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. Indeed, research on hiring shows that faculty at Research I universities received their doctorate degrees from a very select group of institutions, 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.

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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67For 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.
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.
FIGURE 3-5 Physical sciences, mathematics, and engineering 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. There are no URM women in faculty positions in physical sciences, mathematics, and engineering departments. Chair/Dean figures are broken down only by gender 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.
Faculty Mobility

Estimates of faculty attrition are hard to come by. Most available attrition data are on retirements, not on mobility between universities or other nonretirement attrition. There is very little information available on where faculty go who leave academe. In 1999, about 7.7% of full-time faculty left their positions, 2.2% for retirement and 5.5% for a variety of other reasons. The few sources of data for this type of analysis are the Association of American Medical Colleges (AAMC) Faculty Roster, which collects and reports data on medical college faculty; the American Chemical Society Directory of Graduate Research; and the American Institute of Physics Academic Workforce Survey (Box 3-4).

To better understand faculty turnover and mobility, we used the NSF Survey of Doctoral Recipients (SDR), a longitudinal survey of a sample of people who earned doctorates in the United States. We examined the sample of full-time, untenured but tenure-track science, engineering, and social science faculty in 1995 who were also part of the survey 6 years later, in 2001. We found that men and women faculty exhibit different mobility: more men receive tenure or seek positions outside of academe, and more women move to non-tenure-track positions within academe.

- A slightly greater percentage of men than women moved from academe to other sectors of employment in 2001 (8.6% of women and 11.1% of men).
- A greater percentage of women faculty than men were unemployed in 2001 (3.4% of women and 0.8% of men).
- Men and women faculty had a similar likelihood of being employed at the same type of institution in 1995 and 2001 (68.5% of women and 70.1% of men).
- Men and women faculty had a similar likelihood of moving to a different type of institution between 1995 and 2001 (18.7% of women and 17.5% of men).
- Women faculty were significantly more likely than men to change jobs only in the social sciences.
- Of tenure-track faculty in 1995 who were employed in the same type of institution in 2001, more men than women faculty had received tenure (54.5% of women and 59.2% of men).

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**BOX 3-4** The Association of American Medical Colleges’ Faculty Roster, the American Chemical Society Directory of Graduate Research, and the American Institute of Physics Academic Workforce Survey

The AAMC Faculty Roster was started in 1966 through joint sponsorship of the National Institutes of Health (NIH) and AAMC as an effort to assess and track the intellectual capital of medical education. The Faculty Roster contains, on a voluntary basis, employment, educational, and demographic information on faculty members at accredited US medical schools. Currently the roster contains records on about 113,000 active, full-time faculty and 122,000 inactive faculty.4

The Faculty Roster is used for a variety of purposes. Although it was initially conceived to deal with the development of personnel to staff new medical schools, in more recent years it has been used to track the progress of medical schools in increasing the representation of women and minorities in faculty positions. The roster can be used to examine sources of faculty, provide background on faculty training, track inter-institutional movement by faculty, and study reasons behind faculty departure from medical academe.5 NIH uses the Faculty Roster to inform policy decisions, using its data to study such topics as the growth rate of faculty or the typical age of faculty at the time at which they receive their first professorships. In addition to providing the database to its members for communication and research purposes, AAMC uses it to produce a series of annual reports on US medical school faculty, which present data on the national distribution of full-time faculty, including such information as specialty, department, rank, degree, sex, and race or ethnicity.6

The American Institute of Physics conducts a biennial survey on the number of faculty, turnover, retirements, and recruitments at physics degree-granting departments. It also collects information on sex, race, and ethnicity.7 The American Chemical Society also maintains a faculty database, the Directory of Graduate Research (DGR). The DGR focuses on faculty involved in chemistry research and provides information on faculty research field, academic rank, sex, and contact information. It does not collect information on race or ethnicity. The DGR provides a statistical summary of 665 chemical science departments and listings for nearly 11,000 faculty members.8

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4Association of American Medical Colleges. Faculty Roster, http://www.aamc.org/data/facultyroster/start.htm. Inactive faculty are those who are no longer faculty at an institution for reasons of leaving for private practice, retirement, or death.

5Association of American Medical Colleges. FAMOUS User’s Guide, http://www.aamc.org/data/facultyroster/famous.pdf. FAMOUS is the on-line administration system used to enter and edit data in the Faculty Roster.


8The American Chemical Society Directory of Graduate Research is searchable on-line at http://dgr.rinis.com/.
Next, we looked at full-time, untenured, tenure-track science, engineering, and social science faculty employed at a Research I institution in 1995. We found that between 1995 and 2001:

- Faculty at Research I universities were half as likely as the overall population of science, engineering, and social sciences faculty to move to other types of higher education institutions.
- Men were almost twice as likely as women to move to jobs outside academe (8.5% of women and 15.3% of men).
- Women who were employed as tenure-track faculty in 1995 were more likely than men not to be employed in 2001 (2.5% of women, 0.6% of men).
- Women tenure-track faculty who were employed at a Research I institution in both 1995 and 2001 cohorts were less likely than men to have received tenure in 2001 than corresponding men (56.3% of women and 61.6% of men).

**Exiting the Tenure Track**

We did an additional analysis to determine why tenure-track and tenured faculty changed jobs, using the 1995-2003 SDR. To be included in the sample, individuals must have had tenure or have had tenure-track jobs in 1995. Most individuals indicated multiple reasons for job changes. The single most important reason given was pay and promotion—this did not differ by field. Other reasons for changing jobs did differ by field, rank, and sex. Across fields, women faculty consistently ranked working conditions, family, and job location higher than men among their reasons for changing jobs (Table 3-10). Differences were most prevalent in life sciences, particularly among full professors.

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70 The research described in this section was commissioned by the committee from Donna Ginther, Associate Professor of Economics, University of Kansas.

There are sex differences in where women and men land after leaving tenure-track positions. A hazard analysis of the 1973-2001 longitudinal SDR sample shows that across science fields, men were significantly more likely to leave the tenure track for nonacademic employment. The overall hazard rate is 0.830 (p=0.05), which means that about 20% more men than women exited to nonacademic jobs. Where are the women going? Across all fields of science and engineering women are 40% more likely than men to exit the tenure track for an adjunct academic position (p=0.01). In addition to sex, the factors with the strongest correlation to this outcome were race or ethnicity, and employment at a private university or medical school. Women whose primary or secondary responsibility was teaching or those who had government funding were significantly less likely to exit to adjunct positions.

**Tenure**

Faculty mobility may be pushed by the expectation of a negative tenure decision. At MIT, for example, there is a 50% tenure rate in the science and engineering departments.\(^{72}\) This is similar to the overall tenure rate at

Research I universities (see above and footnote 95). Our analysis showed a small 4% difference in tenure rates for men and women; a number of other reports have documented similar differential tenure rates for men and women. Others document differential tenure rates for minority faculty. Some researchers have broken out tenure rates by field; in this finer analysis, between 1973 and 2001, women were between 1-3% less likely than men to get tenure in physical sciences, 2-4% more likely than men to get tenure in life sciences and engineering, and 8% less likely than men to get tenure in social sciences.

In addition to the cohort analysis described above, another way to analyze tenure decisions is by examining faculty who are reviewed for tenure. This analysis excludes faculty who leave the tenure track, and does not address time to tenure. Compared to the cohort analysis, the “review” paradigm yields higher tenure rates that are similar for men and women. For early tenure decisions—those made within 2 years of hiring—tenure rates are 96% to 100% for men, women, and minority faculty. For 4th- and 6th-year tenure review cases, the rates are also similar for men and women in, but are lower for, minority faculty: 85% to 90% of men and women are granted tenure, while 75% to 82% of minority faculty are granted tenure.

Promotion

Women faculty gain promotion more slowly than men and are less likely to reach the highest academic rank, especially in the Research I universities (see Chapter 4). At one university, for example (Figure 3-6), the...
most substantial difference between men and women is in the time it takes to reach the associate professor level, although there is also a difference in the timing between tenure and full professor. The pattern is not unique; it has also been shown at Duke University and at MIT, where women faculty are promoted more slowly than men. Race and ethnicity is an additional

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78 Additional data on time to promotion is provided by the National Academies Committee on Women in Science and Engineering in their 2006 workshop report (Box 1-3).
factor strongly correlated with reduced probability of promotion to full professor: between 1973 and 2001, African American women were almost 10% less likely than men to be promoted to full professor within 15 years of PhD.\textsuperscript{79}

The persistent effect of sex, even after controlling for a number of relevant variables, suggests that there is more to learn about the promotion process. Some researchers suggest that a reasonable explanation of women’s slower promotion and longer time in rank is that women are expected to meet higher standards for promotion, especially at Research I institutions.\textsuperscript{80} Another possibility is that women, particularly in the transition from achieving tenure to full professorship, are less likely to feel ready to apply. As discussed in Chapter 4, research shows that bias affects the judgments made about women scientists and engineers and often results in their research being less valued than research by men.

### Faculty Retention

From a number of reports, projects, and task forces examining factors behind faculty retention and attrition a number of common threads emerge (Box 3-5).\textsuperscript{81}

A key factor in retaining faculty of all types is the problem of differences in salaries between groups. A task force at the University of Colorado at Boulder (UC-Boulder) found that “non-competitive salaries represent the most-cited factor in faculty retention.”\textsuperscript{82} That concern was most prevalent among men; senior women faculty expressed more concern over salaries than junior women faculty. Other studies have found, however, that female faculty were less satisfied with their salaries than male faculty\textsuperscript{83} and studies

\textsuperscript{79}D Ginther, research commissioned by the committee.


at MIT\textsuperscript{84} and elsewhere have noted that women faculty are often underpaid relative to men.\textsuperscript{85}

An important issue related to salary is how universities structure and explain their tenure policies and procedures. Rigid policies for attaining tenure can raise difficulties for women and for junior faculty in general. As discussed above, women are more likely than men to leave the university at early points in their career.\textsuperscript{86} Trower and Chait report that both men and women receive little guidance about tenure policies and that junior faculty are likely to view tenure practices as “outmoded.”\textsuperscript{87} The Study of New Scholars at Harvard University reports significant differences in men and

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women faculty views of the tenure process; men are found to have clearer views of tenure prospects and expectations. Annual reviews and effective mentoring programs have been shown to clarify expectations and improve faculty retention (Box 6-3).

Conflicts between personal and professional life, as in the case of tenure, are often important in retention of junior and women faculty. Several studies show that women faculty are less satisfied than men with the interaction between their personal and professional lives. A task force at Columbia University notes that family responsibilities disproportionately impact women. Women are in their childbearing years at the same time they are developing their careers, and the demands of career and family often conflict. Such policies as child-care options and spousal hiring programs that are cognizant of the conflict can play a significant role in faculty retention. The UC-Boulder task force notes that spouse or partner employment opportunities can be an especially prevalent concern among junior faculty.

Within a given faculty member’s professional life department climate and the presence or absence of a supportive work environment have important influence on attrition and retention. A number of factors commonly cited in faculty retention and attrition studies are related to the environment that faculty encounter in their workplaces. Work done by Callister suggests that department climate is an important factor for universities to consider when attempting to improve faculty job satisfaction and intentions to quit. Callister reports that women faculty tend to be less satisfied than men in their jobs and more likely to quit. In a similar finding, the Study of New Scholars at Harvard reports that women faculty are less satisfied than

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88 Trower and Bleak (2004), ibid.
90 Trower and Bleak (2004), ibid.
93 Callister (2006), ibid.
men faculty with their workplace expectations and relationships, including availability of support, mentoring, and collaboration.\textsuperscript{94}

The UC-Boulder task force noted a sense of “professional isolation” as the third-most common reason for faculty attrition for women and men faculty. Professional isolation may include a lack of support from colleagues, lack of inclusion in the department community, and rude or unsympathetic students. Furthermore, several studies, including ones at Colorado and Columbia, note that women (and junior faculty members) have fewer opportunities to serve on meaningful department and university committees.\textsuperscript{95} The 1999 MIT study expressed concern that women faculty were “excluded from any substantial power within the University.”\textsuperscript{96}

A final issue related to the workplace environment was uncovered in a recent study at Rutgers University, which suggested that some women faculty’s outside offers are less likely than those of men to yield serious responses from university administrators, and it is more likely that those women will move to other universities.\textsuperscript{97}

Surveys of female faculty members illuminate specific climate issues. In a national survey of more than 1,000 university faculty members carried out by the Higher Education Research Institute, women were more likely than men to feel that colleagues devalued their research, that they had fewer opportunities to participate in collaborative efforts, and that they were constantly being scrutinized.\textsuperscript{98} Other researchers found that men tended to devalue women’s contributions to an effort.\textsuperscript{99} In another study, exit interviews of faculty women who “voluntarily” left a large university indicated that one of the key reasons for their departure was the lack of respect that they had been given by their colleagues.\textsuperscript{100} Preston found that a majority of female professors perceived that because of their sex they had not been respected or treated appropriately.\textsuperscript{101} Similarly, in a survey of Professional

\textsuperscript{94}Trower and Bleak (2004), ibid.
\textsuperscript{96}Massachusetts Institute of Technology (1999), ibid.
\textsuperscript{97}Rutgers University (2001). \textit{A Study of Gender Equity in the Faculty of Arts and Sciences}, \texttt{http://fas.rutgers.edu/onlineforms/gender_report.pdf}.
Opportunities for Women in Research and Education grant recipients, women faculty reported that they had limited opportunities to participate in department or decision-making processes, had heard their research trivialized and discounted by other faculty members, had received little guidance about department procedures, and were ill informed about the tenure process. The Yale Women Faculty Forum has developed a specific exit survey and interview process (Box 3-6) that can serve as a model for others; the survey has led to the creation of specific professional development courses for postdoctoral scholars and junior faculty.

When asked why they left academic science and engineering, men overwhelmingly focus on low pay and the lack of career advancement, while women offered three main reasons: desire for more interesting work, lack of mentor or guidance, and difficulty shouldering family and career responsibilities. There is reason to believe that many women (and men) experience those discontents and do not leave the field, which can translate into lack of job satisfaction for more senior employees.

Departments vs. Centers

In light of the findings for faculty employed in university departments, it is interesting to note that participation in academic centers may offer different career opportunities for women scientists and engineers. In a nationally representative dataset on scientists and engineers working in research universities, Corley and Gaughan found that women were as likely as men to join centers and do so at a similar stage in their career. Most of the male-female differences observed in disciplinary settings, such as lower proportions of women in leadership positions, were sustained in centers, but women appeared to have greater research equality. Men and women in centers spend the same amount of time in writing grant proposals, conducting research, supervising graduate students, and administering grants. Corley and Gaughan suggest that centers may potentially serve as a leveling field for men and women academics, but much work remains to be done, particularly at the leadership level (Tables 4-3, 4-4, and 4-5). Women in centers are younger on the average and less likely to be tenured than their male colleagues. There are also fewer women of color in centers than in university departments.


One way to determine the reasons for leaving an academic position is simply to ask. To a certain degree, this is done in the longitudinal Survey of Doctoral Recipients, carried out by the National Science Foundation. However, institutions can gather more detailed information that can help modify existing policies or shape new initiatives focused on faculty retention. One such effort has been spearheaded by the Yale University Women Faculty Forum Task Force on Retention and Promotion of Junior Faculty. The Task Force designed an exit survey and distributed it to those tenure-track ladder faculty who departed in 2004 and 2005. There was a 43% response rate; the task force performed follow-up interviews with many of the respondents.

The task force collected basic demographic information, and asked respondents a series of questions about their employment plans, their experience at Yale, and for their rating of departmental environment. Among the survey questions were:

- Did you come to Yale with a partner or significant other who required employment or desired continuing education? To what extent was Yale helpful in finding an appropriate position for him/her?
- Over the past academic year, what percentage of your time was spent on: scholarship, teaching, advising, administrative, committee work, and professional activities outside Yale?
- Was this departure voluntary or involuntary? If voluntary did you seek a counter-offer?
- When you came to Yale, how did you rate your own chances of obtaining tenure?
- When you came to Yale, to what extent were the expectations you would need to meet to obtain tenure made clear to you?

ECONOMIC IMPACT OF FACULTY ATTRITION

Even while turnover has its benefits in terms of bringing in new talent and ideas, replacing faculty members who leave can represent a substantial cost to universities, so it is worthwhile to invest in policies and practices that encourage faculty retention. Start-up costs associated with hiring new professors are often high. In addition to the costs incurred by a recruitment committee, average start-up costs for a new professor range from about $110,000 for an assistant professor in physics at a public nonresearch university to nearly $1.5 million for a senior faculty member in engineering at a private research institution. The Task Force on Faculty Recruitment

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and Retention at UC-Boulder reports that in general, replacement costs are much greater than retention costs. It estimates that it costs $200,000-$400,000 to replace a natural sciences or engineering faculty member at a public research university, whereas “only a fraction of these costs would go a long way” in programs to help retain existing faculty. Tables 3-11 and 3-12 provide detailed listings of estimated start-up costs for new faculty hires.

Costs associated with hiring new faculty fall into several categories.

> In your opinion, did you receive adequate feedback on whether your performance was meeting expectations?
> • To what extent did your experience at Yale enhance your professional development?
> • To what extent did your experience provide resources to enhance your teaching skills?
> • Did you receive mentoring from faculty inside and/or outside your department? How satisfied are you with the quantity and quality of mentoring you received?
> • How do you think your overall experience at Yale compares with that of your graduate school peers who went on to work at other institutions?
> • In retrospect, was coming to Yale a good decision?

After collating the survey and interview responses, the task force met with the college and graduate school deans, provosts, and the director of the Office of Institutional Research (OIR). OIR provided statistics on tenure and promotion that previously were not readily available. Following this meeting, the Dean of the Graduate School asked all department chairs to report on their mentoring practices for junior faculty. Since then, Yale has instituted a new position, Deputy Provost for Science and Technology and Faculty Development, to oversee the implementation of a core curriculum for the professional development of postdoctoral scholars and junior faculty. The first series of courses are being developed for the 2006-2007 academic year.

> aP Kavathas, M LaFrance, and S Benhabib, Task Force on the Retention and Promotion of Junior Faculty, Yale Women Faculty Forum. For more information or the complete questionnaire contact WFF@yale.edu.
> bAll but six of the over 50 Faculty of Arts and Sciences departments provided names of departing faculty.

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University of Colorado at Boulder (2001), ibid.
There are costs associated with establishing search and recruitment committees and costs associated with relocation allowances, infrastructure, and support (for example, for laboratory renovations, offices, and equipment that might be required in support of new faculty). Those costs are included in the estimates discussed previously (and detailed in Tables 3-11 and 3-12). In addition, there is a substantial secondary cost associated with the loss of faculty and hiring of new faculty: that of research and grant productivity. In many cases, new faculty do not immediately bring the type of research-grant award support that productive, established faculty might. Callister reports that “it can take 10 years for a new faculty member in science or engineering to develop enough of a positive revenue stream from grants and to recoup start-up costs. If a faculty member leaves before start-up costs are recovered, the university loses money and must start over again.”

In monetary terms, that can be substantial. The UC-Boulder task force estimated that a productive faculty member “may bring about $100K per year” in external support to the university, external support that would take a new faculty member several years to generate.

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109 University of Colorado (2001), ibid.
### TABLE 3-12 Start-up Costs Associated with New Professors

<table>
<thead>
<tr>
<th></th>
<th>Private Research 1</th>
<th>Private Nonresearch 1</th>
<th>Public Research 1</th>
<th>Public Nonresearch 1</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Average (N)</td>
<td>Average (N)</td>
<td>Average (N)</td>
<td>Average (N)</td>
</tr>
<tr>
<td>AA Physics and astronomy</td>
<td>395,746 (9)</td>
<td>147,944 (18)</td>
<td>320,932 (42)</td>
<td>169,491 (56)</td>
</tr>
<tr>
<td>AA Biology</td>
<td>403,071 (14)</td>
<td>199,754 (26)</td>
<td>308,210 (38)</td>
<td>172,582 (55)</td>
</tr>
<tr>
<td>AA Chemistry</td>
<td>489,000 (20)</td>
<td>221,052 (29)</td>
<td>441,155 (43)</td>
<td>210,279 (71)</td>
</tr>
<tr>
<td>AA Engineering</td>
<td>390,237 (19)</td>
<td>152,101 (20)</td>
<td>213,735 (52)</td>
<td>118,875 (46)</td>
</tr>
<tr>
<td>HA Physics and astronomy</td>
<td>563,444 (9)</td>
<td>254,071 (14)</td>
<td>481,176 (41)</td>
<td>248,777 (47)</td>
</tr>
<tr>
<td>HA Biology</td>
<td>437,917 (12)</td>
<td>208,886 (22)</td>
<td>430,270 (37)</td>
<td>217,082 (49)</td>
</tr>
<tr>
<td>HA Chemistry</td>
<td>580,000 (17)</td>
<td>259,348 (23)</td>
<td>584,250 (40)</td>
<td>284,269 (60)</td>
</tr>
<tr>
<td>HA Engineering</td>
<td>416,875 (16)</td>
<td>209,057 (21)</td>
<td>259,494 (50)</td>
<td>146,831 (43)</td>
</tr>
<tr>
<td>AP Physics and astronomy</td>
<td>701,786 (7)</td>
<td>90,000 (2)</td>
<td>740,486 (29)</td>
<td>359,783 (23)</td>
</tr>
<tr>
<td>AP Biology</td>
<td>957,143 (7)</td>
<td>481,458 (12)</td>
<td>651,087 (23)</td>
<td>438,227 (31)</td>
</tr>
<tr>
<td>AP Chemistry</td>
<td>983,929 (14)</td>
<td>532,046 (11)</td>
<td>989,688 (32)</td>
<td>550,349 (33)</td>
</tr>
<tr>
<td>AP Engineering</td>
<td>1,441,667 (9)</td>
<td>326,694 (14)</td>
<td>408,443 (38)</td>
<td>223,292 (23)</td>
</tr>
<tr>
<td>HP Physics and astronomy</td>
<td>1,000,000 (4)</td>
<td>418,333 (3)</td>
<td>1,110,577 (24)</td>
<td>455,882 (17)</td>
</tr>
<tr>
<td>HP Biology</td>
<td>1,575,000 (5)</td>
<td>55,500 (10)</td>
<td>856,250 (16)</td>
<td>709,444 (27)</td>
</tr>
<tr>
<td>HP Chemistry</td>
<td>1,172,222 (9)</td>
<td>575,000 (8)</td>
<td>1,187,115 (26)</td>
<td>648,913 (23)</td>
</tr>
<tr>
<td>HP Engineering</td>
<td>1,807,143 (7)</td>
<td>452,000 (34)</td>
<td>472,086 (34)</td>
<td>254,597 (23)</td>
</tr>
</tbody>
</table>

**NOTES:** Responses were tabulated from the Cornell Institute of Higher Education Research Institute Survey of Start-Up Costs and Laboratory Space Allocation Rules that was mailed to 3-5 chairs of selected biological science, physical science, and engineering departments at each research and doctoral university during the summer of 2002. AA: average start-up costs for new assistant professors. HA: high-end start-up costs for new assistant professors. AP: average start-up costs for senior faculty. HP: high-end start-up costs for senior faculty.

Because science and engineering faculty incur costs continuously, some researchers have suggested that the aggregate costs required by new faculty (and not merely the initial start-up costs) should be considered in analyzing the cost of faculty turnover. Joiner\(^{110}\) has suggested an economic model for calculating the cost of turnover based on net present value (NPV). This model is commonly used in business to project the value of projects. It views faculty as long-term investments by considering all positive and negative cash flows for faculty members over time. Applying the model to faculty costs allows projections of the yearly costs of faculty salary, fringe and personal benefits, supplies and equipment, facility renovation, and other factors that are typically part of the costs accrued by universities in support of faculty (either new or existing). At the same time, the positive cash flows provided by a faculty member to the university (grant support, clinical revenues, and so on) are estimated. In concert, those two parts of the NPV model yield an estimate of the net cost (or financial yield) of a faculty member to a university.\(^{111}\)

Using the NPV model, one could estimate the length of time a faculty member must remain at an institution for the institution to see a financial return on its investment. From a strictly economic perspective, if a faculty member leaves an institution prematurely (before the NPV model shows a positive yield), the institution loses money. In essence the NPV model dictates that “a dollar today is worth more than a dollar tomorrow.”\(^{112}\) Existing faculty are likely to have a positive NPV, whereas new faculty are likely to show a negative net cost. Accordingly, this model suggests that it is in the best financial interest of the university to direct efforts at retaining faculty. Some effective retention practices are outlined in Box 3-7.

**CASE STUDY: CHEMISTRY\(^ {113}\)**

To examine the issue of faculty recruitment in more detail, the committee focused on chemistry, a field with a relatively high proportion of women PhDs. Information on the age, sex, and training of chemistry faculty members was obtained from the American Chemical Society’s 2001 DGR. The study was limited to faculties in the departments of chemistry, chemical biology, or chemical biology at 86 Research I institutions. Only


\(^{111}\)Joiner (2005), ibid.

\(^{112}\)Joiner (2005), ibid.

\(^{113}\)This section is based on research commissioned by the committee from Valerie J Kuck, Visiting Professor, Seton Hall University (Retired, Bell Labs).
EXPERIMENTS AND STRATEGIES

BOX 3-7 The University of Washington
Faculty Retention Toolkit

“Faculty retention is critical to the health of a university department both for morale reasons and also for economic reasons . . .”

Recognizing that, the University of Washington has developed a toolkit designed to assist department chairs in retaining faculty of all ranks. The toolkit contains nine specific measures that when applied together act to encourage faculty satisfaction and productivity. The measures are designed to be applied to all faculty in a department but are noted to be “particularly important to women and underutilized minorities.” The toolkit contains the following measures:

1. **Monitoring the health and welfare of departments.** Avoid disparities in workload, resources, salary, and recognition. Departments should provide regular state-of-the-department reviews, monitor faculty workload, and establish a process of individual faculty review meetings.

2. **Transparency in operations including fair and open promotion and tenure guidelines.** Encourage open communication in the tenure process. Committee members should rotate, and faculty should have access to the evaluation process.

3. **Creating a welcoming department climate.** Professional isolation is a common reason for faculty attrition. Encourage the development of a common department community, including social activities and professional recognition programs.

4. **Mentoring.** Mentoring can be used as a powerful tool for fostering a sense of community and for professional development, learning, and collaboration.

5. **Valuing diversity in the department.** Not all faculty fit the traditional view of a professor. Criteria of excellence should be expanded to include diverse approaches and values, such as involvement in outreach activities or nontraditional approaches to research.

6. **Supporting career development of pretenure faculty.** New and pretenure faculty are at the highest risk of attrition. Specific efforts should be made to support and retain new and pretenure faculty by providing recognition, mentoring, professional development opportunities, and balanced workloads.

7. **Encouraging midcareer professional development.** Professional development activities should continue for midcareer faculty. They include mentoring, professional recognition, and providing support to encourage creativity.

8. **Faculty development programs, benefits, and resources.** Provide ongoing development programs, such as workshops and seminars, to introduce new faculty to programs on campus and renew and reinvigorate existing faculty.

9. **Flexible and accommodating policies and practices.** Flexible family leave policies, dual career partner hiring programs, and transition support programs can play important roles in faculty productivity and retention.

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data on persons holding the rank of assistant, associate, or full professor were ascertained. Persons for whom there was no biographical information on training or rank were excluded from the study.\textsuperscript{114} The hiring data clearly show that chemistry faculty who have done their graduate work at Research I universities are overwhelmingly preferred; in addition, women faculty are drawn from a smaller pool of institutions than men.

Of the 2,476 faculty members at the Research I institutions, 10.5\% were female (Table 3-13). 12.3\% of the faculty members earned their doctorates at a non-US institution; of these 6.9\% were women—a smaller fraction than they were of all the faculty members. The top foreign institutions training the greatest number of future faculty members were Cambridge University, University College of London, and Oxford University.

The median and average age of men faculty members were 49 years and $50 \pm 11.8$ years, respectively. The women faculty members were on average younger, with a median age of 42 years and an average age of $44 \pm 9.2$ years. It should be noted that a number of individuals did not give their date of birth (20 men and 11 females); therefore, they could not be included in these calculations.

Since 1981 there has been an increase in the hiring/retention of women. A comparison of the number of men and women faculty members who received their doctorates during the same years indicates that the growth in the number of women faculty members has mirrored that of men who received their doctorate in the same time interval (Figure 3-7).

In 2001, women held 18.3\% of the positions at the rank of assistant professor and 17.9\% of associate professor (Table 3-14) at Research I universities. A much lower percentage, 6.4\%, of the full professor positions were held by women.

Less than 4\% of chemistry doctorates were found to hold faculty

\begin{table}[h]
\centering
\begin{tabular}{lll}
\hline
 & Total & Men & Women \\
\hline
All & 2,476 & 2,218 & 261 (10.5\%) \\
Foreign PhD & 305 & 284 & 21 (6.9\%) \\
\hline
\end{tabular}
\caption{2001 Chemistry Faculty Members, by Country of Doctorate}
\end{table}

\textsuperscript{114}The DGR contained the names of about 20 faculty members with no other information on their training or rank.
positions at Research I institutions. With the exception of the years 1971-1975, a higher percentage of men than women who earned chemistry PhDs ever were employed on Research I university faculties (Table 3-15). It appears that after all the efforts to increase the diversity of faculties, women with doctorates are still lagging behind men in attaining faculty positions at Research I institutions.

There is a strong preference by Research I chemistry departments to hire graduates from a small subset of universities. Ten of the top 11 institutions were common to both men and women faculty (Table 3-16). Eleven

![Comparison of the number of men and women chemistry faculty members at RI institutions.](source)

**TABLE 3-14 Chemistry Faculty, by Sex and Rank, 2001**

<table>
<thead>
<tr>
<th>Rank</th>
<th>Total</th>
<th>Men</th>
<th>Women</th>
</tr>
</thead>
<tbody>
<tr>
<td>Assistant professor</td>
<td>464</td>
<td>379</td>
<td>85 (18.3%)</td>
</tr>
<tr>
<td>Associate professor</td>
<td>408</td>
<td>335</td>
<td>73 (17.9%)</td>
</tr>
<tr>
<td>Full professor</td>
<td>1,605</td>
<td>1,502</td>
<td>103 (6.4%)</td>
</tr>
</tbody>
</table>

departments graduated 54.6% of the US-trained men future RI faculty; Harvard University and the University of California, Berkeley, trained by far the most. For women, 11 departments graduated 51.7% of the US-trained women future RI faculty members, and Berkeley trained by far the most.

During the years 1988-1997, women received 26.4% of the doctorates in chemistry. A lower proportion of women doctorates obtained faculty positions at Research I institutions than did men doctorates (Table 3-17). Of those Research I universities that hired more than 5 faculty, 4 hired above the pool, 7 hired at about the pool, and 19 hired substantially below the available pool of women chemistry PhD graduates.

Programs designed to increase the representation of women chemistry faculty need to take into account cuts in the number of full-time faculty slots at doctorate-granting institutions, as demonstrated by the larger proportion but smaller number of women faculty (Table 3-18). This shrinkage of the tenure track is a general phenomenon. The academic employment of

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TABLE 3-15 Proportion of Chemistry Doctorates Who Obtain Chemistry Faculty Positions at Research I Institutions, by Sex and Year of PhD

<table>
<thead>
<tr>
<th>Years</th>
<th>Chemistry PhDs Granted</th>
<th>Chemistry PhDs Who Obtain an R1 Faculty Position</th>
</tr>
</thead>
<tbody>
<tr>
<td>Women</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1966-70</td>
<td>686</td>
<td>14 (2.0%)</td>
</tr>
<tr>
<td>1971-75</td>
<td>928</td>
<td>28 (3.0%)</td>
</tr>
<tr>
<td>1976-80</td>
<td>1,038</td>
<td>8 (0.8%)</td>
</tr>
<tr>
<td>1981-85</td>
<td>1,488</td>
<td>47 (3.2%)</td>
</tr>
<tr>
<td>1986-90</td>
<td>2,231</td>
<td>54 (2.4%)</td>
</tr>
<tr>
<td>1991-95</td>
<td>2,964</td>
<td>50 (1.7%)</td>
</tr>
<tr>
<td>1996-99</td>
<td>2,545</td>
<td>31 (1.2%)</td>
</tr>
<tr>
<td>Men</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1966-70</td>
<td>8,689</td>
<td>278 (3.2%)</td>
</tr>
<tr>
<td>1971-75</td>
<td>8,730</td>
<td>214 (2.5%)</td>
</tr>
<tr>
<td>1976-80</td>
<td>6,805</td>
<td>195 (2.9%)</td>
</tr>
<tr>
<td>1981-85</td>
<td>7,163</td>
<td>244 (3.4%)</td>
</tr>
<tr>
<td>1986-90</td>
<td>7,732</td>
<td>233 (3.0%)</td>
</tr>
<tr>
<td>1991-95</td>
<td>7,931</td>
<td>226 (2.8%)</td>
</tr>
<tr>
<td>1996-99</td>
<td>7,412</td>
<td>135 (1.8%)</td>
</tr>
</tbody>
</table>

EXAMINING PERSISTENCE AND ATTRITION

TABLE 3-16 Institutions Training the Greatest Number of Chemistry Faculty at Research I Institutions, by Sex and Year of PhD

<table>
<thead>
<tr>
<th>Institution</th>
<th>Men Faculty Members</th>
<th>Women Faculty Members</th>
</tr>
</thead>
<tbody>
<tr>
<td>Harvard</td>
<td>179</td>
<td>Berkeley</td>
</tr>
<tr>
<td>Berkeley</td>
<td>175</td>
<td>California Institute</td>
</tr>
<tr>
<td>MIT</td>
<td>123</td>
<td>of Technology</td>
</tr>
<tr>
<td>California Institute of Technology</td>
<td>96</td>
<td>Harvard</td>
</tr>
<tr>
<td>Stanford</td>
<td>82</td>
<td>Cornell</td>
</tr>
<tr>
<td>University of Illinois, Urbana-Champaign</td>
<td>75</td>
<td>University of Illinois, Urbana-Champaign</td>
</tr>
<tr>
<td>Columbia</td>
<td>68</td>
<td>UCLA</td>
</tr>
<tr>
<td>Chicago</td>
<td>62</td>
<td>Stanford</td>
</tr>
<tr>
<td>Yale</td>
<td>52</td>
<td>Columbia</td>
</tr>
<tr>
<td>Cornell</td>
<td>51</td>
<td>Chicago</td>
</tr>
<tr>
<td>Total</td>
<td>1,055</td>
<td>Total: 124</td>
</tr>
</tbody>
</table>

- a54.6% of US-trained male faculty members.
- b51.7% of US-trained female faculty members.
- cNumber of PhDs trained at institution who subsequently hold faculty position at RI institution.


Science and engineering PhDs increased from 118,000 in 1973 to 258,300 in 2003, full-time faculty positions grew more slowly than postdoctoral and other full- and part-time positions, and growth was slower than in the government and business sectors.115

CONCLUSION

Individual efforts can have dramatic effects but sustained change is unlikely unless there is a transformation of the process by which students and faculty are educated, trained, recruited, and retained. To increase the numbers of women in science and engineering education and academic careers, policy action should focus on specific lever points: the transition to

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### TABLE 3-17 Number of Faculty Hired at Selected Research I Institutions, by Sex, 1988-1997

<table>
<thead>
<tr>
<th>Hiring Institution</th>
<th>Number of Faculty Hired</th>
<th>Men</th>
<th>Women</th>
<th>Total</th>
<th>% Women</th>
</tr>
</thead>
<tbody>
<tr>
<td>University of California, Berkeley</td>
<td></td>
<td>49</td>
<td>19</td>
<td>68</td>
<td>27.9</td>
</tr>
<tr>
<td>Harvard University</td>
<td></td>
<td>32</td>
<td>3</td>
<td>35</td>
<td>8.6</td>
</tr>
<tr>
<td>California Institute of Technology</td>
<td></td>
<td>27</td>
<td>6</td>
<td>33</td>
<td>18.2</td>
</tr>
<tr>
<td>MIT</td>
<td></td>
<td>25</td>
<td>0</td>
<td>25</td>
<td>0.0</td>
</tr>
<tr>
<td>Stanford University</td>
<td></td>
<td>23</td>
<td>5</td>
<td>28</td>
<td>17.9</td>
</tr>
<tr>
<td>University of Wisconsin, Madison</td>
<td></td>
<td>19</td>
<td>2</td>
<td>21</td>
<td>9.5</td>
</tr>
<tr>
<td>University of Illinois, Urbana-Champaign</td>
<td></td>
<td>18</td>
<td>2</td>
<td>20</td>
<td>10.0</td>
</tr>
<tr>
<td>Yale University</td>
<td></td>
<td>15</td>
<td>5</td>
<td>20</td>
<td>25.0</td>
</tr>
<tr>
<td>University of California, Los Angeles</td>
<td></td>
<td>13</td>
<td>4</td>
<td>17</td>
<td>23.5</td>
</tr>
<tr>
<td>University of Chicago</td>
<td></td>
<td>12</td>
<td>4</td>
<td>16</td>
<td>25.0</td>
</tr>
<tr>
<td>Columbia University</td>
<td></td>
<td>12</td>
<td>1</td>
<td>13</td>
<td>7.7</td>
</tr>
<tr>
<td>Cornell University</td>
<td></td>
<td>12</td>
<td>6</td>
<td>18</td>
<td>33.3</td>
</tr>
<tr>
<td>North Carolina State University</td>
<td></td>
<td>10</td>
<td>2</td>
<td>12</td>
<td>16.7</td>
</tr>
<tr>
<td>University of Texas, Austin</td>
<td></td>
<td>10</td>
<td>0</td>
<td>10</td>
<td>0.0</td>
</tr>
<tr>
<td>Northwestern University</td>
<td></td>
<td>8</td>
<td>1</td>
<td>9</td>
<td>11.1</td>
</tr>
<tr>
<td>University of Pennsylvania</td>
<td></td>
<td>8</td>
<td>0</td>
<td>8</td>
<td>0.0</td>
</tr>
<tr>
<td>University of Arizona</td>
<td></td>
<td>7</td>
<td>0</td>
<td>7</td>
<td>0.0</td>
</tr>
<tr>
<td>University of Michigan, Ann Arbor</td>
<td></td>
<td>7</td>
<td>1</td>
<td>8</td>
<td>12.5</td>
</tr>
<tr>
<td>University of Minnesota</td>
<td></td>
<td>7</td>
<td>2</td>
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<td>1</td>
<td>6</td>
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</tr>
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<td>2</td>
<td>6</td>
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<tr>
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<td>3</td>
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<td>1</td>
<td>5</td>
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<td>Texas A&amp;M University</td>
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<td>1</td>
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<td></td>
<td>3</td>
<td>2</td>
<td>5</td>
<td>40.0</td>
</tr>
</tbody>
</table>

*aOnly Research I universities that produced more than 5 faculty members are included.


...college, graduate school faculty interactions, application and recruitment to faculty positions, and retention of faculty.

Increasing the number of women and underrepresented minority-group faculty substantially will require assistance from faculty, individual departments, and schools; oversight and leadership from provosts and presidents; and sustained normative pressure, possibly from external sources. As dis-
<table>
<thead>
<tr>
<th></th>
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<td>Full professor</td>
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<td>3.1</td>
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<td>557</td>
<td>563</td>
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<td>30.6</td>
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<td>0.0</td>
<td>23.5</td>
<td>10.0</td>
<td>0.0</td>
<td>11</td>
<td>7</td>
<td>17</td>
<td>13</td>
<td>3</td>
<td></td>
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<tr>
<td>Total</td>
<td></td>
<td>8.3</td>
<td>12.8</td>
<td>15.9</td>
<td>18.5</td>
<td>18.7</td>
<td>3,058</td>
<td>3,744</td>
<td>4,842</td>
<td>4,270</td>
<td>2,844</td>
<td></td>
</tr>
</tbody>
</table>

NOTE: N/A indicates data not available.

cussed in the previous chapter, the first step is to understand that women are as capable as men of contributing to the science and engineering enterprise. As discussed in the next chapter, the science and engineering community needs to come to terms with the biases and structures that impede women from realizing their potential. The data show that policy changes are sustainable only if they create a “new normal,” a new way of doing things. The community needs to work together, across departments, through professional societies, and with funders and federal agencies, to bring about gender equity so that our nation can perform at its full potential.
CHAPTER HIGHLIGHTS

Progress in academic careers depends on evaluations of one’s accomplishments by those more senior in a process widely believed to be objective. Research shows, however, that bias negatively affects the evaluations and judgments made about women scientists and engineers and their work. Women consequently are not only underrepresented in numerous science and engineering fields, but are also likely to work in less prestigious institutions than men, to hold lower rank, to take longer to be promoted and tenured, to win fewer awards and honors, and to be named less often to positions of leadership in their institutions and disciplines.

One of the key factors in career advancement is productivity, as measured by the number of published papers that carry the faculty member’s name. Women scientists and engineers have long been considered less productive than men because they published fewer papers. Evidence shows, however, that productivity is not an independent characteristic of individuals but rather a reflection of their positions in the academic hierarchy and the access to resources that those positions make possible. When academic position, available resources, type of institution, and other personal and institutional factors are held constant, men and women scientists and engineers are equally productive. Other evidence indicates that women’s publications have greater average impact than men’s.
Many people believe that discrimination involves explicit, blatant hostility, but current bias against women scientists and engineers is often subtle, implicit, and unexamined. Under prevailing gender schemas, competent women are often viewed as “overaggressive” and “not nice” whereas traditionally subservient women are seen as “incompetent.” In addition, organizational rules and policies that appear egalitarian often produce different results for men and women. The playing field is not level. Women and minority groups make up an increasing proportion of the labor force. They also are an increasing proportion of the pool of students from which universities can recruit faculty. To capture and capitalize on this talent, policies adopted when the workplace was more homogeneous need to be changed to create organizational structures that manage diversity effectively. Equity efforts need to address the systemic changes required to build and sustain educational, research, and workplace environments that promote effective participation in an increasingly pluralistic society.

FINDINGS

4.1 Throughout a scientific or engineering career, advancement depends on judgments of one’s performance by more senior scientists and engineers. A substantial body of research shows these judgments contain arbitrary and subjective components that disadvantage women. The criteria underlying the judgments developed over many decades when women scientists and engineers were a tiny and often marginal presence and men were considered the norm.

4.2 Gender bias—often unexamined, and held and acted on by people of both sexes who believe themselves unbiased—has affected many women scientists’ chances of career progress. Minority-group women face the double bind of racial and gender bias.

4.3 Incidents of bias against individuals not in the majority group tend to have accumulated effects. Small preferences for the majority group can accumulate and create large differences in prestige, power, and position. In academic science and engineering, the advantages have accrued to white men and have translated into larger salaries, faster promotions, and more publications and honors relative to women.

4.4 Women have the qualities needed to succeed in academic careers and do so more readily when given an equal opportunity to achieve. For example, publication productivity is one of the most important factors by which scientists are evaluated for hiring, promotion, and
tenure. Women scientists’ publication productivity has increased over the last 30 years and now matches men’s. The critical factor affecting publication productivity is access to institutional resources; marriage, children, and elder-care responsibilities have minimal effects.

4.5 Career impediments based on gender or racial or ethnic bias deprive the nation of an important source of talented and accomplished researchers.

RECOMMENDATIONS

4.1 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.

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

4.3 Deans, department chairs, and their tenured faculty should take the 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.

4.4 Faculties and their Senates should initiate a full faculty discussion of climate issues.

4.5 Universities should provide management and leadership training for deans, department heads, search committee chairs, and other faculty with personnel management responsibilities; they should also provide management training to new faculty as part of a professional development core.

4.6 University leaders should, as part of their mandatory 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.

4.7 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.

4.8 Scientific and professional societies should provide professional development training for members that includes a component on bias in evaluation; develop and enforce guidelines to ensure significant representation of women on meeting speaker lists, on editorial boards, and in other significant leadership positions; and 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.

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

4.10 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.

4.11 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.

4.12 Federal funding agencies should collect, store, and publish composite information on demographics, field, award type and budget request, review score, and funding outcome for all funding applications.

4.13 Funding organizations should expand support for research on the efficacy of organizational programs designed to reduce gender bias, and for research on bias, prejudice, stereotype threat, and the role of leadership in achieving gender equity.

To build a successful academic career, a scientist or engineer must succeed—and be seen by colleagues and superiors to have succeeded—at
each of a number of increasingly demanding stages of development. Judgments of performance are widely thought to be objective, but a substantial body of research shows that they are significantly affected by biases.

The effect of any specific instance of bias may not in itself be large—receiving a somewhat lower evaluation or a less enthusiastic recommendation than would be true in the absence of bias, not being invited to chair a session at a meeting, or being excluded from conversations in a friendship network.

Such instances of bias would not prevent a person from doing research or pursuing a career. A growing body of evidence shows, however, that such incidents of bias tend to accumulate. In a highly competitive field in which reputation and influence are crucial aspects of professional standing, small preferences can accumulate into large differences in prestige, power, and position (Box 1-4). In academic science and engineering, the advantages accrued to white men have translated into increased salaries, faster promotions, and more publications and honors relative to women.

BUILDING A CAREER

A career has four interlocking dimensions: education, position, productivity, and recognition. Whether a given scientist or engineer succeeds in building such a career depends on a number of factors, some personal and some institutional—as well as luck or happenstance. Does he or she possess the qualities of intellect, character, and personality needed to succeed when there is high-stakes competition? Does he or she work on research questions that produce results worthy of publication and citation? Does he or she succeed in obtaining adequate funding to carry out research? Does he or she develop relationships that help to advance the research and the career? Do the institutions where he or she was educated and trained and where he or she attempts to establish and further a career provide advantages or impose disadvantages that make success more or less likely?

Productivity

College and university faculty members fulfill three main functions: teaching, research, and service in various capacities, such as committee members or department officials involved in running the institution. For purposes of hiring and advancement to higher rank, however, research productivity—defined as authorship of peer-reviewed publications—is

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weighed most heavily, even though efforts have been made to expand the definition of scholarship to include teaching, the integration of knowledge, grants awarded, and applications of research in addition to original discoveries.

Publications, particularly those in high-prestige journals or conference proceedings, carry the greatest weight. That is true regardless of whether the responsibilities of the faculty member’s position actually involve doing research or instead focus on administration, teaching, or service. Faculty productivity measured by quantity of publications has also been shown to correlate with stamina and opportunity but not with creativity or measured intelligence. And studies show that teaching and research have opposite relationships to publication productivity: increased time commitments to teaching are associated with decreased publication productivity.

Observers have argued that emphasis on number of publications over-values the work of men scientists and engineers at the expense of women because of the unequal allocation of tasks that characterizes academic life. Women, on average, devote more time than men to teaching and service, while men, on average, devote more time than women to research. Recent evidence from faculty surveys indicates that more women than men faculty feel that mentoring as a service activity is undervalued by their department (Figure 4-1). Some have suggested that discrepancy reflects value differences between the sexes, namely that women give greater emphasis to such nurturing activities as teaching and advising students and men give greater emphasis to competition. Others argue that the discrepancy reflects the fact that women generally have less power and less opportunity to obtain positions at research universities, where support systems and resources clearly increase faculty productivity.
Especially during the probationary years, graduate students, postdoctoral scholars, and assistant professors feel intense pressure to prove that they are not only productive, but serious about their science and engineering careers. They often spend very long hours at their work and try to show a total commitment to an academic career. “By its nature, academic work is potentially boundless: there is always one more question to answer; one more problem to solve; one more piece to read, to write, to see, or to create.” 9 In addition, for scientists or engineers working on federal grants, the granting agencies impose time accounting requirements. 10

FIGURE 4-1 Individual and perceived institutional value of student mentoring, by rank and sex.

NOTE: The survey asked faculty to rate whether they valued mentoring more, the same, or less than they perceived their department valued mentoring.


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Some have suggested that a postdoctoral fellow intent upon a research career should be spending 60-80 hours per week in the laboratory and clinical fellows 80-120 hours per week. The National Science Foundation (NSF) has determined the average workweek for science and engineering faculty to be 50.6 hours per week. At one research university, faculty with and without children reported engaging in professional work 51-60 hours per week, but women faculty with children spend substantially more time than men faculty with children on household and child-care responsibilities (Figure 4-2). Those findings mirror what is seen in a national sample of science and engineering doctorates. Men engage in professional work an average of 0.7 hour per week more than women, but the difference was associated with having children living in the household. Men and women without children reported working 49 hours per week, and women with children—but not men with children—reported working 46 hours per week.

Those statistics belie the nature of work for a scientist or engineer, whose productivity does not depend solely on total hours logged in the laboratory. Indeed, other sorts of work—including reading literature, going to meetings, and discussions with colleagues—may occur off site but are no less important. For persons with major caregiving responsibilities, particularly the care of children or other dependent family members, the limitless time demands of a competitive academic career present a major challenge. The great majority of those bearing caregiving responsibilities are women, and their effort in their family responsibilities does not count as “work” in the academic schema, but rather as a distraction from work.

11S Kern (2002). Fellowship Goals for PhDs and MDs: A primer on the molecular biology postdoctoral experience. Cancer Biology and Therapy 1:74-85. Kern notes the total hours include research and reading; he also notes that the routine 80-120 hours in clinical training “may be incompatible with a researcher’s need for creativity and precision.”


14Hoffer and Grigorian (2005), ibid.
The “ideal worker” is someone whose commitment to work is unlimited by child bearing or rearing—i.e., a man. Success in academia today continues to be aligned with traditional masculine stereotypes of autonomy, competitiveness and heroic individualism. The ‘ideal worker’ is someone for whom work is primary, the demands of family, community, and personal life secondary, and time to work unlimited.

—Ellen Ostrow, clinical psychologist and founder of Lawyers Life Coach

### Sex Differences in Publication Productivity

Why is publication productivity important? It is through publications that research results are communicated and verified. Publication productivity is both the cause and the effect of status in science and engineering.

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Several researchers have shown that publication productivity reflects and partially accounts for the depressed rank in status of women in science and engineering.\textsuperscript{16} However, this assumes that it is the number of papers that is important and does not account for differences in the impact of papers.

In decades past, data have shown an apparent gender gap in the numbers of papers published by men and women faculty. In a study of scientists who received PhDs in 1969-1970, Cole and Zuckerman estimated that, on average, women published slightly more than half (57\%) as many papers as men.\textsuperscript{17} Little information is available on publication rates for minority-group scientists.\textsuperscript{18}

The root of the difference in publication productivity is an essential question. Several studies have examined the effect of family-related factors. Although more women than men leave academe because of family responsibilities, research on the effects of marriage, children, or elder-care responsibilities has yielded mixed results.\textsuperscript{19} The critical variable appears to be access to resources. A recent longitudinal analysis by Xie and Shauman of faculty in postsecondary institutions in 1969, 1973, 1988, and 1993 shows that the sex difference in research productivity has declined—from a female: male ratio of 0.580:1 in 1969 to 0.817:1 in 1993. In that period, the primary factor affecting women scientists’ research productivity was their overall structural position, such as institutional affiliation and rank. When type of institution, teaching load, funding level, and research assistance are factored in, the productivity gap disappears.\textsuperscript{20}


\textsuperscript{19}Reviewed in LJ Sax, S Hagedorn, M Arredondo, and FA Dicrisi (2002), ibid.

Another analysis provides a clear illustration of the correlation between productivity, institutional affiliation, and rank. Overall, men academic scientists and engineers produced 30% more publications than women academic scientists and engineers, but when men at Research I universities were compared with women at the same type of institution, the productivity gap fell to 25%. Women were much more likely to be in non-tenure-track posts than men, and comparing only scientists and engineers who held faculty positions reduced the productivity gap to 13%. Focusing on tenured faculty members found tenured men with only 8% more publications than their women tenured colleagues. The difference in publication productivity between men and women who are full professors of science or engineering at the Research I institutions was under 5%.

The effect of a scientist’s institutional affiliation on his or her productivity is so great that the prestige of the department or university has been found to affect scientists’ productivity, rather than the other way around. Prestige serves as a symbolic stand-in for an array of characteristics that can foster or hamper productivity, including financial, physical, and staff resources and intellectual environment. Evidence shows that when scientists move to more prestigious institutions, their productivity increases.

Another essential question is whether number of papers is the appropriate metric of productivity. In a study of biochemists, Long found that articles by women received, on average, more citations than articles with men primary authors. Some have argued that both quantitative and qualitative measures of productivity should be taken into account in making important decisions about a scientist’s career. Indeed, recent metrics have been developed to measure citations of an article—its “impact factor”—as well as the prestige of the journal in which it is published.

Recognition

Another indicator of scientific productivity, and one especially germane to career advancement, is recognition in the field. Being invited to

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24 Sonnert and Holton (1996), ibid.
speak at major professional society meetings is one type of recognition, but women are not well represented among symposium speakers and keynotes (Box 4-1).

Recognition of lifetime achievement by election to a high-prestige honorific society is a cherished honor. However, the numbers of women elected to such societies as the National Academy of Sciences, the National Academy of Engineering, the Institute of Medicine, the American Academy of Arts and Sciences, and the American Philosophical Society, or awarded such prestigious honors as the Lasker Prize or the National Medal of Science have been small (Table 4-1).

Some organizations point to the low numbers of women who are “eligible” for honors and awards; to a first approximation, the nomination pool for lifetime achievement honors, such as election to an honorific society, is the cohort who received PhDs about 30 years ago. Indeed, the representation of women in that cohort is quite small. Recent classes of electees, however, have included younger people, and not all societies elect solely PhD recipients. A recent report from the InterAcademy Council (IAC) concludes that the disproportionately small number of women in the science and technology enterprise, particularly in leadership positions, is a major hindrance to strengthening science capacity worldwide.26 The IAC called upon all academies to address the underrepresentation of women in their memberships, in particular by implementing internal management practices that encourage and support women, and by influencing policy makers and other leaders to bring about broader change.

As with the tenure-track applicant pool (see Chapter 3), the nominee pool for honors and awards likely underrepresents the available pool of excellent women researchers. A case in point is the recent experience with the Pioneer Awards offered by the National Institutes of Health (NIH) (Box 4-2). In its first year, not only did the new program designed for early-career researchers not select any women, but all the awardees were well established and in middle to late career. In response to community concern, NIH took the time and energy to diagnose the problem, and found that several small changes in the program announcement and attention to the selection process changed the outcome greatly in the program’s second year.

One issue brought to the fore by the Pioneer Award was the difference in the number of women who self-nominated as opposed to those who were nominated by mentors or peers. It appears, as with hiring, that relying on

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established networks can lead to underrepresentation of women in the nominee pool.\textsuperscript{27} One organization, the Committee on the Advancement of Women Chemists (COACh), is working with professional societies to ensure that qualified women are nominated for awards and leadership positions (Box 4-3).

**LEADERSHIP POSITIONS**

Women, especially minority-group women, are underrepresented in science and engineering faculties at all levels.\textsuperscript{28} The dearth of women is even more pronounced in the upper tiers of the academy. In addition to being outnumbered, women have lower salaries,\textsuperscript{29} are awarded less grant money,\textsuperscript{30} and perceive the scientific workplace as unwelcoming and even hostile.\textsuperscript{31} Few women are chief editors of top-rated journals and their representation varies substantially by field (Table 4-2). Even a cursory glance at most organization charts in research organizations shows that women are underrepresented, not only in senior faculty positions but also in leadership positions. According to a recent study of academic medical

\textsuperscript{27} Networks have also been shown to affect decisions to publish; as gender balance improves within a field, network access changes, and the representation of women as authors also improves. See JM McDowell, LD Singell, and M Stater (2006). Two to tango? Gender differences in the decisions to publish and coauthor. *Economic Inquiry* 44(1):153-168.


EXPERIMENTS AND STRATEGIES

BOX 4-1 Speaker Representation at Scientific and Professional Society Meetings

The invitation to speak at a professional or academic society conference is one of the key benchmarks of a successful academic career. To ensure the proper recognition and advancement of women scholars in science and engineering, it is essential that the process for inviting conference speakers be absent of gender bias. Invited and distinguished conference speakers are usually selected by program committees and the speaker nomination process often fails to ensure adequate gender representation. Program committees lacking gender diversity tend to result in a lack of diversity among invited speakers. The common practice of program committee members nominating themselves as invited speakers augments this effect.

Table B4-1 presents data on the percentage of invited speakers to speak at prestigious symposia at professional and scientific society conferences who were women in a number of disciplines. It has proven challenging to ensure that speakers at society-sponsored events reflect the diverse membership of the society with respect to appropriate representation by gender.

<table>
<thead>
<tr>
<th>Conference (2004-2005)</th>
<th>% of Invited Speakers Who Were Women</th>
<th>Total Number of Invited Speakers</th>
</tr>
</thead>
<tbody>
<tr>
<td>American Association for Artificial Intelligence (AAAI)</td>
<td>17</td>
<td>12</td>
</tr>
<tr>
<td>American Chemical Society (ACS)</td>
<td>18</td>
<td>174</td>
</tr>
<tr>
<td>American Society for Cell Biology (ASCB)</td>
<td>36</td>
<td>22</td>
</tr>
<tr>
<td>American Society of Mechanical Engineers (ASME)</td>
<td>6</td>
<td>17</td>
</tr>
<tr>
<td>International Conference on Computer Graphics and Interactive Techniques</td>
<td>17</td>
<td>78</td>
</tr>
<tr>
<td>Oceanic Engineering Society Meeting</td>
<td>4</td>
<td>72</td>
</tr>
<tr>
<td>Federation of Clinical Immunological Societies (FOCIS)</td>
<td>22</td>
<td>480</td>
</tr>
<tr>
<td>Society for Neuroscience (SFN)</td>
<td>9</td>
<td>11</td>
</tr>
</tbody>
</table>


Some societies have implemented speaker selection criteria to mandate that those who propose symposia specifically consider diversity of suggested speakers. At the American Society for Cell Biology (ASCB) 45th Annual Meeting, 36% of the invited speakers were women, which is an appropriate reflection of the nearly
40% of women professors in biological sciences. ASCB employs the following speaker selection guidelines:

- Invite co-organizers who look different than you do.
- Actively seek suggestions for speakers.
- Scan programs of past meetings in different, but related, fields.
- Avoid the usual suspects (avoid the cadre of major figures who speak multiple times and “[fly] in just for the talk”).
- Adjust your tentative program to ensure diversity.

The Federation of Clinical Immunological Societies (FOCIS) has gone one step further and reformed the way in which invited speakers are selected. For mini-symposium speakers at their 12th annual International Congress of Immunology (participants were from 86 countries, and about half were women), FOCIS instituted an abstract review process that was blinded as to author and institution. This resulted in 48% of 976 oral presenters being women. For speakers and chairs, the program committee used research excellence and publication impact criteria for speaker selection. Twenty-two percent of the 480 invited speakers were women, a substantial increase from the previous year, when only 10% of the invited speakers were women.

Other organizations that sponsor and organize scientific conferences instruct and encourage conference planners to include appropriate gender representation among invited speakers and planning committees. The NIH encourages a “concerted effort to achieve appropriate representation of women” as conference organizers, speakers, and attendees for all meetings it sponsors.

Gordon Research Conferences and Keystone Symposia sponsor topically focused interdisciplinary research symposia with a small number of participants to foster discussion and collaboration. Both organizations instruct conference organizers to represent the gender diversity of the discipline when inviting conference speakers.

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10 Prestigious symposia include plenary sessions, keynote addresses, panels, named lectures, and award symposia.
11 All conferences except FOCIS were held in 2005.
12 Data from 2005 International Mechanical Engineering Congress and Exhibition.
13 Association for Computing Machinery (ACM) conference of 2005 with highest attendance (~29,000).
14 Institute of Electrical and Electronics Engineers (IEEE) conference of 2005 with highest attendance (~50,000).
15 Data from 12th International Congress of Immunology.
16 Forsburg (2004), ibid.
### TABLE 4-1 Percentage of Women Nominated to an Honorific Society or for a Prestigious Award and the Percentage of Women Nominees Elected or Awarded, 1996-2005

<table>
<thead>
<tr>
<th>Society</th>
<th>% Nominated</th>
<th>% Elected</th>
</tr>
</thead>
<tbody>
<tr>
<td>American Philosophical Society&lt;sup&gt;a&lt;/sup&gt;</td>
<td>14.6</td>
<td>23.7</td>
</tr>
<tr>
<td>Mathematical and physical sciences</td>
<td>19.0</td>
<td>24.0</td>
</tr>
<tr>
<td>Biological sciences</td>
<td>11.5</td>
<td>23.3</td>
</tr>
<tr>
<td>American Academy of Arts and Sciences</td>
<td>N/A</td>
<td>15.8</td>
</tr>
<tr>
<td>Mathematical and physical sciences</td>
<td>N/A</td>
<td>11.6</td>
</tr>
<tr>
<td>Biological sciences</td>
<td>N/A</td>
<td>20.0</td>
</tr>
<tr>
<td>Institute of Medicine&lt;sup&gt;b&lt;/sup&gt;</td>
<td>19.2</td>
<td>22.7</td>
</tr>
<tr>
<td>National Academy of Engineering</td>
<td>5.3</td>
<td>6.0</td>
</tr>
<tr>
<td>Aerospace engineering</td>
<td>3.1</td>
<td>7.1</td>
</tr>
<tr>
<td>Bioengineering</td>
<td>6.9</td>
<td>4.6</td>
</tr>
<tr>
<td>Chemical engineering</td>
<td>5.9</td>
<td>5.2</td>
</tr>
<tr>
<td>Civil engineering</td>
<td>4.1</td>
<td>2.4</td>
</tr>
<tr>
<td>Computer science and engineering</td>
<td>11.9</td>
<td>8.6</td>
</tr>
<tr>
<td>Electric power and energy systems engineering</td>
<td>3.1</td>
<td>2.3</td>
</tr>
<tr>
<td>Electronics engineering</td>
<td>2.8</td>
<td>3.7</td>
</tr>
<tr>
<td>Industrial manufacturing and operations systems engineering</td>
<td>4.9</td>
<td>4.3</td>
</tr>
<tr>
<td>Materials engineering</td>
<td>5.7</td>
<td>7.8</td>
</tr>
<tr>
<td>Mechanical engineering</td>
<td>2.5</td>
<td>5.6</td>
</tr>
<tr>
<td>Petroleum mining and geological engineering</td>
<td>9.5</td>
<td>8.7</td>
</tr>
<tr>
<td>Special fields and interdisciplinary engineering</td>
<td>5.7</td>
<td>6.3</td>
</tr>
<tr>
<td>National Academy of Sciences</td>
<td>12.5</td>
<td>15.6</td>
</tr>
</tbody>
</table>

### Award

<table>
<thead>
<tr>
<th>Award</th>
<th>% Nominated</th>
<th>% Elected</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lasker Prize</td>
<td>6.1</td>
<td>4.0</td>
</tr>
<tr>
<td>National Medal of Science&lt;sup&gt;c&lt;/sup&gt;</td>
<td>N/A</td>
<td>12.0</td>
</tr>
<tr>
<td>Behavioral and social science</td>
<td>N/A</td>
<td>0</td>
</tr>
<tr>
<td>Biological sciences</td>
<td>N/A</td>
<td>26.1</td>
</tr>
<tr>
<td>Chemistry</td>
<td>N/A</td>
<td>15.4</td>
</tr>
<tr>
<td>Engineering</td>
<td>N/A</td>
<td>0</td>
</tr>
<tr>
<td>Mathematical and computer sciences</td>
<td>N/A</td>
<td>15.4</td>
</tr>
<tr>
<td>Physical sciences</td>
<td>N/A</td>
<td>0</td>
</tr>
<tr>
<td>NIH Pioneer Award&lt;sup&gt;d&lt;/sup&gt;</td>
<td></td>
<td></td>
</tr>
<tr>
<td>First program year (2004)</td>
<td>22.0</td>
<td>0.0</td>
</tr>
<tr>
<td>Second program year (2005)</td>
<td>26.0</td>
<td>46.2</td>
</tr>
</tbody>
</table>

<sup>a</sup>Data from 2000 to 2005.
<sup>b</sup>Data from 1999 to 2005.
<sup>c</sup>Data from 1996 to 2003.
<sup>d</sup>Award first offered in 2004.

N/A: demographic information not solicited or maintained for nominations.

SOURCE: Data were provided by membership departments of listed organizations and awards.
centers, women made up 18% of section chiefs, 11% of department chairs, and 10% of deans.\textsuperscript{32} At the Department of Energy national laboratories, women make up 11% of scientific directors and 3% of directors and deputy directors (Table 4-3). Similar proportions of women serve in leadership posts at the NSF engineering research centers and science and technology centers (Tables 4-4 and 4-5).

Grants and Contracts

Grants and contracts offer another measure of leadership. At NIH over the last 20 years the participation of women has grown in all extramural grant budget categories. For the traditional research project grants (RPGs), also known as R01s, the percentage going to women increased from 17% to 24% from 1990 to 2004. Over the period 1983-2004, the share of grants going to women has increased from 13% to 24% for all RPGs\textsuperscript{33} and 17% to 39% for career development awards. Representation of women among principal investigators on center awards has increased from 4% to 17%, but this is still far below the level of participation of women in the individual investigator grant categories.

The average size of grants varies considerably across budget category, and the differences in sizes of grants to women and men vary as well. In FY 2004, the biggest differences in the average award are for centers, where women serve as principal investigators on grants that are on average only 60% as large as those for men. The average size of the NIH Small Business Innovation Research Program and Small Business Technology Transfer Program awards for women slightly exceeds that of men. And the average RPG and career development award for women is about 90% of the size for men (Figure 4-3).\textsuperscript{34}

Evaluation of Leaders

Underlying this skewed representation of women in leadership positions are sex differences in the expectation and evaluation of leadership. For example, both men and women hold more negative attitudes toward women than toward men authorities, although women’s explicit attitudes


\textsuperscript{33}The RPG category constitutes 79% of NIH extramural awards and 75% of the extramural dollars.

\textsuperscript{34}Office of Extramural Research (2005). \textit{Sex/Gender in the Biomedical Science Workforce}. National Institutes of Health, \texttt{http://grants2.nih.gov/grants/policy/sex_gender/q_a.htm#q5}. 
The NIH director’s Pioneer Award was created in 2004 as part of the NIH Roadmap for Medical Research. The award was designed to promote “exceptionally creative scientists taking innovative approaches to major challenges in biomedical research.” In its first year, outside nominations and self-nominations were solicited. The application consisted of a five-page essay and three letters of recommendation. Of the 1,300 nominations, 20 applicants were asked to interview. All of the awardees were men. Although all were doing exceptional research, they were not representative of the intended target audience—early career researchers.

The award program was in its first year, and NIH did not anticipate the large number of nominations, most of which occurred in the last few days. To review the applications, NIH had to recruit a sizable number of additional reviewers in a short period. As a result, 60 of the 64 reviewers were men. In addition, because self-nominations and external nominations were accepted, reviewers found it difficult to compare self-nomination essays describing applicants’ own accomplishments with external nomination essays written on behalf of the nominees. Carnes et al. suggest several evidence-based reasons why women scientists might have been disadvantaged in the Pioneer Award’s nomination and selection process, including:

- Time pressure placed on evaluators would make it more likely for them to rely on stereotypic assumptions that favor men as scientists.
- Absence of face-to-face discussion of candidates disadvantages women.
- Ambiguity of performance criteria in combination with the word leadership tends to favor men.
- Weight given to letters of recommendation negatively affects women because letters written for women tend to be shorter, have more references to personal life, include more gender terms, contain fewer standout adjectives, and have more gender-stereotypic adjectives.
- The need for finalists to make a formal presentation where the nominee, and not the nominee’s work, was the focus of the evaluation favors men because men scientists are more likely to meet the implicit assumption of what a scientist, pioneer, and leader should look like.

are more egalitarian than men’s. Martell and DeSmet had 151 managers judge the leadership effectiveness of men and women middle managers on various categories of leadership behavior. They found that both men and women managers rated men higher on delegating behavior, and rated

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Jeremy Berg, director of National Institute of General Medical Sciences, and Judith Greenberg, director of the Division of Genetics and Developmental Biology, took on the challenge of revamping the award selection process in 2005. Together, they implemented some minor changes that had a dramatic impact on the result. These changes included:

- Removed leadership potential from criterion.
- Engaged in outreach to women, minorities, and early career scientists to make sure people felt included and welcome to apply. The proportion of women in the applicant pool increased from 20% in the initial response to the call for applications in 2004 to 26% in 2005; and from 10% in the request for a full proposal in 2004 to 35% in 2005.
- Recruited a balanced pool of reviewers. There were 4% women in 2004 and 44% in 2005. Carnes also suggests that a reduction in the number of applicants (from 1,300 in 2004 to 840 in 2005) and greater familiarity with the application process may have reduced time pressure on reviewers, and thus decreased the effects of implicit biases. The fact that the award process was also in the public spotlight may also have reduced the likelihood that reviewers used stereotypes to identify candidates.
- Oriented reviewers to read the nomination announcement, which especially encouraged women and minority-group members to apply. Asked reviewers to consider “innovation density” to level the playing field for younger applicants.
- Changed nominations to only self-nomination.

In 2005, of the 13 recipients of the Pioneer Award, 6 were women, one was an African American man, and all the winners were significantly younger—evidence that the procedural changes created the opportunity and environment in which a diverse pool of candidates could be seriously considered.

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women higher on consulting behavior. Women rated women middle managers more favorably on inspiring, mentoring, problem solving, rewarding, and supporting; men either rated men and women equally or rated men more favorably on these behaviors.

Sinclair and Kunda found that the rating of women evaluators depended more on the nature of the evaluation than that of men. Specifi-
EXPERIMENTS AND STRATEGIES

BOX 4-3 Breaking through the “Polycarbonate Ceiling”—
The Committee on the Advancement of Women Chemists

The Committee on the Advancement of Women Chemists (COACh) was formed in 1998 and is working to increase the numbers and success of women scientists in academe. Initially focused on women in chemistry, it has expanded to include men and women in geology, physics, mathematics, computer science, and biology. COACh has two important missions: first, it brings senior women chemists together for networking events, interactive workshops, and mentoring support; and second, it actively seeks to improve the professional lot of women scientists at academic institutions at all levels.

COACh offers a series of workshops at professional meetings and institutions that are designed to enhance leadership skills, to expand women’s professional networks, to improve institutional climate, and to level the playing field for all faculty. COACh has implemented professional skills workshops that provide negotiation, management, and leadership skills to help women to achieve their professional goals as faculty in the sciences. Through a variety of instructional and interactive approaches, these sessions provide an opportunity to share experiences with others and engage in small group discussions. Over 1,100 women academic scientists from around the country have participated in these workshops in the last 4 years. Nine of 10 women who have taken COACh workshops report increased negotiation and communication skills and reduced workplace stress.a Over 90% of COACh workshop attendees report mentoring other women in the skills they learned.b COACh workshops specifically designed to address issues of minority-group women scientists have recently been launched.

COACh also conducts research on institutional climate and factors contributing to the low number and advancement of women chemistry faculty, including collecting data and personal stories of sexism that women scientists still suffer.c COACh is working to ensure that women are nominated for awards and leadership positions and is working with academic institutions to help them to eliminate biases and barriers that work against underrepresented groups in the sciences. COACh efforts are jointly sponsored by NSF, NIH, and the Department of Energy (DOE). More details about COACh and its programs can be found on its Web site at http://coach.uoregon.edu.

---

### TABLE 4-2 Percentage of Women Chief Editors at Top-Ranked Journals, by Field

<table>
<thead>
<tr>
<th>Field</th>
<th>Top Journals</th>
<th>% Women Editors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Medical</td>
<td>New England Journal of Medicine, Lancet, JAMA, Annals of Internal Medicine, Annual Review of Medicine, British Medical Journal, PLOS Medicine, Archives of Internal Medicine, Canadian Medical Association Journal</td>
<td>50%</td>
</tr>
</tbody>
</table>

*continued*
### TABLE 4-2 Continued

<table>
<thead>
<tr>
<th>Field</th>
<th>Top Journals</th>
<th>% Women Editors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Psychology</td>
<td>Annual Review of Psychology, Psychological Bulletin, Psychology Review, Psychotherapy and Psychosomatics, Neurobiology of Learning and Memory, Cognitive Psychology, Psychosomatic Medicine, Health Psychology, Psychological Medicine, Biological Psychology, and Cognitive Psychology</td>
<td>9%</td>
</tr>
<tr>
<td>Social sciences&lt;sup&gt;c&lt;/sup&gt;</td>
<td>Research in Organic Behavior, Evolution of Human Behavior, Econometrica, Social Science and Medicine, Psycho-Oncology, Sociology of Health and Illness, AIDS and Behavior, Future Child, Accident Analysis and Prevention, Hastings Center Report</td>
<td>40%</td>
</tr>
</tbody>
</table>

<sup>a</sup>Top 10 journals were determined by impact factor using the Thompson ISI rating system; in some fields there are more than 10 due to a tie.

<sup>b</sup>Included only chief editor position; some journals have more than one chief editor.

<sup>c</sup>The top 10 journals in these fields were determined by looking at all subdisciplines within the larger field using Thompson ISI Journal Citation Reports, for example, Chemistry includes the subdisciplines of Physical Chemistry, Analytical Chemistry, Biochemistry, etc.

SOURCE: Journals: Thompson ISI 2005 Journal Citation Reports. Editors: individual journal Web sites, August 2006.

Cally, women evaluators were viewed as less competent than men evaluators after providing negative feedback to a rater but not after providing positive feedback. Other studies find mixed evidence of sex differences in the evaluation of leaders. A meta-analysis of perceptions of men’s and women’s leadership showed no sex differences when the data were analyzed in the aggregate. Yet, although men and women were found to be...
equally effective in leadership positions overall, both sexes were found to be more effective in gender-congruent roles.\textsuperscript{38} That these findings from the world of business cross into science and engineering is evident in Tables 4-2 to 4-4 in the difference in representation of women in scientific director positions versus administrative director positions.

\textbf{EVALUATION OF SUCCESS}

People pursue their careers in organizations and workplaces populated by others and governed by rules, norms, and practices quite independent of any individual worker’s control. Persistent wage and employment sex differentials exist in the labor market as a whole and for scientists in particular.\textsuperscript{39} Research has amply documented discrimination against women and minority-group members in hiring and evaluation, especially in traditionally male fields.\textsuperscript{40} Social psychologists argue that most discriminatory behavior takes the form of implicit bias and results from gender schemas, the largely unexamined sets of ideas people hold concerning gender roles.\textsuperscript{41} For example, women’s performance ratings exceed men’s in jobs that are sex-typed female, one meta-analysis found, but suffer in comparison with men in jobs considered male.\textsuperscript{42} One program is using theater to examine the heretofore unexamined biases that affect interactions and decision making (Box 4-4).

\begin{footnotesize}
\begin{enumerate}
\end{enumerate}
\end{footnotesize}
# TABLE 4-3 Department of Energy National Laboratory Leadership Positions

<table>
<thead>
<tr>
<th>Laboratory</th>
<th>Director and Deputy Directors</th>
<th>Scientific Directors</th>
<th>Administrative Directors</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ames</td>
<td>Male: 2, Female: 0</td>
<td>Male: 11, Female: 0</td>
<td>Male: 7, Female: 7</td>
<td>Division directors and unit directors</td>
</tr>
<tr>
<td>Argonne</td>
<td>Male: 3, Female: 0</td>
<td>Male: 23, Female: 0</td>
<td>Male: 12, Female: 5</td>
<td>Division directors, associate directors, and unit directors</td>
</tr>
<tr>
<td>Brookhaven</td>
<td>Male: 3, Female: 0</td>
<td>Male: 17, Female: 1</td>
<td>Male: 22, Female: 8</td>
<td>Directors, associate directors, and unit directors</td>
</tr>
<tr>
<td>Fermi</td>
<td>Male: 4, Female: 0</td>
<td>Male: 19, Female: 2</td>
<td>Male: 10, Female: 5</td>
<td>Division directors, division deputies, unit heads and associate unit heads</td>
</tr>
<tr>
<td>Idaho</td>
<td>Male: 4, Female: 0</td>
<td>Male: 6, Female: 0</td>
<td>Male: 8, Female: 3</td>
<td>Directors, deputy directors, and associate laboratory directors</td>
</tr>
<tr>
<td>Lawrence Berkeley</td>
<td>Male: 3, Female: 0</td>
<td>Male: 15, Female: 0</td>
<td>Male: 11, Female: 0</td>
<td>Directors, deputies, and associates</td>
</tr>
<tr>
<td>Lawrence Livermore</td>
<td>Male: 3, Female: 1</td>
<td>Male: 8, Female: 2</td>
<td>Male: 7, Female: 3</td>
<td>Directors, associate laboratory directors, division directors, and department heads</td>
</tr>
<tr>
<td>Laboratory</td>
<td>Directors</td>
<td>Deputy Directors</td>
<td>Associate Directors</td>
<td>Total (%)</td>
</tr>
<tr>
<td>-----------------------</td>
<td>-----------</td>
<td>------------------</td>
<td>---------------------</td>
<td>-----------</td>
</tr>
<tr>
<td>Los Alamos</td>
<td>2</td>
<td>0</td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td>Renewable Energy</td>
<td>1</td>
<td>0</td>
<td>15</td>
<td>7</td>
</tr>
<tr>
<td>Oak Ridge</td>
<td>3</td>
<td>0</td>
<td>5</td>
<td>1</td>
</tr>
<tr>
<td>Pacific Northwest</td>
<td>3</td>
<td>0</td>
<td>4</td>
<td>0</td>
</tr>
<tr>
<td>Sandia</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td><strong>Total (%)</strong></td>
<td>32</td>
<td>1</td>
<td>128</td>
<td>16</td>
</tr>
</tbody>
</table>

**NOTES:** Scientific directorates include Biology, Science and Technology, Research, Materials Science, Engineering, Chemistry, and Physics. Administrative directorates include Human Resources; Diversity; Administration; Security and Facility Operations; Technical Services; Information Technology; Legal; Business Support Services; Communications; Public Affairs; Environment, Safety, Health and Quality; Partnerships; Technology Transfer and Economic Development; Education Programs; and Infrastructure. N/A = not available.

**SOURCE:** Personnel data obtained from organizational charts published on-line by each laboratory. Data retrieved February 16, 2006.
<table>
<thead>
<tr>
<th>Engineering Research Center (ERC)</th>
<th>Director and Deputy Directors</th>
<th>Scientific Directors</th>
<th>Administrative Directors</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Male</td>
<td>Female</td>
<td>Male</td>
<td>Female</td>
</tr>
<tr>
<td>Georgia Tech/Emory Center for the Engineering of Living Tissues</td>
<td>2</td>
<td>1</td>
<td>7</td>
<td>1</td>
</tr>
<tr>
<td>Computer-Integrated Surgical Systems and Technology ERC</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Biomimetic MicroElectronic Systems</td>
<td>2</td>
<td>0</td>
<td>7</td>
<td>0</td>
</tr>
<tr>
<td>VaNTH ERC in Bioengineering Educational Technologies</td>
<td>4</td>
<td>2</td>
<td>4</td>
<td>0</td>
</tr>
<tr>
<td>Engineered Biomaterials ERC</td>
<td>1</td>
<td>1</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td>Center for Advanced Engineering Fibers and Films</td>
<td>2</td>
<td>0</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Center for Environmentally Beneficial Catalysis</td>
<td>5</td>
<td>0</td>
<td>10</td>
<td>1</td>
</tr>
<tr>
<td>ERC for Reconfigurable Machining Systems</td>
<td>2</td>
<td>0</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>ERC/Multidisciplinary Center</td>
<td>Director</td>
<td>Co-PI</td>
<td>PI Assistant PI</td>
<td>Co-Director</td>
</tr>
<tr>
<td>-----------------------------</td>
<td>----------</td>
<td>-------</td>
<td>-----------------</td>
<td>------------</td>
</tr>
<tr>
<td>Pacific Earthquake ERC</td>
<td>2</td>
<td>0</td>
<td>7</td>
<td>1</td>
</tr>
<tr>
<td>Mid-America Earthquake Center</td>
<td>2</td>
<td>0</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Multidisciplinary Center for Earthquake Engineering Research</td>
<td>2</td>
<td>0</td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td>ERC for Extreme Ultraviolet Science &amp; Technology</td>
<td>1</td>
<td>1</td>
<td>5</td>
<td>2</td>
</tr>
<tr>
<td>ERC for Collaborative Adaptive Sensing of the Atmosphere</td>
<td>5</td>
<td>1</td>
<td>4</td>
<td>0</td>
</tr>
<tr>
<td>Center for Wireless Integrated MicroSystems</td>
<td>4</td>
<td>0</td>
<td>5</td>
<td>0</td>
</tr>
<tr>
<td>Center for Subsurface Sensing and Imaging Systems</td>
<td>6</td>
<td>0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Integrated Media Systems Center</td>
<td>2</td>
<td>0</td>
<td>5</td>
<td>1</td>
</tr>
<tr>
<td>Center for Power Electronics Systems</td>
<td>6</td>
<td>0</td>
<td>6</td>
<td>1</td>
</tr>
<tr>
<td><strong>Total (%)</strong></td>
<td>49</td>
<td>6</td>
<td>73</td>
<td>11</td>
</tr>
</tbody>
</table>

(11%) (13%) (46%) 28

**Source:** Personnel data obtained from organizational charts published on-line by each center. Data retrieved May 1, 2006.
<table>
<thead>
<tr>
<th>Science and Technology Center (STC)</th>
<th>Director and Deputy Directors</th>
<th>Scientific Directors</th>
<th>Administrative Directors</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Male</td>
<td>Female</td>
<td>Male</td>
<td>Female</td>
</tr>
<tr>
<td>Adaptive Optics</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Advanced Materials for Water Purification</td>
<td>1</td>
<td>0</td>
<td>6</td>
<td>0</td>
</tr>
<tr>
<td>Behavioral Neuroscience</td>
<td>1</td>
<td>0</td>
<td>5</td>
<td>0</td>
</tr>
<tr>
<td>Biophotonics</td>
<td>2</td>
<td>0</td>
<td>14</td>
<td>4</td>
</tr>
<tr>
<td>Earth-Surface Dynamics</td>
<td>1</td>
<td>1</td>
<td>6</td>
<td>0</td>
</tr>
<tr>
<td>Embedded Networked Sensing</td>
<td>1</td>
<td>1</td>
<td>11</td>
<td>0</td>
</tr>
<tr>
<td>Environmentally Responsible Solvents and Processes</td>
<td>3</td>
<td>0</td>
<td>4</td>
<td>0</td>
</tr>
<tr>
<td>Field</td>
<td>Director</td>
<td>Associate Director</td>
<td>Program Coordinator</td>
<td>Business Manager</td>
</tr>
<tr>
<td>-------------------------------------------</td>
<td>----------</td>
<td>--------------------</td>
<td>---------------------</td>
<td>------------------</td>
</tr>
<tr>
<td>Integrated Space</td>
<td>2</td>
<td>0</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Weather Modeling</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Materials and Devices for Information</td>
<td>2</td>
<td>0</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>Technology Research</td>
<td></td>
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SOURCE: Personnel data obtained from organizational charts published on-line by each center. Data retrieved May 1, 2006.
Many academic scientists and engineers believe that they function within a meritocratic system that objectively rewards ability and productivity, and that careers should be open to talent.43 The institutions making up that system, however, are differentiated by major distinctions of prestige, power, and available resources. As described above, those factors influence the ability to do research and influence the evaluation of efforts. The characteristics and policies of an institution therefore can exert a major influence on career outcomes.

Because the path to an academic career is long and consists of multiple steps, any advantages or disadvantages that befall a scientist or engineer, even apparently small ones, can accumulate and lead to further advantages or disadvantages.44 The reputation of one’s degree institutions, the connec-

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FIGURE 4-3 Average NIH research grant award to women and men by budget category, FY 2004.

tions and eminence of one's mentors, the resources of the laboratories where one works, the significance of the problems one works on, the stature of the journals in which one publishes—these and many similar factors can foster or impair a researcher's rise in the academic world.

Gender Bias in Evaluation

Deeply ingrained in the culture of academic science is the assumption that merit, as revealed by the purportedly objective process of peer review, determines the distribution of status, rewards, and opportunities. From Marie Curie to Christiane Nüsslein-Volhardt, prominent women have had their work recognized because it was so important and original. Research, however, has shown that gender colors evaluation of scientific and engineering accomplishment and thus affects the opportunities and rewards that women receive. In the intense competition for academic standing, even small differences in advantage can accumulate over the span of a career and create large differences in status and prestige. That results in white men scientists and engineers often receiving greater rewards for their accomplishments than women or minority-group members.45

A study of the peer-review scores awarded on applications for postdoctoral fellowships in Sweden—the country named by the United Nations as the world leader in gender equality—revealed that men received systematically higher competence ratings than equally productive women. A woman, in fact, had to be more than twice as productive as a man to be judged equally competent. “It is not too far-fetched to assume that [similar] gender-based discrimination may occur elsewhere,” the researchers suggested. They argued that the documented discrepancy in the perception of female work could “entirely account” for the shortage of women in senior faculty positions.46 Other research suggests that there is a similar gendered evaluation of research grants in the United States.47

Gendered evaluation runs deep in science. Tregenza, studying journal peer review in ecology, a field in which senior academics are predominantly male and younger researchers are close to gender parity, found differences in acceptance rates across journals according to the sex of the first au-

47 I. Broder (1993). Review of NSF economics proposals: Gender and institutional patterns. *American Economic Review* 83:964-970. This researcher found female reviewers rated female-authored proposals lower than did male reviewers of the same proposals, while no gender differences in the review of male proposals was observed.
EXPERIMENTS AND STRATEGIES

**BOX 4-4 Center for Research on Learning and Teaching (CRLT) Theater Program:**

NSF ADVANCE at the University of Michigan

Interactive theater can be used to build community, raise awareness, and stimulate discussion. It has been used to confront issues that are difficult to resolve due to conflicts between ideals and practice. The Center for Research on Learning and Teaching (CRLT) Theater Program, sponsored by the NSF ADVANCE program at the University of Michigan, uses interactive performances to demonstrate how faculty interactions shape and reflect the climate. They have developed performances that explore search committee discussions of job candidates, mentoring of junior faculty, and committee meeting discussions of tenure candidates. The performances are based on extensive faculty interviews, focus groups, and faculty and administrative consultation and review conducted at the University of Michigan.

The main component of the CRLT Theater Program is the CRLT Players, a theater troupe composed of professional and student actors who use interactive sketches to draw attention to everyday issues in academe surrounding pedagogy, diversity, and inclusion. Using research from the experiences of faculty members and students, the players present different viewpoints to draw the audience in with a mix of comedy and drama. At the end of the show, the actors continue to play their roles during a question-and-answer session with the audience.

In one theater presentation, the CRLT Players enact a meeting of search committee for a faculty position in the computer science department. The actors discuss which of two candidates—one man, one woman—they should hire. The five men and one woman simulating the search committee debate their research backgrounds, credentials, potential family plans, and gender diversity in the department. The scene ends with the chair stating that he would give the name of the man candidate to the dean for hiring. After the presentation, faculty observing the skit question the actors, who, in turn, answer the questions while remaining in character. The audience is allowed to critique the discussions and results of the search committee.

Some researchers argue that journals should use blinded peer review to minimize gender bias (Box 4-5). Trix and Penska evaluated letters of recommendation written by senior professors in support of men and women candidates for US medical school faculty positions and found that gender stereotyping systematically resulted in women candidates receiving less favorable recommendations than men.

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The program seems to be effective at multiple levels. Immediate feedback is provided during the question-and-answer session to help the troupe improve their performance. Audience members are asked to fill out a survey at the end of each performance. And the ADVANCE program also monitors long-term effects on department and university policies and procedures.

Audience members have given consistently high ratings to the relevance and effectiveness of the performances:

- Both men and women rate the issues and topics raised as useful (4 on scale of 5, n=519).
- More women than men found the issues raised reflected personal experiences (3.38-3.91 for women, 2.8-3.53 for men).
- Both men and women found the audience/actor interactive discussion enhanced their understanding of the issue (4 on scale of 5).

The CRLT performance centered on mentoring was used to augment the development and roll-out of the Faculty Advising Faculty Handbook and departmental mentoring plans. In general, based on follow-up correspondence with attendees on what worked and what did not, it has become clear that the performances have caused faculty members to reflect on their own behavior and on group dynamics during various committee meetings. They have found that the most critical issues are setting, audience composition, and framing—giving the target audience a reason to care about the information presented and way to make use of it.

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Steinpreis and colleagues examined gender stereotyping in evaluation of curricula vitae (CVs). They sent academic psychologists CVs ostensibly submitted by men and women candidates for an assistant professorship and for tenure. In fact, the documents recounted the career of a real woman psychologist who had been hired as an assistant professor and attained early tenure. The CVs for each career level were identical, except that half of respondents received a version identified by a stereotypically male name and half by a stereotypically female name. Both men and women faculty members showed a significant preference for hiring the man, rating “his” research, teaching, and service above the identical record of the woman candidate. Although the “man” and “woman” tenure candidates proved
FOCUS ON RESEARCH

BOX 4-5 Blinded Peer Review

High publication demands and the low acceptance rate of peer-review journals place journal editors and their reviewers in a powerful position. Journal reviewers have a vital role not only in influencing the journal editor’s publication decisions, but also in the very nature and direction of scientific research. Because of their influence in peer-review outcomes, journal editors and reviewers are aptly described as the “gatekeepers of science.”

Almost all English-language scientific and medical journals use anonymous review, in which authors do not learn the names of reviewers, but fewer than 20% use blinded review, in which reviewers do not learn the names of authors. Journal editors who use blinded review have argued that blinding serves to decrease bias in the review process. Indeed, several studies have examined the effect of blinding and found that it reduced reviewer bias with regard to personal characteristics of the authors, including nationality, institutional affiliation, sex, friendship with the reviewer, race or ethnicity, and intellectual conformity with the reviewer.

This phenomenon was demonstrated with alarming clarity in a study examining the effects of blinding auditions for symphony orchestras, where, similar to universities, the training period is long, there are many more candidates than slots available, and in which number of positions is highly fixed and turnover is slow. The practice of “blind” auditions (placing a screen between the player and the judge) increased by 50% the probability that women would advance out of preliminary rounds, and explained between 30 to 55% of the increase in the proportion of women among new hires and between 25 to 46% of the increase in the percentage of women in the orchestras from 1970 to 1996.

Additional research controlling for a variety of author, article, and journal attributes shows that articles published in journals using blinded peer review were equally likely to be promoted on the basis of the superb CV, respondents were 4 times more likely to ask for supporting evidence about the woman, such as a chance to see her teach or proof that she had won her grants on her own, than they were for the man. Earlier research has shown that department chairmen evaluating male and female applicants with identical records tended to hire the men as associate professors and the women as assistant professors.

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Some have suggested that in addition to blinded review, journal editors conduct periodic internal and external evaluations of their journals' peer-review process and outcomes to ensure that review bias is minimized.f


The University of Wisconsin-Madison’s Women in Science and Engineering Leadership Institute (WISELI) provides workshops to train search committee chairs on good search methods and to sensitize them to hiring bias (Box 4-6). WISELI recommends spending 15-20 minutes on each application, reading the entire application rather than relying on one measure of performance, developing criteria for evaluations that can be consistently applied, and periodically evaluating decisions to determine whether qualified women and minority-group members were included. The Uni-

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53Women in Science and Engineering Leadership Institute, University of Wisconsin-Madison, ibid.
EXPERIMENTS AND STRATEGIES

BOX 4-6 Searching for Excellence and Diversity: Workshops for Search Committee Chairs at the University of Wisconsin-Madison

The Women in Science and Engineering Leadership Institute (WISELI) at the University of Wisconsin-Madison offers workshops for faculty chairs of search committees that aim to increase the diversity of candidates recruited and hired for faculty and administrative positions. Relying on principles of active learning and peer education, the workshops encourage faculty to share search experiences and strategies across department and school/college boundaries. The workshops emphasize the 5 Essential Elements of a Successful Search. An introduction to and discussion of the effects of unconscious biases and assumptions on evaluation of candidates is an important feature of the workshop experience. From 2003 through 2006, 152 faculty members representing 70 different departments (57% of all departments in the university) participated in the workshops.

WISELI has been evaluating the success of this approach to improving the hiring process at UW-Madison by tracking:

(1) Workshop participants’ ratings of the usefulness of the workshops. Overall, all workshop participants who responded to our request for feedback (N=65; 42% response rate) indicated that the workshop they attended was “Somewhat” or “Very” useful; none reported that the workshop was not at all useful. Similarly, all respondents reported that they would recommend the workshop to others, and no respondents indicated they would not recommend the workshop.

(2) Self-reported gains in skill related to the search process on an all-faculty survey. Workshop participant responses on the 2006 Study of Faculty Worklife at the UW-Madison (N=1,230; 56% response rate) indicate that participants did significantly increase their skill in the following areas: establishing search procedures to ensure the equitable review and hiring of candidates and creating a welcoming environment for new hires.

(3) Survey responses of new faculty satisfaction with various elements of the search process. New hires in departments that sent at least one faculty member to the WISELI training reported an increase in their satisfaction with the hiring process, while departments that did not participate saw a decrease in their new members’ satisfaction with the hiring process, from 2003 (before the workshops were implemented) to 2006 (Figure B4-6A).

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http://wiseli.engr.wisc.edu/initiatives/hiring/training_hiring.html.
http://wiseli.engr.wisc.edu/Products/facultyversion06.pdf.
Actual percentages of women and minority faculty hired.\(^f\) Departments who sent at least one faculty member to a workshop showed a 19% increase in the percentage of their new assistant professors who were women, compared to a 23% decrease for those departments that did not participate (Figure B4-6B).

\(^f\)Fine and Sheridan (2006), ibid.
These measures indicate that WISELI’s approach to educating search committee chairs appears to be working, although many other factors such as the motivation of the individual search committee chairs and departments are likely to also play an important role.

WISELI plans to continue implementing workshops across the UW-Madison campus, expanding them beyond faculty and administrative searches to searches for other staff as well. One large college made participation in these workshops mandatory for all search committee chairs beginning in 2005/2006. WISELI is also visiting other campuses to offer a day-long session, “Searching for Excellence & Diversity: Implementing Training for Search Committees,” to help universities, university systems, and/or regional collectives develop and present search workshops on their own campuses.9

9http://wiseli.engr.wisc.edu/initiatives/hiring/ImplementingTraining.htm.

BOX 4-6 Continued

University of Michigan has its STRIDE (Strategies and Tactics for Recruiting to Improve Diversity and Excellence) program,54 which uses senior professors of science and engineering who have been trained by social scientists to work with recruitment committees to overcome biases. University administrators can make departments accountable by making participation in such programs a condition for undertaking a faculty search. Building in a measure of accountability reduces the use of stereotypes in choosing job candidates.55

Understanding Discrimination56

Although women today in the United States have many more opportunities than women of previous generations, many societal traditions inhibit their full participation in the technical workforce. Women have been struggling for access into universities and entrance into the labor force since the


middle of the 19th century. But, admission was only half the battle. Women were often co-opted into the science and engineering professions to provide lower-cost labor necessary to combat temporary workforce shortages. In addition, as described in Chapter 5, when women are hired into faculty or upper management, institutions do not provide contexts conducive to their productive potential or retention.

Subtle, Implicit, or Unexamined Bias

Even as gender equity gains ground and a national consensus has developed that explicit racial hostility is abhorrent, people may still hold prejudiced attitudes, stemming in part from the US history of overt sex and racial prejudice. Although prejudicial attitudes do not necessarily result in discriminatory behavior with adverse effects, the persistence of such attitudes can result in unconscious and subtle forms of discrimination in place of more explicit, direct hostility. Such subtle prejudice is often abetted by differential mass-media portrayals and by de facto segregation in education and occupations. All manifestations of subtle prejudice constitute barriers to full equality of treatment. Subtle prejudice is much more difficult to document than more overt forms, and its effects on discriminatory behavior are more difficult to capture. However, subtle does not mean trivial or inconsequential; subtle prejudice can result in major adverse effects. More recently, legal scholars have begun to use the term unexamined to describe such discriminatory behavior, arguing that it shifts the burden of proof and acknowledges that such behavior can be changed.


Pervasive, unexamined gender bias has played a major role in limiting women’s opportunities and careers because American culture generally stereotypes science, mathematics, and engineering as domains appropriate to white men and much less suitable for women or members of racial or ethnic minorities. If gender bias takes a so-called benevolent form, women are viewed as pure and morally superior, although not suited for male occupations. Under a hostile form of gender bias, women who aspire to traditionally masculine roles are seen as undermining or attacking the rightful prerogatives of men. The combination of those biases often causes competent women to be perceived as “not nice” or even “overly aggressive” and traditionally subservient women to be perceived as “incompetent” and “trivial.”

As described in Chapter 2, in-group and out-group stereotypes can lead to lower test performance and reduce confidence and can lead some women and members of underrepresented minorities to develop less interest in pursuing science- and mathematics-based careers, even when they major in those fields. It can also affect students’ interest in taking on the leadership roles that are necessary for success in academic research. The tendency to see women and minority-group members as less competent than white men and their accomplishments as less worthy and significant is a prominent component of the “glass ceiling,” the well-known complex of attitudes and biases that keeps women and minorities in many organizations and professions out of the most powerful, influential, and prestigious positions because they are assumed to be unfit for leadership. Stereotyping and cognitive bias thus create a “built-in headwind” for women and minorities in the sciences and engineering.

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The main effect of subtle prejudice seems to be to favor the in-group rather than to directly disadvantage the out group.\textsuperscript{65} One might, for example, fail to promote someone on the basis of race, perceiving the person to be deferential, cooperative, and “nice” but essentially incompetent, whereas a comparable in-group member might receive additional training or support to develop greater competence. Conversely, one might acknowledge an out-group member’s exceptional competence but fail to see the person as sociable and comfortable—and therefore not fitting in, not “one of us,” and less collegial—and on that account fail to promote the person as rapidly.

The Case for Diversity: “There Goes the Neighborhood?”

There have been dramatic changes in workforce demographics over the last 40 years. As discussed in Chapter 1, women and minority groups make up an increasing proportion of science and engineering students and the technical labor force.\textsuperscript{66} The benefits of workforce diversity seem clear in knowledge-based innovative work requiring creativity and flexibility.\textsuperscript{67} In the past decade, a number of reports and popular books have touted the benefits of workplace diversity,\textsuperscript{68} connecting it to enhanced group problem solving, increased creativity, and increased profits.\textsuperscript{69} A vast and growing body of research provides evidence that a diverse student body, faculty, and


\textsuperscript{66} See, for example, A Antonio (2003). Diverse student bodies, diverse faculties. Academe 89(6):14-18.


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staff benefits the joint missions of teaching and research. However, if the structural conditions and individual perspectives do not exist to harness their benefit, diverse workgroups can lead to increased workplace tension, team fragmentation, and increased staff turnover. Ineffective processes and policies are manifested as workplace bias: differences in career outcomes by gender or race/ethnicity that are not attributable to the differences in skills, qualifications, interests, or preferences that individuals bring to the employment setting.

Diversity and discussions of it can be turbulent and uncomfortable, but it also is clarifying, illuminating, leading to a deeper understanding of one’s self and one’s world. Diversity advances innovation. Diversity powers excellence.

—Shirley Jackson, President, RensselaerPolytechnic Institute (2005)

Businesses and universities realize that to capture and capitalize on this talent, they need to change policies adopted when the workplace was more homogeneous and create new organizational structures. Most organizational efforts have focused on race and gender, but many also incorporate other aspects of diversity, including socioeconomic status, ethnic heritage, sexual orientation, and disability status. At the same time, organizations must consider increasing challenges to the concept of affirmative action and the discontinuation of programs seen to be providing advantage to any


specific group. Equity efforts need to address not just individual needs but also the systemic changes needed to build and sustain educational, research, and workplace environments that promote effective participation in an increasingly pluralistic society. As described below (Box 4-7), such structures would include proactive recruiting, programs to enhance team-building and interpersonal skills, compensation equity, family friendly policies, mentoring and career development programs for junior and senior employees, and accountability through annual appraisals and evaluations.

Accountability and Evaluation

Program evaluation must be an integral part of any diversity initiative. Models for some best practices have begun to emerge from some ADVANCE institutions (Box 5-5). However, none of the ADVANCE institutions have to date completed their 5-year institutional transformation grant, so evaluation of the success of these programs is not possible. Progress can be gleaned from annual reports to NSF and on many of the individual program Web sites.

Effective assessment is an iterative self-diagnostic process. It ideally involves continuous cycles of program improvement and refinement. A program should incorporate a hypothesis, a set of measurable goals, and should collect baseline (formative) and outcomes (summative) data to test that hypothesis. Reasoned analyses and plans are followed by “experimental” trials with continuous testing, learning, and program refinement from those planned trials. A percentage of total program funding should be allotted to evaluation activities and an individual should be designated to be responsible for data collection and analysis; 5% of total project funding is a common allocation for evaluation in federal programs.

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78Available at http://www.nsf.gov/advance.

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BOX 4-7 Making Diversity Work

“If you think managing diversity is a program, you don’t get it.”a

Considerable research has shown the barriers limiting the appointment, retention, and advancement of women faculty. The question is how to move beyond these barriers and make diversity work. An evaluation of a wide-ranging campus diversity initiative in the University of California system provides specific lessons for academe. Programs that were effective had three key components: the campus had a framework for monitoring progress, a commitment to analyze and use data for organizational change, and a commitment to take corrective action.b

These results mirror what is found in other organizations that have implemented successful diversity management programs. Several researchers have examined program efficacy using a variety of techniques, including tracking of workforce composition and employment practices,c and case studies in industryd and federal agencies.e While there are some important differences, there are some common factors that successful programs—those shown to improve workforce diversity—exhibit. These benchmarks of success are:

1. Management involvement (CEO, President)—resource commitments, internal communication of goals, alignment of strategic goals and organizational mission.
2. Close tailoring of diversity initiative to organizational needs, starting with performance of an organizational survey to identify demographics, issues, and needs.
3. Program not specific to a demographic group.f
4. Changes individual behavior.
5. Changes personnel systems and existing organizational procedures and practices.
6. Involves organizational development—participation of top managers, sequencing of educational programs so that managers back up training of nonsupervisory staff, long-term effort to reach a large proportion of employees, and considerations of the length and depth of programs.
7. Incorporates measurables and accountability—regular monitoring of patterns of job segregation, pay, and career advancement by gender and race/ethnicity; and explicit evaluation of managers and supervisors in contributing to initiative goals.

Industries that have large research and development (R&D) components may be most likely to hold lessons for academia. In this context, several actions are correlated with increased workforce diversity:g

- Mentoring programs have been highly effective in moving white and African American women and African American men into management.
- Culture audits and surveys of workers have resulted in increases in white and African American women in management, whereas they show mixed effects in non-R&D industries.
- Targeted recruitment is particularly effective in R&D industries.
Overall, these findings support the creation of systems of authority and accountability (diversity committees, affirmative action plans) (Box 6-2), the use of targeted searches and incentives (Box 3-6), the use of surveys to assess university culture (Box 6-7), and the implementation of mentoring programs (Box 6-3). While diversity training is helpful in R&D intensive industries, it is important to note that corporate diversity training is very different from the sort of diversity initiatives found in the ADVANCE programs (Box 5-5), in which academic scientists rather than hired consultants lead training and create ongoing feedback and learning systems (Boxes 4-3, 4-4, and 4-6). Such training systems are akin to diversity committees, which are quite effective in both R&D industries and elsewhere. To derive maximal benefits from diversity, members of academic communities must show respect for each other’s cultural and stylistic preferences and awareness of unconscious assumptions and behaviors that may influence interactions. Only when differences are openly discussed and learned from do the positive effects of diversity accrue; open discussion makes it possible for the groups to create psychological safety. The goal is to create a climate in which everyone feels personally safe, listened to, valued, and treated fairly and with respect.

\[ \text{References:} \]


Some research indicates that broad diversity initiatives may not help, and in some cases may hinder, the promotion of minorities; reviewed in Naff and Kellough (2003). Other research indicates that reducing the saliency of group identity helps to reduce backlash by majority groups; reviewed in Gilbert et al. (1999), ibid; Bendick et al. (1998), ibid. It should be noted in this context that those programs shown to be effective at increasing the retention of women faculty are almost immediately broadened to include all faculty (Box 6-3).


EXPERIMENTS AND STRATEGIES

BOX 4-8 Specific Steps for Overcoming Bias

1. Avoid language that activates unexamined and implicit biases (Box 2-4).
2. Make positive role models visible (see Boxes 2-4 and 4-2).
3. Include women and minority-group members on evaluation committees (Box 4-2).
4. Create an enhanced sense of community and partnership (Box 5-2).
5. Discuss possible bias and challenge decisions openly (Box 4-4).
6. Make the community aware of the research on bias and emphasize the neutral effect of the gender of the evaluator, thereby defusing the issue and avoiding accusations and defensiveness (Box 4-9).
7. Define criteria at the outset of the selection process to ensure that they select the best academic traits rather than simply replicating past patterns (Boxes 4-1, 4-6, and 4-7).
8. Hold accountable people and committees that conduct evaluations of people for hiring, tenure, promotion, and awards (Boxes 4-2, 4-6, and 4-7).

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BOX 4-9 Top Research Articles on the Effects of Bias on Evaluation

Each of the 19 institutions that have received NSF ADVANCE grants were asked which research publications have proven most effective in their institutional transformation projects. The most-cited publications were these:


All 19 ADVANCE institutions were polled on the top 3-5 articles that have proven the most effective in their institutional transformation projects. Poll conducted between January 20 and March 20, 2006.
The committee has prepared a detailed scorecard for the purposes of measuring progress toward improving the representation of women in university programs and faculties (Box 6-7). Measurables include

- Changes in the representation of women and minorities in the student body, new faculty interviews, hire offers, faculty rank positions, and in administrative positions.
- Changes in hiring, promotion, tenure, retention, and turnover. Exit interviews can be an important means of evaluating reasons for turnover and designing retention programs (Box 3-5).
- Differences in salary or resource allocation.

BEYOND BIAS

The underrepresentation of women and minorities in science and engineering faculties stems from a number of issues that are firmly rooted in our society’s traditions and culture. To accelerate the rate at which women and minority-group members take their places as leaders in science and engineering, it is essential that all members of the scientific and engineering community—men and women alike—reflect on their own values, beliefs, and behavior to ensure that they do not further stereotypes, prejudices, policies, practices, or climates that discourage or exclude women and minorities from academe (Box 4-8).

A powerful way to reduce evaluation bias has been to bring to the attention of those performing evaluations—including provosts, department chairs, and search committees—the research in the field (Box 4-9).

CONCLUSION

Our analysis shows that women possess the qualities needed to succeed in academic careers and can do so when given an equal opportunity to achieve. Furthermore, reducing the homogeneity of faculty enhances problem solving, teaching, and research. The need to eliminate bias against women scientists and engineers—whether explicit, covert, or unexamined—is therefore more than a moral or legal obligation of universities. It is a requirement for assuring a scientific workforce of the highest quality. Only the best possible scientific workforce will permit the nation to compete in an increasingly global world of science and engineering.
5

Institutional Constraints

CHAPTER HIGHLIGHTS

In addition to bias, systematic constraints and expectations built into academic institutions have impeded the careers of women scientists and engineers. The traditional scientific or engineering career presumes the model of an out-of-date male life course. It is predicated on the assumption that the faculty member will have an unlimited commitment to his or her academic career throughout his or her working life. Attention to other serious obligations, such as family, is taken to imply lack of dedication to one’s career. Historically, that career model depended on a faculty member having a wife to take care of all other aspects of life, including the household, family, and community. The model still fits some men but is increasingly unsuitable for both men and women who need or want to participate in other activities important to them and their communities.

The traditional career model is clearly difficult for women scientists and engineers to fulfill, especially if they have children. Because the burden of family, household, and community care generally falls more heavily on women than on men—and because women seldom have substantial spousal support—women scientists and engineers often experience intense conflict between their family and professional roles. A well-documented complex of biases known as the maternal wall or family responsibilities discrimi-
nation hampers the career advancement of women scientists and engineers with children and the minority of male scientists and engineers who bear major caregiving responsibilities. Those on highly competitive academic career tracks are aware of these issues and often make compromises to lessen the conflict or choose not to avail themselves of accommodations for which they are eligible, such as stopping the tenure clock or reducing work responsibilities, out of fear of damaging their career prospects. Women scientists and engineers in fast-track positions, for example, are less likely than those on less competitive career tracks to be married or to have children. Those who are mothers tend to have fewer children than comparable men. Furthermore, the perseverance of women scientists and engineers is seldom perceived as evidence of the very high level of devotion to their profession that it represents.

Anti-discrimination law requires universities to remedy conditions that differentially affect women’s entry into and promotion in academic scientific and engineering careers. Under recent legal decisions, the existence of stereotyping can serve as proof of discrimination. Legal trends thus encourage institutions to reduce stereotyping and also to change the institutional practices and norms that limit women’s advancement. Other steps needed to remove barriers include documenting the status and progress of underrepresented groups, establishing a work environment that is explicitly inclusive, and providing services that allow scientists and engineers to be productive while meeting their responsibilities outside of work. All those steps require leadership—and resource commitments—at the highest department and institutional levels. The most necessary and most difficult change is a thorough reconsideration of the long-accepted recruitment and evaluation practices implicit in the outdated academic career model.

FINDINGS

5-1. Systematic structural constraints built into academic institutions have impeded the careers of women scientists and engineers. A successful academic career has traditionally involved the presumption that unlimited attention can be given to that throughout one’s life.

5-2. Deviation or delay, any substantial hiatus, or serious attention to responsibilities outside of the academic realm have harmed faculty members’ ability to compete successfully because it has been taken to indicate a lack of seriousness about their careers.
5-3. Scientists and engineers without substantial spousal support, particularly those who shoulder major caregiving responsibilities, are disadvantaged in meeting the norms and expectations of academe.

5-4. The mere existence of apparently family-friendly policies at universities will not reduce the pressure on women faculty or their fear that family life will damage or even destroy their careers.

5-5. Well-planned, data-driven efforts to remove institutional constraints on women academics’ careers can produce significant results.

5-6. Whether those efforts involve “small wins” or institution-wide transformations, to be successful they must be based on accurate information about the existing situation, attention to problematic elements in the institution’s culture and practices, input from affected persons to help to identify those elements, evaluation of results, and buy-in from leadership at all institutional levels. Recalcitrance at lower levels can torpedo top-down initiatives, and bottom-up efforts can sink without support from those with power at top levels.

5-7. Adequate data gathering, planning, implementation, and evaluation of changes require the dedication of sufficient resources to the objective of increasing diversity.

RECOMMENDATIONS

5-1. For lasting change to occur, academic institutions, professional societies, and federal agencies should work together to provide leadership on issues of equity, hold their constituents accountable for change, and provide clear methods and measures for compliance.

5-2. University leaders should incorporate into campus strategic plans goals of counteracting bias against women in hiring, promotion, and treatment. This includes working with the inter-institution monitoring organization (see recommendation 5-7 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 entire board of trustees.

5-3. University leaders should take action immediately to remedy inequities in hiring, promotion, and treatment.

5-4. University leaders should require evidence of a fair, broad, 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.
5-5. 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 central policies and 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.

5-6. 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.

5-7. The committee recommends that the American Council on 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 discuss implementation of an oversight/intermediary body. Analogous to the National Collegiate Athletics Association, this body would act as an intermediary between academic institutions and federal agencies in establishing norms and measures, in collecting data, and in cross-institution monitoring of compliance and accountability. A primary focus of the discussion should be on defining the scope and structure of data collection.

5-8. Scientific and professional societies should serve in an analogous role to individual national governing bodies for sports and set professional and equity standards and collect and disseminate field-wide education and workforce data.

5-9. Universities and scientific and professional societies should provide child-care and elder-care grants or subsidies to enable their members to attend work-related conferences and meetings.

5-10. 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 and foundations should 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. They should establish policies for extending grant support for researchers who take a leave of absence due to caregiving responsibilities, and create additional funding mechanisms to provide for interim technical or administrative support during a leave of absence related to caregiving.

5-11. Federal agencies and foundations should lay out clear guidelines and leverage their resources and existing laws to increase the science and engineering talent developed in this country, including enforcing federal anti-discrimination laws at universities and other higher education institutions through regular compliance reviews and prompt and thorough investigation of discrimination complaints.

5-12. 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.

5-13. 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.

5-14. 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.

5-15. Federal enforcement agencies, including the Equal Employment Opportunity Commission (EEOC); the Department of Justice, the Department of Labor, and 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 anti-discrimination laws, creating a clearinghouse for dissemination of
strategies that have been proved effective, and providing awards and recognition for model university programs.

5-16. 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 EEOC, the Department of Labor, and the science granting agencies, including the National Institutes of Health and 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.

A number of factors disadvantage women scientists and engineers compared with their men colleagues. Bias plays an important role, but it is only one of the features of academic life that creates obstacles for women. Various institutional practices—especially those related to recruitment, tenure, and promotion—have differential effects on women and men. Such practices can have unintended detrimental effects on people whose circumstances do not fit the traditional assumptions on which these practices were based.

The traditional image of the “ideal” scientist or engineer (see below) tends to disadvantage women and advantage men. Even when an institution applies its rules and practices without explicit regard to sex, members of a group that constitutes a small minority in the organization—one less valued and less influential in setting norms—experience the effects of rules and practices differently from members of the more prestigious majority group. That often works to the detriment of the minority. Seemingly neutral practices, based as they are on the life experiences and characteristics of men, can create barriers to the careers of women in science and engineering.

Social connections between academic institutions and other institutions—such as church, day care, schools, health care, or banks—can constrain the options of some people but not others, particularly with regard to expected work schedules. Women still bear the brunt of caregiving and experience the major conflict with such expectations. Institutions will need to recognize the features of their institutional life that disproportionately and systematically burden women and accordingly change policies and practices. Simple one-shot efforts will not remedy the effects of long-standing and pervasively male-biased expectations and norms. Careful analysis of particular situations and thoughtfully designed, multipronged approaches are needed to bring real change and foster the advancement of women scientists and engineers.
THE “IDEAL” SCIENTIST OR ENGINEER

As discussed in the previous chapters, an important constraint on women’s careers is the traditional image of who merits an academic position. Not only are men presumed competent while women have to prove their worth, the traditional career model assumes that aspiring researchers can devote the decades of their twenties and thirties single-mindedly to their careers. Deviation or delay in following that course, any substantial hiatus or serious attention to responsibilities outside the academic realm, have traditionally harmed the scientist’s or engineer’s ability to compete successfully because it has been taken to indicate a lack of seriousness about one’s career.

In that model, scientists and engineers may marry, become parents, and participate in family life while pursuing their demanding careers because they have full-time spousal support to assume the major household responsibilities, including rearing children and running the home. It thus presumes a life course and social role that no longer fits many men and does not fit most women.¹ The model clearly does not take into account the life course of women who wish to become parents inasmuch as it requires unbroken concentration on work during the peak female reproductive years. Nor does it take into account the needs of unmarried, divorced, or widowed scientists and engineers who shoulder household, family, and community obligations without spousal support. It is a model that fits the lifestyle of an ever smaller group of people. Furthermore, this outdated model may not fit current trends in science and engineering, which call for more collaborative and less single-minded and individualistic approaches. The need is urgent to transform academic norms and expectations so that the academy can continue to attract the best people.

Beyond the assumptions about timing, the traditional career model assumes that successful faculty members will become part of a community of colleagues in their laboratories, departments, and disciplines, and will receive the guidance and support of senior faculty members. For that to occur, aspiring scientists and engineers must gain acceptance and a feeling of belonging among their colleagues. As discussed in Chapter 3, women constitute a minority—and often a very small minority—in many scientific and engineering fields, and commonly feel isolated, left out, or not accepted. Bringing women and other minority groups into the mainstream is a necessary prerequisite to capturing the talent of the diverse workforce (Box 4-7).

Assertiveness and single-mindedness are easier to measure quantitatively than the qualities that we are really interested in, intellectual curiosity, dedication, and so on, which have more human dimensions. Assertiveness and single-mindedness are stand-ins that worked pretty well for a large group of men in previous generations. Even though they are no longer very appropriate, our system still selects for them. And because it “works” (at least if you ignore gender discrimination and such things), we haven’t tried very hard to do better.

—Howard Georgi, Mallinkrodt Professor of Physics, Harvard University

RECRUITMENT

Are the recruitment practices used by academic institutions inviting and accessible to women? To understand how to increase the proportion of women and minority-group applicants, universities are studying their own recruitment and hiring practices. In one example, the University of California, Berkeley (UCB) examined department-level data on hiring and recruitment practices and noted which practices correlated with hiring women above, at, or below their percentage in the applicant pool. Departments that were successful in recruiting women did not assume that women feel sufficiently confident or included to send in an application. Merely taking such steps as designating an affirmative action officer to serve on the search committee or stating in the job announcement that women and minority-group members are encouraged to apply correlated with hiring below the level of the applicant pool. However, departments that hired at or above the level of women in the applicant pool used specific strategies that included getting input from graduate students, selecting diverse search committees, and establishing relationships with women at professional meetings and inviting them to apply.

Conflict between work and family also affects the applicant pool. Mason and Goulden have found that married women who have children are

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50% less likely to gain faculty positions, compared with single women or married men who have children. Ginther, examining career progression by field, found single women scientists and engineers 16% more likely than single men to be in tenure-track jobs 5 years after the PhD while married women with children were 45% less likely than married men with children to be in tenure-track positions. Having children, especially young children, decreases the likelihood of women’s obtaining a tenure-track job by 8% to 10% in all science and engineering fields but has no significant impact on men. Ginther attributes those differences to the coincident timing of the tenure and biological clocks and to women’s role as primary caregivers for children.

Narrow position specifications also affect the applicant pool and the numbers of women hired. There is mounting evidence that women are choosing to work at the boundaries of disciplines. Among the science, technology, engineering, and mathematics (STEM) faculty at UCB, 26% of the women and 15% of the men have joint appointments. Women tend to hold joint appointments in business, biology, law, city and regional planning, economics, and environmental science. In one of the newer departments, bioengineering, half of the faculty are women. When the biological sciences were restructured to include broad, multidisciplinary approaches, the proportion of women faculty increased to 50%.

I can’t tell you how many times I have reviewed searches in which the people—predominantly women and minority-group members—were not hired, because they didn’t “fit”.

—Angelica Stacy, Professor of Chemistry and Associate Vice Provost for Faculty Equity, University of California, Berkeley (2006)

As part of its diversity initiative, UCB has started to hold some full-time equivalent faculty positions centrally to encourage groups of faculty and

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6At UCB, STEM denotes science, technology, engineering, and mathematics but does not include biology or health sciences.

INSTITUTIONAL CONSTRAINTS

departments to pool resources and propose hires in new multidisciplinary research areas. The University of Wisconsin, Madison, and a number of other institutions have similar central-hire or cohire programs based on a commitment to enhance interdisciplinary research.8 Those policies counteract the tendency of departments to hire people to fill the mainstream slots, rather than moving the institutions forward into new fields. To accomplish the latter, institutional leadership is important.

INSTITUTIONAL INTERACTIONS

As shown in Chapter 4, distinctions based on sex and race or ethnicity emerge from the identification of people as members of a group, rather than their identification as individuals. Our findings on the education and career trajectories of men and women scientists and engineers do not reveal differences in ability, training, or even productivity that explain the sex differences in career progression. Rather, a web of factors—including psychosocial features, family patterns, institutional requirements, and aspirations and expectations—combine to produce unequal career outcomes for men and women. Various institutions of society—including family, schools, and employers—interact to create obstacles to women’s careers.

Those interactions strongly influence the differential choices that men and women make at crucial points along their educational and career progressions. Such choices are not necessarily voluntary. Rather, career choices reflect the broad social structure and therefore tend to reinforce the current sex segregation of occupations.9 Examples include the greater propensity of women scientists to enter biological science rather than physical science fields and the lower propensity of men than women in general to respond to career setbacks by withdrawing from the workforce and devoting themselves to family responsibilities. Indeed, the latter may be a rational response for women who perceive their career success as adversely affected by factors they cannot (or choose not to) change, such as being female or having children.

The set of societal and institutional connections around family formation are particularly complex and have starkly different effects on men and women scientists and engineers. The institutions on which parents depend for support in caring for their families typically have rules, traditions, as-

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sumptions, and policies of their own that may conflict with those of laboratories and universities. Familial roles embody implications about available time, energy, and income. Day care providers, schools, and other child-centered organizations run on calendars that assume that parents can be available at particular hours, on particular days, or for entire seasons of the year and can afford particular costs. Laboratories assume that scientists or engineers are available when needed for research, and departments assume that researchers are free to travel to present results and deal with collaborators. Fellowship and hiring committees assume that people are free to relocate to maximize career opportunities.

The importance of institutional connections shows up in the differential career effects of marriage and the presence of young children. They spur the career advancement of men but slow the advancement of women.\(^10\) On average, 64.4% of women doctoral scientists and engineers in tenure or tenure-track careers are married; 83.4% of men are married, 42.2% of women have children, and 50% of men have children. These proportions differ by field, but have not changed substantially between 1993 and 2003 (Figure 5-1). Of those women who are married, more women scientists and engineers are married to men who work full time (Figure 5-2), and depending on field, 64% to 81% of women scientists and engineers marry fellow scientists and engineers (Figure 5-3).

The academic job market is national. Geographic mobility is important for career advancement. At a minimum, most successful academics relocate from where they did their graduate work. A number of lines of evidence indicate that mobility of women academics differs from that of men, and that this is tied to the increased likelihood that more women than men are in dual-career marriages, particularly in marriages to other academics. Research since the 1970s shows that women academics are more likely to be living in large urban areas, a strategy that increases the likelihood that both partners in a dual-career marriage will find satisfactory employment.\(^11\)


FIGURE 5-1 Percent of women and men doctoral scientists and engineers in tenured or tenure-track positions, by sex, marital status, and presence of children, 2003.

FIGURE 5-2 Spousal employment of science and engineering PhDs, 30-44 years old in 1999: Married PhDs.

FIGURE 5-3 Employment expertise of spouses of science and engineering PhDs, 30-44 years old in 1999: Married PhDs with employed spouses.
NOTES: Yes = married to another scientist or engineer; No = not married to another scientist or engineer.
Irrespective of sex, unmarried scientists have the highest mobility rates, and scientists married to nondoctorate professionals have the lowest mobility rates. Life scientists and physical scientists have higher mobility rates than social scientists. The main difference in mobility by sex centers on the presence of young children. Women’s mobility appears much more constrained than men’s by preschool (women 11% less likely to move) and elementary-age children (women 39% less likely to move). Whatever the reasons, early parenthood often corresponds with the early years of the mother’s scientific or engineering career, so lower mobility limits many women’s ability to respond to career opportunities that may make a crucial difference in their ultimate career outcomes. Compromises made in initial faculty appointments can have long-term detrimental effects because the quality of colleagues and the resources available at the crucial early stages of a career affect productivity and visibility in a field. Men’s geographic mobility does not appear constrained until their children reach their teens. By that time, an academic career is generally well established and lessened mobility may have a smaller effect on ultimate outcomes.

All those considerations indicate that differences in career trajectories for men and women are generated and reinforced by the social structures in which people are situated and by the networks of interactions in which they participate. Increasing women’s representation in science and engineering requires many social, cultural, and economic changes that are large in scale and interdependent.

Family Responsibilities and the Bias Against Caregivers

Underlying the disproportionate disadvantage for the careers of women academic scientists and engineers of parenthood or other significant care responsibilities is a strong cultural devaluation of femininity and a consequent bias against caregivers that is deeply embedded in a number of practices and attitudes in academe. American culture generally stereotypes caregiving as feminine work; many more women than men carry the main or exclusive responsibility for caregiving—whether of children or of elderly

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12Shauman and Xie (1996), ibid.
13Shauman and Xie (1996), ibid.
or disabled relatives—within their families. This is reflected in the fact that overall, women between the ages of 20 and 40 take off more time from work than men to care for children, including disability leave and more time in the hospital. In the United States, 9 in 10 women return to work within a year after the birth of a child; family leave coverage increases the likelihood that a woman will return to work after childbirth. After age 45, the differences in disability leave reverse. Men experience more episodes of chronic illness, longer hospital stays, and are more likely to go on long-term disability.

In academe, caregiving is often seen as competing for the time and attention needed to succeed in highly competitive fields and, therefore, as indicating a lack of dedication to a scientific career. The determination to overcome the difficulties inherent in doing science while bearing caring responsibilities is somehow not generally seen as indicating the even greater dedication to science or engineering that it represents.

I really felt by having a child I gave up a lot of respect I had worked very hard to earn.

—Anonymous woman professor, 2001

22 Participant in leadership workshop hosted by the Committee on the Advancement of Women Chemists (COACh).
The Maternal Wall

Women attempting to pursue scientific or engineering careers while also carrying major child-care responsibilities encounter a well-documented complex of constraints and biases called the maternal wall, which contributes to the scarcity of women in the upper faculty ranks. Research has shown that the maternal wall, also known as family responsibilities discrimination, penalizes mothers, potential mothers, and fathers who seek an active role in family care. The researchers document that mothers experience gender stereotyping in how jobs are defined, in the standards to which they are held, and in assumptions that are made about them and their work; for example, a man who is absent is assumed to be presenting a paper, whereas a woman who is absent is assumed to be taking care of her children. Mothers also face negative assumptions about their competence, specifically, that they are less competent or committed than other workers. Similarly, fathers who take parental leave or even a short leave to deal with family matters often receive fewer rewards and lower performance ratings and are viewed as less committed.

I have been under a lot of stress dealing with expectations after having a child. In the eyes of the departmental administration I was no longer a faculty member but had become a “pregnant female.” There was no prior experience with this overlap so the expectations of me were way out of line with how we normally treat faculty.

—Anonymous woman professor, 2001

Because of those effects, parenthood, especially when it begins early in an academic career, affects women’s prospects for advancement far more adversely than men’s. Motherhood has been identified as the factor most

25Participant in leadership workshop hosted by COACh.
likely to preclude a woman with science or engineering training from pursing or advancing in an academic career. As discussed above, women scientists and engineers disproportionately marry fellow scientists and engineers. For example, 44% of women members of the American Physical Society are married to physicists, and another 25% are married to other scientists. 80% of women mathematicians and 33% of women chemists are married to men in their fields. Marrying within an academic discipline, termed 

disciplinary endogamy, is more widespread in the sciences and engineering than in other academic fields. It can create problems for hiring (especially for women), because most universities do not have dual-career hiring policies. Even in the 1980s, 20% of faculty resignations were related to spousal employment. Wolf-Wendel and colleagues have surveyed dual-career policies at 360 institutions of higher education, performed case studies of five colleges and universities, and compiled a detailed compendium of institutional policies and practices.

That said, women on highly competitive academic career tracks are less likely to marry or reproduce and more likely to divorce than comparable men or than women in lower-level academic posts. A longitudinal study of more than 160,000 academics shows that two-thirds of women who took academic jobs on the fast track before they had become mothers never had children. While there was no change in marriage rates of PhD recipients from 1978 to 1994, both men and women PhDs are increasingly

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33Mason and Goulden (2002), ibid.
delaying having children until later in their career.\footnote{M Mason and M Goulden (2004). Marriage and baby blues: Redefining gender equity in the academy. \textit{Annals of the American Academy of Political Social Science} 596:86-103.} About 45% of women who have tenure do not have children. That rate of childlessness—much higher than among tenured men—reflects the belief of many young female academics that they must choose between tenure and children and can have one only at the cost of the other.\footnote{R Drago (2006). The value of work-family policies. In \textit{Biological, Social, and Organizational Components of Success for Women in Academic Science and Engineering}. Washington, DC: The National Academies Press.}

Given the tie between gender and caregiving, ostensibly gender-neutral institutional policies often seriously disadvantage women scientists and engineers. They may be as apparently innocuous as providing funding to cover travel expenses but not additional child care expenses for scientists attending out-of-town conferences to present papers. The widely used 7-year tenure clock and the pressure on tenure candidates to show early promise, although apparently gender-neutral, often force women to choose between taking time out for pregnancy, childbirth, and child care, or pursuing a fast-track career.

Scientists and engineers are generally well aware of the bias against caregivers, and those seeking fast-track academic careers use a number of strategies to keep family responsibilities from damaging their careers. One is to minimize family commitments that interfere with career progress. The most obvious method is avoiding marriage and parenthood. Overall, 17% of women at research universities stay single, as opposed to 10% of men; 30% of women but only 13% of men have limited their number of children to avoid anticipated career damage; 18% of women but only 8% of men have delayed their second child for the same reason.\footnote{A Stacy (2006), ibid.}

A number of universities permit faculty members to request that the tenure clock stop for a period or that their workload be temporarily lightened to mitigate the career effects of childbearing and childrearing. Many academics, however, fearful of seeming to lack dedication and seriousness, decline to avail themselves of those opportunities. Over a 7-year period at one large research university, for example, only four parents of either sex, of the 257 on the tenure track, took advantage of official family leave.\footnote{Drago et al. (2005), ibid.} That tactic typifies the effort to deflect attention from one’s family responsibilities. Other tactics include missing children’s events and returning to

\begin{thebibliography}{9}
\item A Stacy (2006), ibid.
\item Drago et al. (2005), ibid.
\end{thebibliography}
work earlier than desired after a birth. Studies show that more women than men engage in these tactics, which adds to their stress. For faculty—men and women—who engage in bias avoidance behaviors, time to tenure was reduced and age at tenure was reduced by over a year.38

Thus, the mere existence of apparently family-friendly policies at universities will not reduce the pressure on women faculty or their fear that family life will damage or even destroy their careers. Rather, to reduce the conflict between work and family that faculty members experience, university leaders, including top administrators and department chairs, must adopt policies that recognize and mitigate the disadvantages imposed by caregiving and, through word and deed, demonstrate their belief that faculty members can combine a high level of professional achievement with family life (Box 5-1).39

Glass Ceilings

In addition to the maternal wall, women scientists must contend with the “glass ceiling,” another complex of attitudes and practices that keeps women in many organizations and professions out of the most powerful, influential, and prestigious positions because they are assumed to be unfit for leadership.40 The tendency to see women as less competent than men and their accomplishments as less worthy and significant is a prominent component of the glass ceiling. Scientific and professional societies and universities need to recognize talented women and provide opportunities to serve in leadership roles; these can be as various as keynote speaker, center director, elected position, prestigious award, or an administrative position.41 That said, the eagerness to find talented women sometimes causes them to be promoted before they have had enough experience. As with any

38Drago, et al. (2005), ibid.
41If University leaders do appoint women to positions of prominence, where they can gain leadership experience, these women have a high probability of going on to even greater things. For example, every woman ever appointed to the position of Provost at Yale has as her next job become President of a prestigious university (Hanna Gray, President of University of Chicago; Judith Rodin, President of the University of Pennsylvania; Alison Richard, Vice Chancellor of Cambridge University; and Susan Hockfield, President of the Massachusetts Institute of Technology).
promotion, this works only if there is enough advice and support from above. The Committee on the Advancement of Women Chemists (COACH) program is an example of what can be done to “break” the glass ceiling (Box 4-3).42

PIONEERS AND TIPPING POINTS

The obstacles and impediments that women scientists and engineers experience as they pursue careers in academic institutions do not arise

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42See also J Sheridan, PF Brennan, M Carnes, and J Handelsman (2006). Discovering directions for change in higher education through the experiences of senior women faculty. Journal of Technology Transfer 31:387-396.
solely from institutional constraints, stereotyping, or bias. Organizational studies show that introducing members of previously excluded groups into social units creates predictable attitudes and reactions among both the new arrivals and the established group members. The exact nature of these behaviors depends in part on the personalities and attitudes of the established members and on the number of newcomers relative to the group at large. Sometimes the members engage in bullying or threatening behavior, at other times, welcoming and supportive behavior. The reactions evolve as the proportion changes.

Bullying behavior is often systematically applied to women and can persist even in the highest levels of the academic hierarchy. Bullying is an abuse or misuse of power characterized by work-oriented aggression and is distinct from sexual harassment in nature and target of the aggression. Work-related bullying may involve excessive assignment of work, reassignment of responsibilities, unfair criticism, and excessive monitoring. Bullies tend to target newcomers, particularly those from groups not well-represented in the workplace. In science and engineering academic environments, this means women are often targeted. Furthermore, gender plays a role in the form and perception of bullying. So, although both men and women are bullied, women tend to be affected differently. The combined effects of being more likely to be targeted, less likely to report bullying behavior, and lacking support structures can translate to a hostile environment for women in high academic and administrative positions. Mentoring programs have been effective at strengthening the support infrastructure and helping women faculty survive and overcome bullying. Ombuds offices are another avenue providing advocacy and support for those targeted.

For the small numbers of women in faculty and leadership positions in science and engineering a major issue is singularity or tokenism (Box 5-2). Numerical representation is an influential structural characteristic of most work organizations. Minority-group size affects attitudes, achievement, and the frequency and quantity of interpersonal contact between

majority and minority group members \(^{46}\) and may also affect salaries.\(^ {47}\) However, as discussed in Chapter 4 (Box 4-7) the reliance on quotas to eliminate the occupational inequalities faced by tokens, the “add women and minority-group members and stir” model, may hinder the integration of the workplace if the underlying institutional structures are not addressed.\(^ {48}\)

Pioneering women scientists and engineers who are among the first of their sex to enter a field or laboratory or to be hired in a department face the predictable problems of tokenism and scarcity, including social isolation and extreme visibility. \(^ {49}\) The problems are more pronounced for pioneering women who belong to underrepresented racial or ethnic minorities.\(^ {50}\) Thus, even when women scientists and engineers achieve high academic rank in research I universities, full equality with their male colleagues often eludes them.

A survey of women science faculty members at MIT, for example, found that those in junior positions felt that their departments supported them and that gender bias would not threaten their future careers. Many of the women in tenured senior positions found themselves effectively “invisible” and “marginalized” within their departments and excluded from par-


When these women enter the workforce, they all begin with a common assumption: I have a chance. They believe their degrees, their raw talent, their ingenuity, and their industry will be the keys to their success. Then somewhere along the way, the women—especially the black women—begin to see that people still question their intelligence, and discount what they think. They are told to wait for opportunities, to prove themselves. So they wait. They continue to prove themselves. They contribute to the company’s bottom line, they take on leadership positions, and they put in excessive time, often to the detriment of their personal lives. Yet, even the most successful women reach the point where they realize their own expectations haven’t been met. That the rewards are not always commensurate with the costs. Many keep searching—and aching—for an answer. Others find this too toxic, and regrettably, bow out.

Commitment to an organization is directly related to a person’s comfort with their relationship to the organization: are opinions, experiences, and perspectives heard and respected? Are contributions valued? Most newcomers enter the workplace expecting no difficulty fitting in. However, when a newcomer is identified by the current workers as an outsider—whether that determination be based on demographic factors such as race or gender, or cultural, physical, or role-related factors—that optimism can turn to a sense of being tolerated rather than accepted. The resulting emotional conflict is likely to lead to increased absence and turnover.

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continued
There is an implicit assumption that the differences between groups are larger than the variance within groups. This leads to the phenomenon called “out-group homogeneity.” In effect, when it comes to values, personality traits, and other characteristics, people tend to see outsiders (members of a group to which one does not belong) as more alike each other than insiders (members of the group to which one belongs). As a result, outsiders are at risk of being seen as interchangeable or expendable, and they are more likely to be stereotyped. Why is this? In-group members usually have less contact with outsiders, but this is not the sole factor. People tend to organize and recall information about insiders in terms of persons rather than abstract characteristics. In some cases, people are also more motivated to make distinctions among others with whom they will have future contact. Together, these factors produce a group of differentiated insiders and a relatively homogeneous, undifferentiated outsider group. This tendency of people to favor their own group, known as insider bias, has been found in cultures around the world.

Some researchers argue that increasing the number of outsiders in a group or organization will lead to a reduced perception of difference and hence reduced discrimination. Others argue that increased numbers threaten the current majority group and lead to increased discriminatory behavior, termed backlash, and suggest that any numerical increase must be combined with attention to status and power relationships. Certainly, the historical representation of women in a job

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has tremendous impact on compensation, reward, mobility prospects, and workplace culture. Women who are relatively new to traditionally male-dominated work settings often attract more attention, are evaluated more extremely, are perceived as outsiders, receive less support, and are more likely to be viewed as a disruptive force in the workplace than male co-workers. Similar consequences are seen in workplaces with skewed racial distributions.

Strategies used to bring newcomers into a group influence how people express and manage tensions related to diversity, whether members of traditionally underrepresented groups feel respected and valued by their colleagues, and how people interpret the meaning of their sex or racial identity at work. These, in turn, have implications for how well the workgroup and its members function. There are three basic strategies employed by groups and organizations to incorporate people with different backgrounds and perspectives: acceptance, assimilation, or convergence.

Acceptance. That “essential differences” exist between groups is hotly debated; empirical research shows that acceptance of the differences hypothesis does not alter power imbalances and can often exacerbate outsider status.

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*Beyond Bias and Barriers: Fulfilling the Potential of Women in Academic Science and Engineering* [http://www.nap.edu/catalog/11741.html](http://www.nap.edu/catalog/11741.html)
Assimilation of outsiders leads to feelings of inauthenticity—for women, the "men in skirts" phenomenon. At the same time, some argue that there is little reason to assume that outsiders placed in an organization will be able to withstand pressure to conform.

Convergence. In workplace situations where repeated personal interaction is required, game theory indicates that cooperation is the preferred strategy, particularly where players are able to monitor each other or mobility is low, two conditions that often exist in the workplace. To achieve cooperation among diverse group members, research shows that creating a convergent environment in which group members are seen as individuals rather than group members reduces between-group differences and creates a common in-group identity—everyone rooting for the same team. Empirical research shows that only the convergence per-

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**BOX 5-2 Continued**

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If the number of women in a field or department grows to about 20% of total membership, a “critical mass” develops, and a social tipping point occurs.\(^{52}\) Women now form a noticeable contingent in the organization and start to perceive their common interests, joining together to press for improvements in policies relevant to their needs, such as those concerning

family issues. They also begin to appear in leadership positions. With these signs of solidarity, however, the first signs of backlash begin to appear among the men, who start to perceive women as a threat to the established order and to their traditional position and privileges. Men may begin to resist further hiring or promotion of women, sometimes overtly but often covertly.53

It seems that when I stand up for myself and speak my mind, I am told that I am crazy, that I am a trouble-maker. What makes this particularly difficult to deal with is that this is exactly opposite to the way I was treated when I first arrived here. For the first 3 or 4 years I had a voice and was seemingly a highly respected and contributing member of the department. Getting cut off and invalidated in this way seemed to correlate almost exactly with the many outward signs of my success as a scientist in my field. It was then that I did not receive the greater respect that I had seemingly earned. Instead, I was cut off and treated in a patronizing manner.

—Anonymous female associate professor, 200454

If female representation continues to increase and reaches 40%-60% of the group, a second tipping point occurs. Now gender issues seem to matter less and attract less attention. Such issues as bias and inequality in hiring, pay and promotion seem to disappear. If the proportion of women continues to grow, however, a third tipping point occurs; at 90% gender segregation returns; the department or field is now perceived as female and therefore less appropriate to men. The changeover from male to female can bring substantial consequences, in that fields viewed as female are less prestigious and poorer paying than those viewed as male.55

54 Participant in leadership workshop hosted by COACh.
The need for universities to develop practices that provide women scientists and engineers an equal chance of career success is far more than a moral imperative. Under modern anti-discrimination law, it is also a legal requirement. The low representation of women in the upper reaches of academe was long attributed to the “chilly climate” of those high realms. Today, however, legal thinkers argue that remedial action must go beyond vague formulations of creating a culture of faculty support. Universities must meet their obligation as employers to provide a workplace free of unlawful discrimination.  

As discussed in Chapter 3, the numbers of women earning bachelor’s and graduate degrees have increased, but in many fields of science and engineering, an increasing PhD pool has not necessarily led to increased representation of women on faculties. What legal options exist to redress this situation? Some have argued for using the federal Title IX statute to compel science and engineering departments to hire women by threatening to withhold federal funding from institutions that fail to do so. That strategy has worked well to increase the number and accessibility of athletic programs for women.

Legal theory and practice have evolved to combine a numerical analysis of workplace representation with an analysis of the underlying policies and climate that affect occupational entry or promotion. The legal avenues for redressing workplace discrimination are detailed in Box 5-3. Effective use of both Title IX and Title VI is critical for women—and especially women of color—in science and engineering fields. In addition, Title VII of the Civil Rights Act of 1964 prohibits employment discrimination based on race, color, religion, sex, or national origin in any organization with more than 15 employees. It bars discrimination from recruitment through termination, and it has been used in most tenure denial cases. Even though

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Title VII was originally intended to protect racial minorities from employment discrimination, it appears to have been more effective in remedying sex segregation. The Equal Pay Act of 1963 bars sex-based wage differentials between people who do the same or substantially similar jobs. Executive Order 11246 requires all federal contractors to file a discrimination statement and affirmative action plans. The Family and Medical Leave Act applies to all workplaces with 50 or more employees and guarantees an employee 12 weeks per year of unpaid leave to care for a family member. Title IX, passed in 1972, prohibits sex-based discrimination in or exclusion from any educational program or activity receiving federal financial assistance. Finally, constitutional standards of equal protection apply, but only for public organizations.

Traditionally, proving discrimination involved comparing a plaintiff—for example, a woman denied tenure who claimed to be the subject of discrimination—with a similarly situated person in the other group. Recent cases, however, have opened a promising new approach by finding that the existence of stereotyping can serve as proof of discrimination. Thus, a woman caught under the glass ceiling for purportedly being “too aggressive” to be a collegial colleague, or one up against the maternal wall for “lacking dedication” to her career because she sought to reduce her hours during her child’s infancy may have grounds for a suit.

Those legal trends can encourage institutions not only to take steps to reduce stereotyping but also to provide services and establish programs that meet federal requirements and remove constraints that limit faculty (usually women) who have caretaking responsibilities. One-third of academic institutions, for example, have family policies that appear to violate the Pregnancy Discrimination Act, which forbids treating pregnancy differently from other temporary disabilities. Women—and, in some cases, men—aquadems who try to assert their rights under such laws as the Family and


INSTITUTIONAL CONSTRAINTS

Medical Leave Act, which mandates 12 weeks of unpaid leave and the right to return to work, however, often find themselves pressured to return sooner than they wish and face increased scrutiny, adverse career consequences, and other forms of retribution.\textsuperscript{65}

The odds in sex discrimination cases do not favor plaintiffs. In most sex discrimination cases that reach trial, universities win. Most cases never reach trial, however, because they are dropped or resolved during the litigation process (Box 5-4 for a description of types of discrimination warranting legal action). A report by the American Association of University Women revealed that women academics won only a minority of lawsuits alleging improper denial of tenure.\textsuperscript{66} Bringing such a case usually entails substantial effort and financial risk and the possibility of being considered a troublemaker. “It taints all levels of your professional life at the university,” according to a woman who sued and ultimately settled with the university. Although the legal process can be financially and emotionally draining, however, it can empower plaintiffs.

\begin{quote}
Beyond the economic risks of charges, institutional theory calls attention to the role legal sanctions may play in cultivating a normative environment that discourages discrimination. One factor that constitutes firms’ institutional environment is industrial sector. EEO charges and settlements against a single firm in an industry may reverberate throughout the entire industry, providing legal and normative pressure for change and raising legitimacy concerns for recalcitrant firms. For example, a sex discrimination settlement against Home Depot may serve as a wake up call to Lowe’s or other home improvement stores to get more women out on the sales floor.

—Elizabeth Hirsh, University of Washington (2006)\textsuperscript{67}
\end{quote}

In some cases, publicity generated by discrimination cases can benefit the plaintiff and women faculty because it attracts the attention of legislators, advocates, and other organizations that can work toward long-term safeguards against discrimination and improvements in hiring and promotion. In \textit{Penk v. Oregon State Board of Higher Education} (816 F.2d 458

\begin{footnotes}
\item[65]Williams (2006), ibid.
\item[67]Hirsh (2006), ibid.
\end{footnotes}
DEFINING THE ISSUES

BOX 5-3 A Primer on Anti-discrimination Laws

Title VII of the Civil Rights Act of 1964

Title VII covers employees and applicants and bans employment discrimination based on sex, race, national origin, and religion by all employers with 15 or more employees, whether or not those employers receive federal funds. Title VII applies to employment in institutions of higher education. Thus, depending on the facts of their working arrangements, graduate fellows and teaching assistants can be covered under Title VII as employees, as well as under Title IX as students or employees. Title VII is enforced by the Equal Employment Opportunity Commission, which investigates and resolves discrimination complaints and can bring lawsuits on behalf of claimants. Individual commissioners may also file commissioner’s charges to initiate investigations of discrimination even absent a specific complaint.

Title IX (20 USC § 1681)

Title IX bans sex discrimination in education and covers (a) students, faculty and employees at institutions of higher education that receive federal funds and (b) students and employees of educational programs that are offered by other institutions that receive federal funds. Statutes parallel to Title IX bar discrimination by recipients of federal aid on the basis of race (Title VI of the Civil Rights Act of 1964), disability (Section 504 of the Rehabilitation Act of 1973), and age (the Age Discrimination Act of 1975). Every federal agency that gives funds to institutions of higher education or to other institutions that run educational programs—including all cabinet agencies (such as the Department of Education and the Department of Defense) and such agencies as the National Science Foundation, the National Institutes of Health, and the National Aeronautics and Space Administration—is obliged to enforce Title IX. Each federal agency has issued regulations delineating its enforcement responsibilities under the law, and each has the authority to investigate and resolve discrimination complaints and to initiate compliance reviews of recipients of federal aid. For educational programs, Title IX is enforced by the Department of Education and by each federal agency that provides federal funds to the program. The Department of Justice is charged with coordination of agency efforts under Title IX and is obliged to ensure overall enforcement of the statute.

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Executive Order 11246

Executive Order 11246 bans discrimination and requires federal contractors (including universities) to maintain affirmative action plans that set goals and timetables for increasing the representation of women and underrepresented minorities in their workforces. The executive order is enforced by the Office of Federal Contract Compliance Programs of the Department of Labor, which has the authority to resolve complaints and undertake compliance reviews of federal contractors.

Equal Protection (a constitutional claim) (42 USC §1983)

Academics who teach in public universities can recover damages if they can prove that men were disadvantaged compared with women, as when parental leave is routinely offered to women but men are forbidden to or severely discouraged from taking it. Women in public universities also can sue if they are not given equal protection of the law.

Equal Pay Act (29 USC § 206)

It is illegal to pay higher salaries to men than to women doing “equal work” in jobs that require substantially “equal skill, effort, and responsibilities . . . under equal working conditions” (29 USC § 206(d)(1)). One federal case, *Lovell v. BBNT Solutions, LLC*, 295 F. Supp. 2d 611 (E.D. Va. 2003), refused to apply a categorical rule excluding a part-time chemist from being compared with full-time chemists, in a ruling that suggests that professors on part-time tenure track should be paid the proportion of their salary equal to the proportion of a full-time schedule that they work (for example, 75% pay for a 75% workload).

Pregnancy Discrimination Act (PDA) (42 USC § 2000e-(k))

Employers are required to treat pregnant professors “the same” as other workers whose ability to work is similar. Evidence of a violation of the PDA includes stereotyping a pregnant woman as incompetent or not committed to her career, stripping a pregnant woman of duties and opportunities, and imposing conditions on her that are not applied to nonpregnant employees.

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*Equal Pay Act of 1963 The EPA, which is part of the Fair Labor Standards Act of 1938, as amended (FLSA), and which is administered and enforced by the EEOC, prohibits sex-based wage discrimination between men and women in the same establishment who are performing under similar working conditions, http://www.eeoc.gov/policy/epa.html.


continued
The Family and Medical Leave Act of 1993 (FMLA) (29 U.S.C. § 2601) applies to all organizations with 50 or more employees; it gives professors and other university employees (including most postdoctoral scholars and some graduate students) the legal right to up to 12 weeks of unpaid leave per year if the employee or his or her child, partner, or parent has a serious health condition, or if he or she has or adopts a child. Giving leave is mandatory. Covered employers are prohibited from denying or interfering with leave, including implying that leave will be seen as a lack of commitment to career.

Americans with Disabilities Act (ADA) (42 USC § 12101) Employees may not be discriminated against because they are caring for a family member whose illness or disability is covered by the ADA.

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9Americans with Disabilities Act (ADA) of 1990: Title I of the ADA, which became effective for employers with 25 or more employees on July 26, 1992, prohibits employment discrimination against qualified individuals with disabilities. Title I applied to employers with 15 or more employees beginning on July 26, 1994. Title V contains miscellaneous provisions which apply to EEOC’s enforcement of Title I. The Civil Rights Act of 1991 (Pub. L. 102-166) (CRA) amends sections 101(4), 102 and 509 of the ADA. In addition, section 102 of the CRA amends the Revised Statutes by adding a new section following section 1977 (42 U.S.C. 1981) to provide for the recovery of compensatory and punitive damages in cases of intentional violations of Title VII, the Americans with Disabilities Act of 1990, and section 501 of the Rehabilitation Act of 1973, http://www.eeoc.gov/policy/ada.html.

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(9th Cir. 1987)), the plaintiffs—women faculty—lost but the Oregon State legislature subsequently passed a law against discrimination in the state’s institutions of higher education.

Are the outcomes of individual cases leading to lasting change in organizations? Affirmative action laws have made inroads for women, but they have not always resulted in better working conditions in industry or academe. Even in companies, many of which have private dispute processes, workers file 25,000 cases of sex discrimination a year with the EEOC. About one-fifth result in favorable outcomes for complainants. In a retrospective 10-year analysis of 2,000 firms that filed EEOC reports in 2000, Hirsh has shown that sex discrimination lawsuits often cause other firms in the same industry sector to make pre-emptive changes, apparently

68All firms with 50 or more employees are required to file EEOC reports annually.
avoid problems of their own.\textsuperscript{69} That suggests that the pressure of EEOC enforcement is indirect—that firms are more sensitive to the enforcement mechanisms they experience in their institutional environments than to the direct coercive pressure that discrimination charges bring. Institutional theorists argue that the law plays a role in shaping organizational behav-

\textsuperscript{69}E Hirsh (2006). Enforcing Equal Opportunity: The Impact of Discrimination Charges on Sex and Race Segregation in the Workplace (Working Paper). Department of Sociology, University of Washington. Research and development firms are about half as likely to be issued sex discrimination charges as firms in other industry sectors.
ior, not because sanctions deter noncompliance, but rather because the law cultivates a normative environment, a “new normal,” that legitimates and motivates compliance.\textsuperscript{70}

BRINGING INSTITUTIONAL CHANGE

Transforming academic institutions so that they will foster the career advancement of women scientists and engineers is a complex task. The NSF’s ADVANCE program is geared specifically to promote such institutional transformation (Box 5-5). It reflects the increasing understanding that individual accommodations and help are not sufficient to bring gender

Partnerships for Adaptation, Implementation, and Dissemination Awards support the analysis, adaptation, dissemination, and use of existing innovative materials and practices that have been demonstrated to be effective in increasing representation and participation of women in academic science and engineering careers.

During the first funding cycle of the ADVANCE program, nine colleges and universities each received about $4 million from NSF over 5 years. Some of the successful programs that have been funded through the ADVANCE program are the University of Michigan NSF ADVANCE Project (Box 4-4), the WISELI program at the University of Wisconsin-Madison (Box 4-6 and Box 6-4), the NSF Program for Institutional Transformation at the Georgia Institute of Technology, and the Committee on the Advancement of Women Chemists (COACh) program (Box 4-3).

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Small-Win Experiments

A number of organizations have successfully fostered female employees’ career advancement by undertaking experiments that produce small but important changes in work procedures, practices, or norms. In most

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The Alfred P. Sloan Foundation, in partnership with the American Council on Education and the Families and Work Institute, has created the Alfred P. Sloan Awards for Faculty Career Flexibility to promote institutional efforts in research universities toward broader implementation of flexible career policies, critical for recruiting and retaining talented women scientists and engineers. The awards, initiated in 2006, will provide five research institutions each a $250,000 grant to recognize leadership and accomplishments in implementing ground-breaking policies for tenured and tenure-track faculty. In addition, two $25,000 awards will be given to universities that have shown innovative practices in career flexibility. The Sloan awards reward those institutions that have career-flexible policies and incentives to programs seeking to develop policies and programs.

Institutions will be judged according to their use of the following models:

- Career on-ramps and off-ramps
- Extended time to tenure (tenure clock adjustment).
- Shortened time to tenure, with prorated standard of productivity.
- Active service and modified duties (full-time service, with selected reduced duties).
- Part-time appointments (allowing mobility between full-time and part-time work).
- Phased retirement (partial appointments for finite periods).
- Delayed entry or re-entry opportunities (including practices that foster later-than-usual career starts).

An expert review panel will use a two-part process to select awardees. In the first round, applicants fill out a survey about the career flexibility offered to tenured and tenure-track faculty. The score that the university receives on the questionnaire determines whether it can advance to the next stage. In the second round, the selected institutions will complete a survey of tenured and tenure-track faculty regarding perceptions of, access to, and use of flexible career policies and practices. Universities will also be asked to devise a university-wide plan for accelerating the development and use of career flexibility among faculty to achieve institutional goals. Applicants will be asked to develop this plan while administering the survey to the faculty. Each university that participates in the second round will receive information about their ratings on the institutional survey and an anonymous comparison to the average ratings of other award applicants.

More information about the Sloan awards program can be found at http://www.acenet.edu/Content/NavigationMenu/ProgramsServices/Leadership/SloanAwards/index.htm.
organizations in which women’s advancement and leadership opportunities have been limited, the problem is not old-style, overt sex discrimination, but rather unrecognized features of the organizational culture that affect men and women differently. Those features tend to be so embedded in organizational life as to be invisible. They generally also bear no obvious relationship to gender. The only indication that such issues exist may be an unexplained inability of the organization to attract, retain, or promote women in sufficient numbers despite an apparent willingness to do so.

In an approach to overcoming such problems called small-win experiments, members of the organization, preferably with the backing of leadership, systematically seek out the features and set about finding ways to change them. An example of such a constraining cultural feature in one organization was a looseness about punctuality and the length of meetings that made it difficult for many women—who often live with tighter time restrictions than men because of their family responsibilities—to attend all the meetings they needed to attend to keep abreast of developments in the organization. Overtly establishing a new norm that meetings start and end at the announced times is a small-win experiment that made the organization much more congenial to women. 72 In another example, the custom of giving major credit for a successful project to the lead scientist devalued the “invisible work” of other professionals and support staff, many of whom were women.73 The solution was to establish a way to give public recognition to the importance of “invisible work” and the people who do it.

Successful small-win experiments must be carefully tailored to the specific circumstances of a particular organization (Box 5-7). That requires a close examination of the organization’s culture to uncover unstated assumptions about what constitutes success and who attains it, as well as implicit norms about how work is done and recognition granted. The consequences of the assumptions and practices must also be examined, and then discrete, concrete ways of changing the ones that adversely affect women must be devised. Once the project is under way, however, “it’s surprising how quickly people can come up with ideas for small wins—and how quickly they can be put into action.”74

One career customization work analogue in the academy is the suggestion of “5 in 10,” that is, any time within 10 years of hiring, a faculty member can choose 5 years on which to base his or her tenure application. Other customized tenure options are explored by the American Council on Education (Box 5-8).

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74Meyerson and Fletcher (2005), ibid, p. 85.
Identifying Barriers to Success in Science and Engineering

Universities across the country have begun to conduct studies of the institutional “climate” for women and minority-group scientists and engineers. Among the issues addressed by the climate studies are whether there is fair representation of women and minorities at various levels of academia; whether space, research support, and salaries are fairly allocated; and whether university policies reflect an understanding of the challenges faced by scientists and engineers in underrepresented groups. A data-

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EXPERIMENTS AND STRATEGIES

BOX 5-7 Deloitte and Touche: Leadership in Industry Case Study

A corporate example shows how it is possible to bring together a number of such change processes with fairly dramatic effects on the number of women in leadership positions. Deloitte and Touche USA, LLP, has recognized that formal flexible work arrangements are not sufficient to bring about that result. They have instituted a process of “mass career customization” whereby employees have a series of choices about position and responsibilities, rate of career progress, location and schedule, and workload, which may shift during the career. It increased the number of women partners from 3 in 1982 to 116 in 2005—the highest percentage of women partners in the four biggest professional services firms. It also keeps in touch with people who have stopped out temporarily to raise children, paying their professional fees to make it easier for them to come back.

Lessons from the Deloitte and Touche Women’s Initiative:

- Make sure that senior management is “front and center.”
- Make an airtight case for cultural change.
- Let the world watch you.
- Begin with discussion as the platform for change.
- Implement a system of accountability.
- Promote work-life balance for men and women.

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DEFINING THE ISSUES

BOX 5-8 Creating Flexibility in Tenure-Track Faculty Careers

On March 22, 2005, the American Council on Education (ACE) released the report, *An Agenda for Excellence: Creating Flexibility in Tenure-Track Faculty Careers*, which concluded that “higher education leaders urgently need to examine and proactively address the institutional climate that governs the entire career cycle of faculty, from entry-level to tenure-track positions to retirement.”

The panel reports that, for a variety of reasons, an increasing number of new PhDs are leaving academe or opting for careers outside the traditional tenure-track path. To achieve a better balance between personal and professional life, some faculty, especially women, choose adjunct and non-tenure-track positions, despite low pay, minimal or no benefits, and potential lack of job security. The ACE report argues that in many fields, especially science and engineering, the United States cannot afford to lose its potential academic workforce, and US institutions of higher learning should “act immediately to attract the best faculty to the tenure-track professoriate.”

The report makes the following general recommendations:

- Allow colleges, schools, and departments in a university to establish their own agreed-on guidelines for interpreting criteria for promotion and tenure, taking into account heavy teaching loads, professional service activities, and student advising.
- Create flexibility in the probationary period for tenure review without altering the standards or criteria. Longer probationary periods should not be required for all faculty, but flexible timeframes of up to 10 years, with reviews at set intervals, should be offered. This option could benefit faculty who may need to be compensated for lost time or given additional time to prepare because of unanticipated professional or personal circumstances.
- Examine and actively address the work-life issues and professional climate of faculty members throughout the entire career cycle.

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 driven approach to examining those concerns lends credibility to and enables a less confrontational discussion of the issues.77


77Harvard University (2005), ibid.
One approach to documenting the status of women in academic science and engineering is to combine quantitative data collection (see Chapter 3) with qualitative information obtained from faculty, students, and university leaders. For example, the Association for Women in Science (AWIS) created a Web-based interactive toolkit of surveys, literature, Web links, and guidelines to help universities to evaluate the climate for women on their campuses. At the request of department chairs, confidential surveys are used to query faculty and students on department demographics, gendered practices and policies, and the climate for women. Departments are also asked to provide enrollment data. After collecting that background information, a panel of respected scientists who are familiar with climate issues meets with faculty, students, and administrators to discuss their views about the status of women in a department. The panel then makes recommendations based on the information collected and helps the department to implement them.

We must grow our women leadership ranks. We must help our women and our men fit their lives into their work and their work into their lives, so that we can keep our pipeline robust. With women comprising nearly 50% of the labor force, we can’t succeed in the marketplace unless we attract and retain a representative share of women at all levels of our organization, including partner, principal, and director.

—Jim Quigley, Chief Executive Officer, Deloitte and Touche, USA, LLP (2005)

The AWIS program was based on a site visit program established by the American Physical Society (APS) to evaluate physics departments. The goal of APS was to identify and intervene in both the generic and specific problems commonly experienced by women and minority groups in physics departments. After a visit, a team submitted a written report of its findings, including suggestions for improvement, to the department chair. In turn, the department chair was asked to describe in writing actions taken to remedy the problems. Women’s committees in professional societies have been a powerful force for change (Box 5-9).

A number of universities have used a similar approach internally. For