women, science, and technology

a reader in feminist science studies

edited by mary wyer, mary barbercheck, donna cookmeyer, hatice örün öztürk, and marta wayne

third edition

ROUTLEDGE

Women, Science, and Technology

Third Edition

Women, Science, and Technology is an ideal reader for courses in feminist science studies. The editors have extensively revised this anthology to reflect the newest trends in the field. The third edition contains emerging work in feminist science studies that focuses on specific scientific and technological research and calls attention to debates among feminists about how to envision our futures in relation to this research. *Women, Science, and Technology* continues to make the argument that scientific and technological advances are at once deeply implicated in the rigidity of the sex/gender classification system *and* necessarily useful to challenging that classification system. In addition, recent trends in theory motivate a rethinking of related systems of domination, including race/ethnicity, class, sexualities, and global relations. This new edition reflects those important developments as integral to feminist science studies while incorporating a international perspectives.

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A Reader in Feminist Science Studies

Third Edition

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Typeset in Utopia
by Apex CoVantage, LLC

We renew our dedication of this book to all those women in science and engineering who have been denied the good friendship and encouragement that have sustained us. Know that we are cheering for you all.

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PREFACE TO THE THIRD EDITION

As we began the work that launched the third edition of *Women, Science, and Technology* we confronted several challenges to continuing to provide an overview of feminist science studies for use inside and outside of the classroom. Selections in earlier editions were strategically chosen to make feminist perspectives on the sciences accessible to a general audience, to provide a framework that began with familiar themes from liberal feminist perspectives (describing unequal outcomes by gender and race/ethnicity, in education, employment, and training), then moved through the logic of cultural construction of scientific knowledge, ending with articles that pointed toward agency and action in shaping scientific and technological research agendas. It was a framework meant to persuade readers that feminist perspectives improved one's ability to critically examine the changes sweeping through our lives. In this new edition we advance from our previous focus to describe a new path forward as it reflects emerging work in feminist science studies that focuses on specific scientific and technological research, and it calls attention to debates among feminists about how to envision our futures in relation to this research. *Women, Science, and Technology,* in our selections, continues to make the argument that scientific and technological advances are at once deeply implicated in the rigidity of the sex/gender classification system *and* necessarily useful to challenging that classification system. In addition, recent trends in theory motivate a rethinking of related systems of domination, including race/ethnicity, class, sexualities, and global relations. This new edition reflects those important developments as integral to feminist science studies.

The 2013 edition of *Women, Science, and Technology* marks the fifteenth year since we began teaching our course, "Women and Gender in Science and Technology," at North Carolina State University, which sparked the development of the book. The first year we offered the course there were just five students enrolled, with all five of us teaching it. The course now routinely attracts more than 400 students a year and satisfies a university general education requirement at NC State, and it has been adopted widely throughout the United States. Our decisions about content for the new edition are in part due to the evolving interests and enthusiasms of students, who are more inclusive, global thinkers than their predecessors. What has become apparent to us in the past fifteen years is that our students are better educated about gender issues than they were when we began our work, that the topic of "feminist science studies" is not as scary to them as it once may have been, and that the topics that resonate most profoundly for them are related to the body. By "the body" we refer to women and men as embodied, laboring, thinking, breathing humans whose individual desires, dreams, and choices are contained by barely visible social, institutional, and economic boundaries. This third edition reflects this emphasis, around which there is lively debate within feminist theory, with articles that focus literally on the body as an object and subject of scientific and technological innovation as well as articles that engage the theoretical debates. Because of the increasingly specific level of terms and concepts that new scholars are bringing to feminist science studies, we trust that the third edition will challenge educators and students alike to talk across traditional disciplinary divides to embrace their inner feminist scientist.

In our hunt for new material and our review of the earlier introductions, we discovered several arenas in which significant change has taken place, and we want to mention these here—not to lay out a claim of discovering that all is well with the world, but rather to mark the moment and honor the change that has taken place. The arenas in which we note improvements, to name a few, are: the increasing representation of women as undergraduate and graduate degree earners in science, mathematics, and engineering; the increasing visibility of women's health care in public policy discussions; the increasing recognition that women scientists and engineers bring useful and (perhaps) distinct experiences to the table in the development, implementation, and adaptation of new discoveries; the increasingly institutionalized commitments of colleges and universities to denounce gender bias in education, employment, and training in science and engineering fields; and the decreasing representation of science and scientists as necessarily masculine (never mind engineering or computer science for the moment).

There is no shortage of heady concerns, however. Feminist theory is troubled by the analytic limitations of the sex/gender paradigm, the implications of recognizing that feminist lenses are as partial as those we critique, the increasing disconnect between research on issues related to exclusionary practices in STEM (science, technology, engineering, mathematics) fields and feminist science studies, the continuing lack of cross-talk between feminist science theorists and feminist scholars in traditional disciplines, and the need to enhance the level of scientific literacy within the ranks of women's and gender studies faculty. We leave to you the task of considering the possibilities of this dialog in light of your conversations around essays and themes herein. This book represents our effort to make a small wave in a sea of change.

In terms of professional changes, the five coeditors of this book have very different careers than those we held in the first edition, advancing through the academic ranks and no longer located at the same institution. We continue to bring divergent and specialized perspectives into our work together. Mary Wyer is now associate professor of psychology and women's and gender studies. She teaches theory and research on intersectionality, stereotypes, and feminist psychology. Her publications and empirical research program focus on how individuals' self-concept as scientists and attitudes toward equality in science influence career commitments and persistence in science, with attention to gender and race/ethnicity. Mary Barbercheck is a professor of entomology at Penn sylvania State University, with research and extension in sustainable agriculture. Her research focus is on soil ecology and the effects of management practices on insects and related organisms in organic cropping systems. Her interests in women and gender have expanded from STEM to include women in agriculture. These interests include conducting research with the

Pennsylvania Women's Agriculture Network, with a focus on improving agricultural production and marketing by women farmers in Pennsylvania and the northeastern United States. Donna Giesman Cookmeyer is now in research administration and is involved both in the oversight of clinical trials and institutional compliance. In her work she continues to rely on qualities central to the feminist scholarship on science, including issues of equity, equal participation, and transparency. Hatice Örün Öztürk divides her teaching time between biomedical engineering and electrical and computer engineering departments. She is the assessment and accreditation coordinator for the undergraduate programs in both departments. For the past four years she worked with the College of Engineering IT staff to implement a software program assessment tool designed under her leadership. She is an active member of the Women's and Gender Studies Program executive council and enjoys the increasing number of her engineering students taking the women and gender in science and technology course. Her first book of poetry is *Bread and Time* and was published in Turkish in 2012. Marta Wayne is now professor of biology and adjunct professor in the Center for Women's Studies and Gender Research at the University of Florida, teaching courses in genetics, genetical ethics, and science studies.

These differences in our professional pathways, particularly geographical distance, have made it logistically difficult to work together, but have also enriched our consideration of the field of articles from which we selected those included in the third edition. We all had to agree that articles spoke to issues of broad concern but in ways that were methodologically and theoretically sound. We decided to feature newer work, agreeing to set aside many articles that are old favorites and classics. We found consensus on the new directions of the work and then developed a narrative that provided coherence. The diversity of backgrounds and our divergent life experiences, shared in kitchen table discussions, proved to be indispensible in assembling the third edition. We hope you enjoy reading it as much as we enjoyed developing it.

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There are several people who have made it possible for us to sustain our work on *Women, Science, and Technology* by reminding us how important our work is and by assuming its merit. We give continuing thanks to the Women's and Gender Studies Program at NC State University; to colleagues in the NSF ADVANCE project (Laura Severin, Margaret Daub, Marcia Gumpertz, and Daniel Solomon); Banu Subramaniam for comments on early plans; the Department of Psychology at NC State; and the National Women's Studies Association Science and Technology Taskforce. All of you have sustained us along the way and often behind the scenes. We also thank Hilary Rampey for her careful, thoughtful, and precise marshalling of the project through every step as a research assistant extraordinaire. We would also like to thank our reviewers:

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INTRODUCTION: FEMINISM, SCIENCE AND TECHNOLOGY— WHY IT STILL MATTERS

This collection of writings is designed to engage the reader in the disorientations and diffractions (to borrow Donna Haraway's term) that constitute contemporary feminist science studies. The scholarship represented here begins with familiar feminist themes related to social biases that discourage the participation and advancement of women in science, technology, engineering, and mathematics (STEM), but this third edition of *Women, Science, and Technology* quickly moves into topics related to the content of the curriculum in higher education, critiques of prevailing knowledge about sex and gender, debates from within feminist science studies about the limits and possibilities of feminist theoretical perspectives, and envisioning of new futures unbounded by disciplinary prerogatives. Although it matters that women have been (and continue to be) systematically excluded from, or marginalized within, the intellectual machinery of scientific and technological development and innovation—and it especially matters to those who experience discrimination—this path of work is but a start to thinking about women, gender, science, and technology. The endpoint, for this edition, is to raise questions about what we are teaching in institutions of higher education, to whom, and for what purposes.

In an era in which conversations about diversity and inclusion have taken on national prominence in the United States, and the need to be globally competitive drives efforts to recruit talent to STEM careers, it may seem as if issues of inequality in STEM are passé. How could anyone still think that only white men are fit for STEM careers? The issues, unfortunately, are more complicated than simply recruiting more women and people of color into STEM fields—a *lot* more complicated, in substance, scope, detail, definitions, and debates. Feminist scholars have built an impressive body of theory and research that offers not only important additions and correctives to traditional disciplines but also new visions and insights that take decidedly interdisciplinary turns. Responding to Charlotte Bunch's famous warning that the new scholarship on women requires more than an effort to "add women and stir," feminist educators and researchers have quite literally built a new interdisciplinary field, women's and gender studies (Bunch 1987; Boxer 1998). According to the National Women's Studies Association, there are more than 700 women's studies programs in the United States alone, educating some 15,000 majors and minors (Reynolds, Shagle, and Venkataraman 2007). Thirty-two percent of these institutions offer graduate-level training as well.

At the same time, feminist scholars inside and outside of science and engineering disciplines have been at work developing new scholarship, research, and courses that bring feminist perspectives to a critical reappraisal of scientific knowledge long-assumed to be "objective" and "value-free" (Bleier 1984; Fausto-Sterling 1987, 1992; Harding 1991; Keller 1985, 1992; Longino 1990; Rosser 1997, Spanier 1995). The once controversial insight that knowledge is socially constructed—that human values and practices inevitably shape the knower, knowing, and known (Hawkesworth 1989)—now is less so, as the scientific community appears to acknowledge that some values, practices, and models of the natural world are more enduring and persuasive than others, that received "facts" emerge from consensus and debate, and that facts change over time even while interpretations of them reveal persisting ideologies (admirably argued by example in Richardson, herein; and by Fausto-Sterling [2000]). After all, humans cannot stand off-world, as claimed by the early Greek mathematician and engineer Archimedes, who is said to have (over)confidently asserted: "Give me a place to stand on, and I will move the earth." For instance, Western Enlightenment ideas about the "rational man" cast science as a practice designed to subdue Mother Nature, as represented by Francis Bacon's infamous metaphor, representing nature as a bride who must be subdued. "I am come in very truth leading to you Nature with all her children to bind her to your service and make her your slave" (Keller 1985, 33). Such language captures at once the systematic exclusion of women from scientific practice and a definition of masculinity that embraces objectivity as a quintessentially male mind state. Bacon's description of the relationship between scientists and nature also places scientists (men) in opposition to nature (women) and all too clearly indicates that nature must be controlled. Despite the value we continue to place in being objective and unbiased, science and engineering disciplines are nonetheless products of historical, cultural, and all-too-human invention. Institutions of higher education—their development, organization, practices, and underlying assumptions—have inherited the Enlightenment legacy of (white) male-as-objective, with troubling consequences (Minnich 2004; Flax 1987).

What precisely are the consequences? The list of systematic distortions, ignorance, and normalization of oppressive conditions is a long one. It includes the exclusion of most humanity from the knowledge-making enterprise by requiring a prolonged and expensive training period before one can be credentialed as a researcher; by concentrating decision making about the allocation of resources in the hands of a select few; by appropriating capital (intellectual and financial) from the public for investment in innovations that are exploited for profits, which are then diverted into corporate rather than public coffers; by the wholesale plunder of developing countries for resources to feed the innovation gods new capital investments; and by the appropriation of indigenous knowledge for exploitation by Western science. The liberatory potential of scientific research seems all but useless in the face of new waves of ignorance, misogyny, and violence against women globally and locally. Persisting and cruel inequality across the globe continues to deprive women of the means by which to secure food, shelter, safety, and an education for themselves and their children (Kristof and WuDunn 2009). In the United States many issues that would be resolved if women were recognized as fully entitled to constitutional protections continue to plague us. Debates about public funding of birth control, women's health services, and constitutional rights to privacy and same-sex marriage, for instance, continue to reveal deep societal ambivalences about whether women really ought to be full citizens with all the rights, privileges, and responsibilities of men. Even pay equity, which is widely supported, seems a distant dream.[1]

That these insults to women continue even in the face of important improvements is all the more maddening in light of a stubborn resistance to rationale, objective, and unbiased arguments among those who would use public policy to return women to second-class status.

Nonetheless, improving the educational, economic, and social status of all women is an enduring and keystone commitment of feminist scholarship and activism. There is perhaps no better example of this than the long and continuing struggle to ensure that women with the talent, ability, and interest to contribute to the world's scientific and technological advancement have the opportunity to do so. We have assembled this textbook in order to provoke our readers to envision a future in which scientists and engineers are actively engaged in challenging recalcitrant and calcified assumptions about nature, knowledge, sex, gender, and social change.

The feminist science scholars included in this edition of *Women, Science, and Technology,* represent five general approaches to building on, elaborating, and contributing to the foundations of feminist scholarship. These approaches include: (1) describing local and global inequities in access to education, training, and employment in STEM fields; (2) critiquing distortions and misrepresentations of women's minds and bodies in medical and scientific research and development (i.e., documenting and demonstrating the social construction of knowledge); (3) exploring technoscientific innovations as both colluding and colliding with the sex/gender/sexuality nexus; (4) reflecting on the limitations and possibilities of borderlands in feminist science theory; and (5) examining if/how prevailing paradigms (principally the nature/nurture dichotomy, but also male/female, human/animal, science/technology) direct or contain new insights. These five approaches, we propose, represent major currents in the most recent work in feminist science studies.[2]

1. Describing local and global inequities in access to education, training, and employment in STEM fields

In this approach, as captured by the readings in section 1, researchers have documented the continuing and newly emerging practices and processes that influence if, how, and how successfully women participate in scientific and technological initiatives. Although it is clear that biases continue to suppress, shape, and direct women's opportunities in STEM fields, the authors bring a wide variety of approaches to unveiling the ways in which biases operate and become evident. The experiment-based study report from Moss-Racusin et al., and an overview of data on women in academic science and engineering from Bilimoria and Liang, provide evidence that despite thirty years of dedicated effort, in the United States the proverbial pipeline continues to "leak" women, even at the highest levels and even with steady increases in women's participation. Sue Rosser points toward the patent process as a newly named barrier for advancement of women to the highest levels of influence, as women are less likely than men to convert their intellectual capital to a patentable innovation. Banu Subramaniam's classic fable "Snow Brown and the Seven Detergents" recounts how the "voluntary" erasure of cultural and gender markers is mandated in order to "fit into" the patriarchal culture of Western science. Marta Wayne uses an autobiographical approach to describe her move toward a feminist commitment in her scientific research after a series of bias-charged interactions with peers left her in doubt about her future. Ulf Mellström's study of computer science in Malaysia takes a multimethod approach to understanding how the social categories of Malaysian society (gender, class, race, age) interacted with nationalist development agendas to create a "situated body politics" that generated new economic opportunities for women. Londa Scheibinger and Martina Schraudner provide specific examples to illustrate how scientific research and innovation are distorted by the exclusion of women to make a case for re-educating STEM faculty and students about the consequences of the loss of talent from the creative process. As a whole, the section readings make the case for knowing the details, how/where the biases continue, how inequality affects individuals and structures social relations, how institutional practices support the persisting exclusion of women from positions of power and influence, and how all of this pushes us to think about what we teach, what we know, what we define as significant topics for future research.

Still, we are reminded by Jennifer S. Light's study of women programmers' contribution to the development of the first electronic computer in the 1940s that too little is changing too slowly. As one of these early contributors put it, to succeed one must "look like a girl, act like a lady, think like a man, and work like a dog." Arguably, especially in engineering disciplines where women remain dramatically underrepresented, this remains all too true today. Some would argue that this is further evidence of the continuing dominance of hegemonic masculinity in engineering, so that the best paying and most influential jobs in the global technoscientific economy remain in the hands of men (Cockburn 1985; Faulkner 2000).

2. Critiquing distortions and misrepresentations of women's minds and bodies in medical and scientific research and development (i.e., documenting the social construction of knowledge)

Section 2 is dedicated to providing exemplars of studies documenting the social construction of knowledge as evident in language, evolutionary theory, neurobiology, and the history, development, and use of technologies of the body. These articles argue for the importance of understanding the value of a feminist perspective to unraveling many of the most insidious elements of hegemonic masculinity—insidious because they are barely visible in a backdrop of claims to objectivity. Among the readings are two favorite classics from earlier editions of this textbook: Carol Cohn's groundbreaking (and still relevant) study of the language of defense intellectuals and Rachel Maine's history of the electromechanical vibrator as a socially camouflaged technology. Both articles raise provocative questions about how we "talk" about taboo topics and how language practices silence or mask discussion of topics critical to health and well-being. Two articles explore technologies related to menstruation, a quintessentially female biological process. Jennifer Aengst and Linda L. Layne detail and review debates about menstrual suppression as an "enhancement technology." Chikako Takeshita takes on the development and adoption of IUDs (intrauterine devices), providing a case study of a device that has many meanings, promoted by public health initiatives with purposes that range from providing new options for women to finding new ways to control women's choices. Both articles develop their arguments in the context of global perspectives and the diverse reproductive health needs of women.

In addition, readings in section 2 explore the consequences of unexamined, implicit, and problematic definitions of "nature" and "the natural" in relation to women's bodies and minds. Erika Lorraine Milam's essay follows a trail of shifting stereotypes through the development and application of evolutionary theory to understanding animal and human behavior, specifically sexual selection. Milam's account is a compelling reminder of the ways in which theories are social constructs, that at any given historical moment a theory's guiding concepts, misconceptions, insights, and underlying assumptions are deeply entangled with a host of debates about related questions; in this case, questions such as "What does it mean to be human?" "What is instinct?" "What distinguishes humans from (other) animals?" Rebecca M. Jordan-Young and Raffaella I. Rumiati bring this point home in their assessment of scientific research on the brain and sex differences. Their essay evaluates contemporary neurobiological evidence for the relevance of sex, sex differences, and sexuality in understanding the organization and function of the brain, much of it drawn from animal research. Like their trail blazing forerunner Ruth Bleier (1984), the authors demonstrate how assumptions about the significance of the two-sex system are reinscribed in research in neurobiology to reinforce the notion that there are stable and "natural" universal biological differences between women and men. As the authors point out, the practice of cataloging these differences is not an innocent one.

Deboleena Roy's account of her efforts to escape the differences paradigm in her research on hormonal activity in the brain. Her article resonates with Marta Wayne's account of becoming a feminist drosophila researcher from the first section, but Roy has elaborated her philosophical touchstones from recent feminist theory to posit premises for feminist practice in research in the natural sciences. Her approach includes, among other elements, an aversion to killing animals, which required her to challenge prevailing attitudes and practices but advanced her training and research productivity in keeping with her values. This is a hopeful essay, because it opens the door to feminist pathways to become and be a scientist.

3. Exploring technoscientific innovations as both colluding and colliding with the sex/gender/sexuality nexus

Readings in section 3 reflect feminist science studies scholars' commitment to interrogating the notion that technoscientific advances emerge culture-free and have no intrinsic political or cultural meaning. We have brought these readings together in order to promote discussions about the extent to which investment of intellectual and social resources in these advances drives perpetuation of the binary sex/gender system. These essays provide specific instances in which ideas about sex and gender are, or are not, relevant to foundational knowledge about human biology, knowledge made possible by new technologies. The section launches with Ruth Hubbard's effort to distinguish the ideological content of molecular genetics from the gender ideology that shaped the careers of two major contributors—Rosalind Franklin and Barbara McClintock. She contests the notion that women and men "do science" differently (i.e., x-ray diffraction techniques and microscopes are tools of the trade, no matter who uses them), making the point that there are irreducible facts to be uncovered and that one's sex or gender has little to do with their validity or reliability.

Anne Fausto-Sterling's essay similarly takes an empiricist stand but complicates the arguments considerably by proposing that "our bodies physically imbibe culture." She points to research on human bone development that documents the ongoing influence of social determinants on global differences in bone health, including culturally distinct diets, exercise patterns, physical activities, drug use, aging patterns, and access to health care, among others. Fausto-Sterling posits a systems model for understanding bone development, a model that sees sex and gender as embedded elements of social determinants rather than biological ones.

Challenges to presuming that nature and culture exist as neatly distinguishable opposites continue in the next two articles, one by Rajani Bhatia and one by Dorothy E. Roberts. Bhatia tracks the commercialization and medicalization of reproduction, and the commodification of children, in the growth of sex-selection practices globally and in the United States. Her study provides a compelling example of the ways in which new reproductive technologies are disrupting taken-for-granted notions of who, how, and why people become parents, highlighting the "ability of humans to self-determine biologies and thereby identities, subjectivities, and destinies."

One particular innovation in reprogenetics, preimplantation genetic diagnosis (PGD), makes it possible to biopsy a single cell from early embryos, enabling physicians to screen for hundreds of genetic conditions while making decisions about which embryos to implant in assisted conceptions. Dorothy E. Roberts explores the legal, economic, and social implications of this technology, with attention to race, class, and gender inequalities. She raises an alarm about the growth of a global high-tech fertility industry that brings wealthy clients to tourist destinations in order to shop for the reproductive options they seek. This trend, she argues, does not erode race, class, and gender divisions; rather, it reinforces them by exploiting the notion that race categories are "natural" and "biological" and by appropriating the reproductive capacities of economically disadvantaged women of color to fulfill the parenting dreams of the world's wealthy.

The concluding article in this section recounts the intellectual history of research on the X chromosome. Sarah S. Richardson traces scientific and popular accounts of the X as the "female chromosome" from sex chromosome science in the early twentieth century through contemporary debates about X-mosaicism in autoimmune diseases among women. This is a fascinating account of the ways in which commitments to an ideology of sex differences has driven, distorted, and contained characterizations of the physiological functions on the X chromosome. Changes over time in these characterizations drew from whatever paternalistic, progressive, or misogynist stereotypes of women were in vogue. Richardson's study is a somber reminder that researchers who have no exposure to the critical and self-reflexive practices of feminist science are unlikely to escape the limitations of the intellectual legacy they inherit.

4. Reflecting on the limitations and possibilities of borderlands in feminist science theory

In section 4 authors reach out to feminist frameworks from a wide variety of (inter)disciplinary approaches—including cybermedia studies, material culture studies, queer studies, lesbian studies, labor studies, and postcolonial studies—to describe the current limitations of feminist science studies and to identify newly useful concepts and approaches. The essays touch on themes such as fostering dependence on Western technologies as if they were necessarily beneficial to humankind, the ways in which gender matters especially when women are erased from the calculation of who is human, the emergence of biotechnologies in global domination practices, and the importance of embracing "epistemological pluralism" as an unsettling but productive engagement with the complexities of building knowledge systems that are not Eurocentric or colonialist.

Jesse Daniels opens the section with an overview of cyberfeminist claims to the liberatory potential of digital technologies, describing the tensions between theorists who celebrate disembodied identities as escaping oppressive conditions and theorists who see cyberspace as a new platform for the reassertion of race, gender, and class power relations. Francesca Bray defines the overarching goal of feminist technology studies (as distinct from feminist science studies) as an effort to analyze how technologies are implicated in gender inequalities in order to work toward more democratic forms of technology, emphasizing the coproduction of technology with gender for specific innovations. Bray proposes that adoption of anthropological approaches to studying material culture, in particular the concept of sociotechnical systems, would enhance our ability to see how technologies travel with gender politics across time and space in systems that consolidate power and resist change. This approach shifts the topic from the characteristics of the innovation/gender relation to the processes by which some technologies, but not others, can (and perhaps do) disrupt oppression.

Catharina Landström's essay points out that feminist technology studies' commitment to the notion of technology and gender as coproduced implies that technology is "gender authentic" for men, and alien to women, using a "heterosexual matrix" as the normative framework for talking about technologies (Butler 1999). Landström outlines the possibilities for rethinking technologies from a queer theory perspective to disrupt and abandon the sex/gender binary as inadequate for understanding the full range of power relations that infect women's lives. Similarly, Petra Nordqvist reviews the specific case of reproductive technologies in relation to lesbian conception, noting the ways in which lesbians' use of reproductive technologies presents a challenge to the heteronormative undercurrents of feminist studies of infertility, conception, and reproduction.

The last two essays in this section, one by Catherine Waldby and Melinda Cooper, and the other by Sandra Harding, underscore the importance of transnational perspectives in theory and research on the global impacts of Western scientific and technological innovation. Waldby and Cooper tell a harrowing story about the emergence of a new and largely unregulated bioeconomy that appropriates tissue from women's bodies for stem cell research. We close with Harding's call for coalition between postcolonial and feminist science studies because she adeptly reminds us that although women face threats (global and local) to health and safety that we dared not imagine ten years ago, the best path forward may require us to engage with the uncertainty of it all.

5. Thinking about how prevailing paradigms (principally the nature/nurture dichotomy, but also male/female, human/animal, science/technology) can direct or contain new insights

Feminist science studies began as a critique of deeply flawed scientific claims to objectivity and a thorough examination of the social embeddedness of all knowledge-making activity. Trends in feminist theory in the past decade are reshaping feminist science studies, provoking efforts to develop critical, methodological, and thematic directions that take seriously the dismantling of the sex/gender system. There are several streams to these new directions, but they share a renewed commitment to building the kind of "better knowledge" that perhaps most feminists endorse; that is, one that is fully inclusive of women in all our global diversity, recognizes the multiplicity and simultaneity of social identities and sexualities, and envisions agentic and emerging social actors and selves in context. These new directions are unruly interdisciplinary forces that do not sit comfortably within traditional disciplines and can wreak havoc with conventional definitions of objectivity, detachment, and evidence. Psychology of gender, as one instance, is facing the troubling specter of complicity in generating catalogs of findings about gender differences that may be methodological artifacts (Crawford 2012; Magnusson and Marecek 2012; Shields 2008). Is there a *There* there if gender identities are emergent in social interaction? Are the tangible and material constraints faced by those who are systematically marginalized so inconstant and ephemeral that they escape patterned stabilities? As Donna Haraway puts it, our "problem is how to have *simultaneously* an account of radical historical contingency for all knowledge claims and knowing subjects, a critical practice for recognizing our own 'semiotic technologies' for making meanings, *and* a no-nonsense commitment to faithful accounts of a 'real' world." Such a rethinking of prevailing paradigms of objectivity surely requires contesting (even abandoning) disciplinary boundaries.

The essays included in section 5 reflect the trends, directions, and challenges of such new directions in feminist science studies. Taken together, they evoke conversations about how to best represent the natural world and our active community investments in those representations—the priorities we set, questions we ask, language we use, standards of evidence we require, and the limitations of our analytic tools. The section ends the book with a hopeful essay by Niamh Moore, who reminds us that feminism has a long and enduring history of collective action, however fragmented or diffuse it may seem from time to time.

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On an ending note of collective action, then, this book stands as a call to action for rededication to curriculum transformation efforts that fully embrace feminist science and technology studies within and outside of women's and gender studies. One early premise in the push in the 1990s was that teaching "people-less" STEM courses suppressed or diverted the interests of everyone who valued STEM research and innovation as catalysts for improving human health and well-being (Musil 2001; Rosser 1995, 1997). This dynamic may be especially salient for women and people of color, who have been historically marginalized and excluded from education, research, and training in STEM fields. Research has demonstrated that including information about women and people of color in science classrooms improves students' knowledge about women's contributions in science and their assessment of the classroom climate (Damschen et al. 2005; Wyer et al. 2007). Energy for curriculum transformation has languished of late, and so we would like to posit a plan for steps in a national effort. First, we need to identify institutional partners and allies who have a commitment to the full participation of women and people of color in STEM. Second we need to develop a systematic process of transferring knowledge from feminist science and technology studies to other domains and departments (across the university). A third step, and one that is well underway, is to develop courses, curriculums, and concentrations that bring feminist science studies into routine interaction with STEM educators. A fourth step is to foster the conditions and climate that promote new research and knowledge within feminist science studies.

And the last (unapologetically empiricist) step is to explore and document the impacts that exposure to feminist science studies content has on student learning and interest in STEM fields. This is a worthy national project, one that provides a platform for more inclusive approaches to scientific and technological literacy and engagement. Our review of the literature, so necessary to assembling this textbook, reveals that we have a wealth of expertise, energy, and insight to offer higher education.

NOTES

1. See "The Campaign against Women," *New York Times,* May 19, 2012; "Women Buying Health Policies Pay a Penalty," *New York Times*, October 29, 2008; "Overhaul Will Lower Costs of Being a Woman," *New York Times*, March 29, 2010; "Virginia Lawmakers Vote against Women's Rights," *New York Times*, February 28, 2012; "Three Rulings against Women's Rights," *New York Times*, July 31, 2012; "Hey Baby! Women Speak Out against Street Harassment," CNN, October 6, 2012; "Male-female Pay Gap Persists and Starts Early," *New York Times,* October 24, 2012.
2. Subramaniam (2009) offers a thoughtful and useful overview that complements, but differs somewhat, from our characterization of the field.

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SECTION I

From Margins to Center: Educating Women for Scientific Careers

CHAPTER 1

Science Faculty's Subtle Gender Biases Favor Male Students

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A 2012 report from the President's Council of Advisors on Science and Technology indicates that training scientists and engineers at current rates will result in a deficit of 1,000,000 workers to meet United States workforce demands over the next decade (1). To help close this formidable gap, the report calls for the increased training and retention of women, who are starkly underrepresented within many fields of science, especially among the professoriate (2–4). Although the proportion of science degrees granted to women has increased (5), there is a persistent disparity between the number of women receiving PhDs and those hired as junior faculty (1–4). This gap suggests that the problem will not resolve itself solely by more generations of women moving through the academic pipeline but that instead, women's advancement within academic science may be actively impeded.

With evidence suggesting that biological sex differences in inherent aptitude for math and science are small or nonexistent (6–8), the efforts of many researchers and academic leaders to identify causes of the science gender disparity have focused instead on the life choices that may compete with women's pursuit of the most demanding positions. Some research suggests that these lifestyle choices (whether free or constrained) likely contribute to the gender imbalance (9–11), but because the majority of these studies are correlational, whether lifestyle factors are solely or primarily responsible remains unclear. Still, some researchers have argued that women's preference for nonscience disciplines and their tendency to take on a disproportionate amount of child- and family-care are the primary causes of the gender disparity in science (9–11), and that it "is not caused by discrimination in these domains" (10). This assertion has received substantial attention and generated significant debate among the scientific community, leading some to conclude that gender discrimination indeed does not exist nor contribute to the gender disparity within academic science (e.g., refs. 12 and 13). Despite this controversy, experimental research testing for the presence and magnitude of gender discrimination in the biological and physical sciences has yet to be conducted. Although acknowledging that various lifestyle choices likely contribute to the gender imbalance in science (9–11), the present research is unique in investigating whether faculty gender bias exists within academic biological and physical sciences, and whether it might exert an independent effect on the gender disparity as students progress through the pipeline to careers in science. Specifically, the present experiment examined whether, given an equally qualified male and female student, science faculty members would show preferential evaluation and treatment of the male student to work in their laboratory. Although the correlational and related laboratory studies discussed below suggest that such bias is likely (contrary to previous arguments) (9–11), we know of no previous experiments that have tested for faculty bias against female students within academic science.

If faculty express gender biases, we are not suggesting that these biases are intentional or stem from a conscious desire to impede the progress of women in science. Past studies indicate that people's behavior is shaped by implicit or unintended biases, stemming from repeated exposure to pervasive cultural stereotypes (14) that portray women as less competent but simultaneously emphasize their warmth and likeability compared with men (15). Despite significant decreases in overt sexism over the last few decades (particularly among highly educated people) (16), these subtle gender biases are often still held by even the most egalitarian individuals (17), and are exhibited by both men and women (18). Given this body of work, we expected that female faculty would be just as likely as male faculty to express an unintended bias against female undergraduate science students. The fact that these prevalent biases often remain undetected highlights the need for an experimental investigation to determine whether they may be present within academic science and, if so, raise awareness of their potential impact.

Whether these gender biases operate in academic sciences remains an open question. On the one hand, although considerable research demonstrates gender bias in a variety of other domains (19–23), science faculty members may not exhibit this bias because they have been rigorously trained to be objective. On the other hand, research demonstrates that people who value their objectivity and fairness are paradoxically particularly likely to fall prey to biases, in part because they are not on guard against subtle bias (24, 25). Thus, by investigating whether science faculty exhibit a bias that could contribute to the gender disparity within the fields of science, technology, engineering, and mathematics (in which objectivity is emphasized), the current study addressed critical theoretical and practical gaps in that it provided an experimental test of faculty discrimination against female students within academic science.

A number of lines of research suggest that such discrimination is likely. Science is robustly male gender-typed (26, 27), resources are inequitably distributed among men and women in many academic science settings (28), some undergraduate women perceive unequal treatment of the genders within science fields (29), and nonexperimental evidence suggests that gender bias is present in other fields (19). Some experimental evidence suggests that even though evaluators report liking women more than men (15), they judge women as less competent than men even when they have identical backgrounds (20). However, these studies used undergraduate students as participants (rather than experienced faculty members), and focused on performance domains outside of academic science, such as completing perceptual tasks (21), writing nonscience articles (22), and being evaluated for a corporate managerial position (23).

Thus, whether aspiring women scientists encounter discrimination from faculty members remains unknown. The formative predoctoral years are a critical window, because students' experiences at this juncture shape both their beliefs about their own abilities and subsequent persistence in science (30, 31). Therefore, we selected this career stage as the focus of the present study because it represents an opportunity to address issues that manifest immediately and also resurface much later, potentially contributing to the persistent faculty gender disparity (32, 33).

CURRENT STUDY

In addition to determining whether faculty expressed a bias against female students, we also sought to identify the processes contributing to this bias. To do so, we investigated whether faculty members' perceptions of student competence would help to explain why they would be less likely to hire a female (relative to an identical male) student for a laboratory manager position. Additionally, we examined the role of faculty members' preexisting subtle bias against women. We reasoned that pervasive cultural messages regarding women's lack of competence in science could lead faculty members to hold gender-biased attitudes that might subtly affect their support for female (but not male) science students. These generalized, subtly biased attitudes toward women could impel faculty to judge equivalent students differently as a function of their gender.

The present study sought to test for differences in faculty perceptions and treatment of equally qualified men and women pursuing careers in science and, if such a bias were discovered, reveal its mechanisms and consequences within academic science. We focused on hiring for a laboratory manager position as the primary dependent variable of interest because it functions as a professional launching pad for subsequent opportunities. As secondary measures, which are related to hiring, we assessed: (i) perceived student competence; (ii) salary offers, which reflect the extent to which a student is valued for these competitive positions; and (iii) the extent to which the student was viewed as deserving of faculty mentoring.

Our hypotheses were that: Science faculty's perceptions and treatment of students would reveal a gender bias favoring male students in perceptions of competence and hireability, salary conferral, and willingness to mentor (hypothesis A); Faculty gender would not influence this gender bias (hypothesis B); Hiring discrimination against the female student would be mediated (i.e., explained) by faculty perceptions that a female student is less competent than an identical male student (hypothesis C); and Participants' preexisting subtle bias against women would moderate (i.e., impact) results, such that subtle bias against women would be negatively related to evaluations of the female student, but unrelated to evaluations of the male student (hypothesis D).

RESULTS

A broad, nationwide sample of biology, chemistry, and physics professors ($n = 127$) evaluated the application materials of an undergraduate science student who had ostensibly applied for a science laboratory manager position. All participants received the same materials, which were randomly assigned either the name of a male ($n = 63$) or a female ($n = 64$) student; student gender was thus the only variable that differed between conditions. Using previously validated scales, participants rated the student's competence and hireability, as well as the amount of salary and amount of mentoring they would offer the student. Faculty participants believed that their feedback would be shared with the student they had rated (see Materials and Methods for details).

Student Gender Differences

The competence, hireability, salary conferral, and mentoring scales were each submitted to a two (student gender; male, female) × two (faculty gender; male, female) between-subjects ANOVA. In each case, the effect of student gender was significant (all $P < 0.01$), whereas the effect of faculty participant gender and their interaction was not (all $P > 0.19$). Tests of simple effects (all $d > 0.60$) indicated that faculty participants viewed the female student as less competent [$t(125) = 3.89$, $P < 0.001$] and less hireable [$t(125) = 4.22$, $P < 0.001$] than the identical male student (Figure 1.1 and Table 1.1). Faculty participants also offered less career mentoring to the female student than to the male student [$t(125) = 3.77$, $P < 0.001$]. The mean starting salary offered the female student, $26,507.94, was significantly lower than that of $30,238.10 to the male student [$t(124) = 3.42$, $P < 0.01$] (Figure 1.2). These results support hypothesis A.

In support of hypothesis B, faculty gender did not affect bias (Table 1.1). Tests of simple effects (all $d < 0.33$) indicated that female faculty participants did not rate the female student as more competent [$t(62) = 0.06$, $P = 0.95$] or hireable [$t(62) = 0.41$, $P = 0.69$] than did male faculty. Female faculty also did not offer more mentoring [$t(62) = 0.29$, $P = 0.77$] or a higher salary [$t(61) = 1.14$, $P = 0.26$] to the female student than did their male colleagues. In addition, faculty participants' scientific field, age, and tenure status had no effect (all $P > 0.53$). Thus, the bias appears pervasive among faculty and is not limited to a certain demographic subgroup.

Mediation and Moderation Analyses

Thus far, we have considered the results for competence, hireability, salary conferral, and mentoring separately to demonstrate the converging results across these individual measures. However, composite indices of measures that converge on an underlying construct are more statistically reliable, stable, and resistant to error than are each

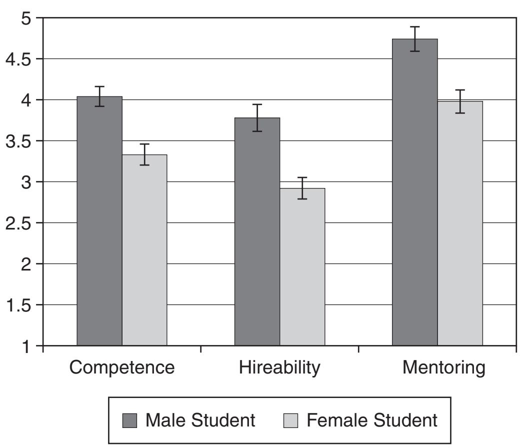

Figure 1.1 Competence, hireability, and mentoring by student gender condition (collapsed across faculty gender). All student gender differences are significant ($P < 0.001$). Scales range from 1 to 7, with higher numbers reflecting a greater extent of each variable. Error bars represent SEs. ^{n}male student condition = 63, ^{n}female student condition = 64.

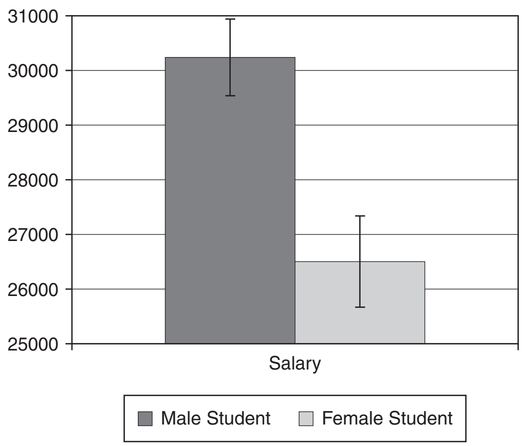

Figure 1.2 Salary conferral by student gender condition (collapsed across faculty gender). The student gender difference is significant ($P < 0.01$). The scale ranges from $15,000 to $50,000. Error bars represent SEs. ^{n}male student condition = 63, ^{n}female student condition = 64.

Table 1.1 Means for student competence, hireability, mentoring and salary conferral by student gender condition and faculty gender

	Male target student				Female target student				
	Male faculty		Female faculty		Male faculty		Female faculty		
Variable	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*	*d*
Competence	4.01^{a}	(0.92)	4.1^{a}	(1.19)	3.33^{b}	(1.07)	3.32^{b}	(1.10)	0.71
Hireability	3.74^{a}	(1.24)	3.92^{a}	(1.27)	2.96^{b}	(1.13)	2.84^{b}	(0.84)	0.75
Mentoring	4.74^{a}	(1.11)	4.73^{a}	(1.31)	4.00^{b}	(1.21)	3.91^{b}	(0.91)	0.67
Salary	$30{,}520.83^{a}$	(5,764.86)	$29{,}333.33^{a}$	(4,952.15)	$27{,}111.11^{b}$	(6,948.58)	$25{,}000.00^{b}$	(7,965.56)	0.60

Scales for competence, hireability, and mentoring range from 1 to 7, with higher numbers reflecting a greater extent of each variable. The scale for salary conferral ranges from $15,000 to $50,000. Means with different subscripts within each row differ significantly ($P < 0.05$). Effect sizes (Cohen's *d*) represent target student gender differences (no faculty gender differences were significant, all $P > 0.14$). Positive effect sizes favor male students. Conventional small, medium, and large effect sizes for *d* are 0.20, 0.50, and 0.80, respectively (51). ^{n}male student condition = 63, ^{n}female student condition = 64. ***$P < 0.001$.

of the individual items (e.g., refs. 34 and 35). Consistent with this logic, the established approach to measuring the broad concept of target competence typically used in this type of gender bias research is to standardize and average the competence scale items and the salary conferral variable to create one composite competence index, and to use this stable convergent measure for all analyses (e.g., refs. 36 and 37). Because this approach obscures mean salary differences between targets, we chose to present salary as a distinct dependent variable up to this point, to enable a direct test of the potential discrepancy in salary offered to the male and female student targets. However, to rigorously examine the processes underscoring faculty gender bias, we reverted to standard practices at this point by averaging the standardized salary variable with the competence scale items to create a robust composite competence variable ($\alpha = 0.86$). This composite competence variable was used in all subsequent mediation and moderation analyses.

Evidence emerged for hypothesis C, the predicted mediation (i.e., causal path; see SI Materials and Methods: Additional Analyses for more information on mediation and the results of additional mediation analyses). The initially significant impact of student gender on hireability ($\beta = -0.35$, $P < 0.001$) was reduced in magnitude and dropped to nonsignificance ($\beta = -0.10$, $P = 0.13$) after accounting for the impact of student composite competence (which was a strong predictor, $\beta = 0.69$, $P < 0.001$), Sobel's $Z = 3.94$, $P < 0.001$ (Figure 1.3). This pattern of results provides evidence for full mediation, indicating that the female student was less likely to be hired than the identical male because she was viewed as less competent overall.

We also conducted moderation analysis (i.e., testing for factors that could amplify or attenuate the demonstrated effect) to determine the impact of faculty participants'

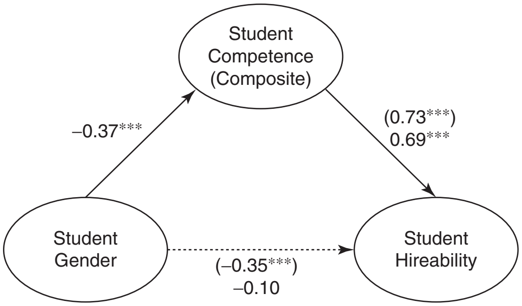

Figure 1.3 Student gender difference hiring mediation. Values are standardized regression coefficients. The value in parentheses reflects a bivariate analysis. The dashed line represents the mediated path. The composite student competence variable consists of the averaged standardized salary variable and the competence scale items. Student gender is coded such that male = 0, female = 1. ^{n}male student condition = 63, ^{n}female student condition = 64. ***$P < 0.001$

preexisting subtle bias against women on faculty participants' perceptions and treatment of male and female science students (see SI Materials and Methods: Additional Analyses for more information on and the results of additional moderation analyses). For this purpose, we administered the Modern Sexism Scale (38), a well-validated instrument frequently used for this purpose (SI Materials and Methods). Consistent with our intentions, this scale measures unintentional negativity toward women, as contrasted with a more blatant form of conscious hostility toward women. Results of multiple regression analyses indicated that participants' preexisting subtle bias against women significantly interacted with student gender to predict perceptions of student composite competence ($\beta = -0.39$, $P < 0.01$), hireability ($\beta = -0.31$, $P < 0.05$), and mentoring ($\beta = -0.55$, $P < 0.001$). To interpret these significant interactions, we examined the simple effects separately by student gender. Results revealed that the more preexisting subtle bias participants exhibited against women, the less composite competence ($\beta = -0.36$, $P < 0.01$) and hireability ($\beta = -0.39$, $P < 0.01$) they perceived in the female student, and the less mentoring ($\beta = -0.53$, $P < 0.001$) they were willing to offer her. In contrast, faculty participants' levels of preexisting subtle bias against women were unrelated to the perceptions of the male student's composite competence ($\beta = 0.16$, $P = 0.22$) and hireability ($\beta = 0.07$, $P = 0.59$), and the amount of mentoring ($\beta = 0.22$, $P = 0.09$) they were willing to offer him. [Although this effect is marginally significant, its direction suggests that faculty participants' preexisting subtle bias against women may actually have made them more inclined to mentor the male student relative to the female student (al-though this effect should be interpreted with caution because of its marginal significance).] Thus, it appears that faculty participants' preexisting subtle gender bias undermined support for the female student but was unrelated to perceptions and treatment of the male student. These findings support hypothesis D.

Finally, using a previously validated scale, we also measured how much faculty participants liked the student (see SI Materials and Methods). In keeping with a large body of literature (15), faculty participants reported liking the female (mean = 4.35, SD = 0.93) more than the male student [(mean = 3.91, SD = 0.1.08), $t(125) = -2.44$, $P < 0.05$]. However, consistent with this previous literature, liking the female student more than the male student did not translate into positive perceptions of her composite competence or material outcomes in the form of a job offer, an equitable salary, or valuable career mentoring. Moreover, only composite competence (and not likeability) helped to explain why the female student was less likely to be hired; in mediation analyses, student gender condition

($\beta = -0.48$, $P < 0.001$) remained a strong predictor of hireability along with likeability ($\beta = 0.60$, $P < 0.001$). These findings underscore the point that faculty participants did not exhibit outright hostility or dislike toward female students, but were instead affected by pervasive gender stereotypes, unintentionally downgrading the competence, hireability, salary, and mentoring of a female student compared with an identical male.

DISCUSSION

The present study is unique in investigating subtle gender bias on the part of faculty in the biological and physical sciences. It therefore informs the debate on possible causes of the gender disparity in academic science by providing unique experimental evidence that science faculty of both genders exhibit bias against female undergraduates. As a controlled experiment, it fills a critical gap in the existing literature, which consisted only of experiments in other domains (with undergraduate students as participants) and correlational data that could not conclusively rule out the influence of other variables.

Our results revealed that both male and female faculty judged a female student to be less competent and less worthy of being hired than an identical male student, and also offered her a smaller starting salary and less career mentoring. Although the differences in ratings may be perceived as modest, the effect sizes were all moderate to large ($d = 0.60$–0.75). Thus, the current results suggest that subtle gender bias is important to address because it could translate into large real-world disadvantages in the judgment and treatment of female science students (39). Moreover, our mediation findings shed light on the processes responsible for this bias, suggesting that the female student was less likely to be hired than the male student because she was perceived as less competent. Additionally, moderation results indicated that faculty participants' preexisting subtle bias against women undermined their perceptions and treatment of the female (but not the male) student, further suggesting that chronic subtle biases may harm women within academic science. Use of a randomized controlled design and established practices from audit study methodology support the ecological validity and educational implications of our findings (SI Materials and Methods).

It is noteworthy that female faculty members were just as likely as their male colleagues to favor the male student. The fact that faculty members' bias was independent of their gender, scientific discipline, age, and tenure status suggests that it is likely unintentional, generated from widespread cultural stereotypes rather than a conscious intention to harm women (17). Additionally, the fact that faculty participants reported liking the female more than the male student further underscores the point that our results likely do not reflect faculty members' overt hostility toward women. Instead, despite expressing warmth to-ward emerging female scientists, faculty members of both genders appear to be affected by enduring cultural stereotypes about women's lack of science competence that translate into biases in student evaluation and mentoring.

Our careful selection of expert participants revealed gender discrimination among existing science faculty members who interact with students on a regular basis (SI Materials and Methods: Subjects and Recruitment Strategy). This method allowed for a high degree of ecological validity and generalizability relative to an approach using nonexpert participants, such as other undergraduates or lay people unfamiliar with laboratory manager job requirements and academic science mentoring (i.e., the participants in much psychological research on gender discrimination).

The results presented here reinforce those of Stenpries, Anders, and Ritzke (40), the only other experiment we know of that recruited faculty participants. Because this previous experiment also indicated bias within academic science, its results raised serious concerns about the potential for faculty bias within the biological and physical sciences, casting further doubt on assertions(based on correlational data) that such biases do not exist (9–11). In the Steinpreis et al. experiment, psychologists were more likely to hire a psychology faculty job applicant when the applicant's curriculum vitae was assigned a male (rather than female) name (40). This previous work invited a study that would extend the finding to faculty in the biological and physical sciences and to reactions to undergraduates, whose competence was not already fairly established by accomplishments associated with the advanced career status of the faculty target group of the previous study. By providing this unique investigation of faculty bias against female students in biological and physical sciences, the present study extends past work to a critical early career stage, and to fields where women's underrepresentation remains stark (2–4).

Indeed, our findings raise concerns about the extent to which negative predoctoral experiences may shape women's subsequent decisions about persistence and career specialization. Following conventions established in classic experimental studies to create enough ambiguity to leave room for potentially biased responses (20, 23), the student applicants in the present research were described as qualified to succeed in academic science (i.e., having coauthored a publication after obtaining 2 years of research experience), but not irrefutably excellent. As such, they represented a majority of aspiring scientists, and were precisely the type of students most affected by faculty judgments and mentoring (see SI Materials and Methods for more discussion). Our results raise the possibility that not only do such women encounter biased judgments of their competence and hireability, but also receive less faculty encouragement and financial rewards than identical male counterparts. Because most students depend on feedback from their environments to calibrate their own worth (41), faculty's assessments of students' competence likely contribute to students' self-efficacy and goal setting as scientists, which may influence decisions much later in their careers. Likewise, inasmuch as the advice and mentoring that students receive affect their ambitions and choices, it is significant that the faculty in this study were less inclined to mentor women than men. This finding raises the possibility that women may opt out of academic science careers in part because of diminished competence judgments, rewards, and mentoring received in the early years of the careers. In sum, the predoctoral years represent a window during which students' experiences of faculty bias or encouragement are particularly likely to shape their persistence in academic science (30–33). Thus, the present study not only fills an important gap in the research literature, but also has critical implications for pressing social and educational issues associated with the gender disparity in science.

If women's decisions to leave science fields when or before they reach the faculty level are influenced by unequal treatment by undergraduate advisors, then existing efforts to create more flexible work settings (42) or increase women's identification with science (27) may not fully alleviate a critical underlying problem. Our results suggest that academic policies and mentoring interventions targeting undergraduate advisors could contribute to reducing the gender disparity. Future research should evaluate the efficacy of educating faculty and students about the existence and impact of bias within academia, an approach that has reduced racial bias among students (43). Educational efforts might address research on factors that attenuate gender bias in real-world settings, such as increasing women's self-monitoring (44). Our results also point to the importance of establishing objective, transparent student evaluation and admissions criteria to guard against observers' tendency to unintentionally use different standards when assessing women relative to men (45, 46). Without such actions, faculty bias against female undergraduates may continue to undermine meritocratic advancement, to the detriment of research and education.

CONCLUSIONS

The dearth of women within academic science reflects a significant wasted opportunity to benefit from the capabilities of our best potential scientists, whether male or female. Although women have begun to enter some science fields in greater numbers (5), their mere increased presence is not evidence of the absence of bias. Rather, some women may persist in academic science despite the damaging effects of unintended gender bias on the part of faculty. Similarly, it is not yet possible to conclude that the preferences for other fields and lifestyle choices (9–11) that lead many women to leave academic science (even after obtaining advanced degrees) are not themselves influenced by experiences of bias, at least to some degree. To the extent that faculty gender bias impedes women's full participation in science, it may undercut not only academic meritocracy, but also the expansion of the scientific workforce needed for the next decade's advancement of national competitiveness (1).

MATERIALS AND METHODS

Participants

We recruited faculty participants from Biology, Chemistry, and Physics departments at three public and three private large, geographically diverse research-intensive universities in the United States, strategically selected for their representative characteristics (see SI Materials and Methods for more information on department selection). The demographics of the 127 respondents corresponded to both the averages for the selected departments and faculty at all United States research-intensive institutions, meeting the criteria for generalizability even from nonrandom samples (see SI Materials and Methods for more information on recruitment strategy and participant characteristics). Indeed, we were particularly careful to obtain a sample representative of the underlying population, because many past studies have demonstrated that when this is the case, respondents and nonrespondents typically do not differ on demographic characteristics and responses to focal variables (47).

Additionally, in keeping with recommended practices, we conducted an a priori power analysis before beginning data collection to determine the optimal sample size needed to detect effects without biasing results toward obtaining significance (SI Materials and Methods: Subjects and Recruitment Strategy) (48). Thus, although our sample size may appear small to some readers, it is important to note that we obtained the necessary power and representativeness to generalize from our results while purposefully avoiding an unnecessarily large sample that could have biased our results toward a false-positive type I error (48).

Procedure

Participants were asked to provide feedback on the materials of an undergraduate science student who stated their intention to go on to graduate school, and who had recently applied for a science laboratory manager position. Of importance, participants believed they were evaluating a real student who would subsequently receive the faculty participants' ratings as feedback to help their career development (see SI Materials and Methods for more information, and for the full text of the cover story). Thus, the faculty participants' ratings were associated with definite consequences.

Following established practices, the laboratory manager application was designed to reflect high but slightly ambiguous competence, allowing for variability in participant responses (20, 23). In addition, a promising but still-nascent applicant is precisely the type of student whose persistence in academic science is most likely to be affected by faculty support or discouragement (30–33), rendering faculty reactions to such a student of particular interest for the present purposes. The materials were developed in consultation with a panel of academic science researchers (who had extensive experience hiring and supervising student research assistants) to ensure that they would be perceived as realistic (SI Materials and Methods). Results of a funneled debriefing (49) indicated that this was successful; no participant reported suspicions that the target was not an actual student who would receive their evaluation.

Participants were randomly assigned to one of two student gender conditions: application materials were attributed to either a male student (John, $n = 63$), or a female student (Jennifer, $n = 64$), two names that have been pretested as equivalent in likability and recognizeability (50). Thus, each participant saw only one set of materials, from either the male or female applicant (see SI Method and Materials for more information on all materials). Because all other information was held constant between conditions, any differences in participants' responses are attributable to the gender of the student. Using validated scales, participants rated student competence, their own likelihood of hiring the student, selected an annual starting salary for the student, indicated how much career mentoring they would provide to such a student, and completed the Modern Sexism Scale.

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CHAPTER 2

Snow Brown and the Seven Detergents

A Metanarrative on Science and the Scientific Method

Banu Subramaniam

Once upon a time, deep within a city in the Orient, lived a young girl called Snehalatha Bhrijbhushan. She spent her childhood merrily playing in the streets with her friends while her family and the neighbors looked on indulgently. "That girl, Sneha [as they called her], is going to become someone famous someday," they would all say. Sneha soon became fascinated with the world of science. One day she announced, "I am going to sail across the blue oceans to become a scientist!"

There was silence in the room. "You can be a scientist here, you know."

"But I want to explore the world," said Sneha. "There is so much to see and learn."
"Where is this place?" they asked.

"It's called the Land of the Blue Devils."

"But that is dangerous country," they cried. "No one has ever been there and come back alive."

"Yes, I know," said Sneha. "But I have been reading about it. It is in the Land of the Kind and Gentle People. In any case, I can handle it."

Her friends and family watched her animated face and knew that if anyone could do it, it would be brave Sneha, and so they relented. The city watched her set out and wished her a tearful farewell. She promised to return soon and bring back tales from lands afar. For forty-two days and nights Sneha sailed the oceans. Her face was aglow with excitement, and her eyes were filled the stars. "It's going to be wonderful," she told herself.

And so one fine day she arrived in the Land of the Blue Devils. She went in search of the Building of Scientific Truth. When she saw it, she held her breath. There it stood, tall and slender, almost touching the skies. Sneha shivered. "Don't be silly," she told herself. She entered the building. The floors were polished and gleaming white. It all looked so grand and yet so formidable. She was led into the office of the Supreme White Patriarch. The room was full. "Welcome, budding Patriarchs," he said, "from those of us in the Department of the Pursuit of Scientific Truth. But let me be perfectly frank. These are going to be difficult years ahead. This is no place for the weak or the emotional or the fickle. You have to put in long, hard hours. If you think you cannot cut it, you should leave now. Let me introduce you to our evaluation system. Come with me."

He led them across the hall into a huge room. At the end of the room stood a mirror, long and erect and oh so white. "This is the Room of Judgment," he continued. "The mirror will tell you how you're doing. Let me show you." He went to the mirror and said, "Mirror, mirror on the wall, who is the fairest scientist of them all?"

"You are, O Supreme White Patriarch!" said the mirror.

The Patriarch laughed. "That is what all of you should aspire to. And one day when it calls out your name, you will take my place. But until then, you will all seek Truth and aspire to be number one. We want fighters here, Patriarchs with initiative and genius. And as for those who are consistently last in the class for six months . . . well, we believe they just do not have the ability to pursue Scientific Truth, and they will be expelled. Go forth, all ye budding Patriarchs, and find Scientific Truth."

Everyone went their way. Sneha found herself in the middle of the hallway all alone. "Go find Truth?" she said to herself. Was this a treasure hunt? Did Truth fall from the sky? She was very confused. This was not what she had thought it would be like. She went looking for her older colleagues. "Where does one find Scientific Truth?" she asked.

"Well," said he, "first you have to find the patronage of an Associate Patriarch or an Assistant Patriarch. You will have a year to do that. Until then, you take courses they teach you and you learn about Truths already known and how to find new Truths. During this time you have to learn how to be a scientist. That is very important, but don't worry, the mirror will assist you."

"How does the mirror work?" asked Sneha.

"Well, the mirror is the collective consciousness of all the Supreme White Patriarchs across the Land of the Kind and Gentle People. They have decided what it takes to be the ideal scientist, and it is what we all must dream of and aspire and work toward if we want to find Scientific Truth. You must check with the mirror as often as you can to monitor your progress."

Sneha tiptoed to the Room of Judgment, stood in front of the mirror, and said, "Mirror, mirror on the wall, who is the fairest scientist of them all?"

The mirror replied, "Not you, you're losing this game, you with the unpronounceable name!"

Sneha was very depressed. Things were not going as she had expected. "Oh, mirror," she cried, "everything has gone wrong. What do I do?"

"More than anything," said the mirror, "you have to learn to act like a scientist. That's your first task. Deep within the forests lives the Wise Matriarch in the House of the Seven Detergents. Go see her, she will help you."

Sneha set out to meet the Wise Matriarch. "Come in, child," she said. "What seems to be the problem?" She appeared to be a very kind woman, and Sneha poured out her misery.

"I know this is a very difficult time for you, but it is also a very important one," the Matriarch said.

"Why do they call you the Wise Matriarch?" Sneha inquired.

"I joined the Department of the Pursuit of Scientific Truth some twenty years ago," the Matriarch replied. "That is why I understand what you're going through. I was expelled. When the department offered me this position, I felt I could begin changing things. Over the years I have advised many budding Patriarchs. You could say I've earned my reputation.

"My child," she went on, "this is where the department sends its scientific misfits. Let me show you what they would like me to have you do." She led Sneha to a room, and in it stood seven jars. "These are the seven detergents," she said. "With them you can wash away any part of yourself you don't want. But the catch is that once you wash it away, you have lost it forever."

Sneha was excited. "First I'd like to get rid of my name and my accent. The mirror told me that."

The Wise Matriarch shook her head, "My child, do not give away your identity, your culture—they are part of you, of who you are," she cried.

"But," said Sneha, "I've always dreamed of being a scientist. I spent all my savings coming here, and I cannot go back a failure. This is truly what I want." Sneha got into the Great Washing Machine with the first detergent. *Rub-a-dub-a-dub, rub-a-dub-a-dub,* went the detergent.

"You may come out now, Snow Brown. Good luck."

Snow Brown went back amazed at how differently her tongue moved. For the next week she met the other budding Patriarchs, decided on her courses, and went out socializing with her colleagues. But everything was new in this land: how people ate and drank, even what people ate and drank. She felt stupid and ignorant. And just as she expected, when she went to the mirror, it told her that such behavior was quite unscientific and that she had to learn the right etiquette. Off she went again to the House of the Seven Detergents and used two other detergents that worked their miracles in the Great Washing Machine.

"Now I act like everyone else," she said, satisfied.

Snow Brown went to her classes. She thought them quite interesting. But the professors never looked her in the eye and never asked for her opinions. "Maybe they think I'm stupid," she said to herself. In class discussions everyone spoke up. Some of the things they said were pretty stupid, she thought. And so she would gather up her courage and contribute. She was met with stony silence. On some occasions others would make the same point, and the professor would acknowledge it and build on it.

She knew the mirror would be unhappy with her, and sure enough, she was right. "You have to be more aggressive," it said. "It doesn't matter so much what you say as how you say it."

"But that's ridiculous," she said. "Most of what is said is just plain dumb. Have you listened to some of them? They like the sound of their voices so much."

"That may be true, but that is the way. You have to make an impression, and sitting and listening like a lump of clay is not the way. And another thing—why did you let the others operate the machine in the lab? You have to take initiative."

"That was a ten-thousand-dollar machine. What if I broke it? I've never used it before." "Leave your Third World mentality behind. The Patriarchs see it as a lack of initiative.

They think you are not interested. You have to shoot for number one, be the very best. You have to act like a scientist, like a winner. Girl, what you need is a good dose of arrogance and ego."

Snow Brown was a little perturbed. She was disturbed by what she saw around her. Did she really want to act like some of the people she had met? What had happened to kindness, a little humility, helping each other? Just how badly did she want this, anyway? Her family was going to hate her when she went back. They would not recognize her. She thought long and hard and finally decided to go ahead.

She went back to the House of the Seven Detergents and used the anti-Third World detergent. When the Great Washing Machine was done, she came striding out, pride oozing out of every pore. The next day the Supreme White Patriarch called for her. "So, what kind of progress are you making in your search for Scientific Truth?" he asked.

"Well," she said, "the mirror has kept me occupied with learning to act like a scientist.

Surely you can't expect me to make as much progress as the others, considering."

"We don't like students making excuses, Snow Brown. You had better make some progress, and real soon. There is no place for laziness here."

Snow Brown started developing some of her ideas. She went to the mirror to talk them over.

"I'm thinking of working with mutualisms," she said. "Organisms associate with each others in numerous ways ecologically. They can both compete for the same resources as in competition. Some live off other organisms, and that's called parasitism. When organisms get into ecological relationships with each other that are mutually beneficial, it's called mutualism."

"To be frank, Snow Brown, I would recommend studying competition or parasitism." "But most of the studies of ecological interactions have focused on them," Snow Brown said. "I am amazed that there has been so little study of mutualisms. We know of some examples, but just how prevalent mutualisms are is still up in the air. For all we know, they may be a fundamental principle that describes demographic patterns of organisms on our planet."

"Whoa! Whoa!" cried the mirror. "You're getting carried away with your emotions. We would all like a and-they-lived-happily-ever-after kind of fairy tale. You are violating one of the fundamentals of doing science—objectivity. You don't pursue a study because you think it would be 'nice.' You base it on concrete facts, data. Then you apply the scientific method and investigate the problem."

"I do agree that the scientific method may have merit," she said. "I will use it to study mutualisms. But tell me, why do you think competition has been so well studied?"

"That's because competition is so important. Just look around you," the mirror replied.

"Are the Patriarchs working with each other for their mutual benefit, or are they competing?

This is what I do—promote competition. It is nature's way."

"Aha!" cried Snow Brown triumphantly. "You throw emotionalism and subjectivity at me. Listen to yourself. You are reading into nature what you see in yourself. I happen to believe that mutualisms are very important in the world. The Patriarchs have decided to work with a particular model. It doesn't mean that it's the only way."

"Get realistic," said the mirror, laughing. "You need the patronage of an Associate or Assistant Patriarch. You need to get money from the Supreme White Patriarch to do the research. Don't forget you need to please the Patriarch to get ahead. And you are still way behind in the game. This is not the time to get radical, and you are not the person to do it."

Convinced that pragmatism was the best course, the overconfident Snow Brown developed her ideas, talked in classes, and aggressively engaged the Patriarchs in dialogue. She was supremely happy. Things were finally going her way. She went to the mirror and said, "Mirror, mirror on the wall, who is the fairest scientist of them all?"

And the mirror replied, "It sure ain't you, Snow Brown. You're still the last one in town."

Snow Brown could not believe her ears. "I act and think like everyone around me. I am even obnoxious at times. What could I possibly still be doing wrong?"

"You're overdoing it," said the mirror. "You don't know everything. You should be a little more humble and subservient."

"Am I hearing things? I don't see anyone else doing that. This place does not validate that. You told me that yourself. What is really going on here?"

"When I advised you last," answered the mirror, "I advised you the way I would advise anyone, but I've been watching how the other Patriarchs interact with you. Apparently their expectations of you are different. You're brown, remember?"

Snow Brown was furious. She stormed out and went to the House of the Seven Detergents, and the sixth detergent washed her brownness away. She was now Snow White. She marched back to the Department of Scientific Truth. All the Patriarchs stared at her. They suddenly realized that what stood before them was a woman, and a beautiful one at that.

"Well, am I white enough for the lot of you now?" she demanded.

"Oh, but you're too pretty to be a scientist," cried the Supreme Patriarch.

"You can be a technician in my lab," said another.

"No, in mine!" urged yet another.

The Wise Matriarch had been right. Sneha had now lost her whole identity, and for what? Why had she not seen this coming? she asked herself. How could she ever have been the fairest scientist? How could she have been anything but last when judged by a mirror that wanted to produce clones of the Supreme White Patriarch? She went to the House of the Seven Detergents.

"It's too late, my child," said the Wise Matriarch. "You cannot go back now. I warned you about it. I wish I had more resources to support you and others like you. I have seen this happen far too often. It is important for you to communicate this to others. You must write down what has happened to you for future generations."

Two days later they discovered Sneha's cold body on the floor of her room. Her face looked tortured. In her sunken eyes was the resigned look of someone who had nothing more to lose to the world she had come to live in. On the nightstand by her body rested a tale entitled "Snow Brown and the Seven Detergents."

ENDING 1: AND INJUSTICE PREVAILS

The Patriarchs stood around the body. "It is so sad," said one. "But she was too emotional, a very fuzzy thinker. Some people are just not meant to pursue Scientific Truth. I wish they would accept it and leave instead of creating all this melodrama."

The other Patriarchs nodded in agreement at the unfortunate event.

"There is no reason for anyone to see this story, is there?" said the Patriarch who had initially spoken.

The others concurred, and they poured the last detergent on her. When they were done, there was nothing left. No pathetic face, no ugly reminders, no evidence.

ENDING 2: INTO EMPIRICISM

Snow Brown in her subversive wisdom sent copies of her story and insights to all in the department. There were some who kept the tale alive. It soon became apparent that there were dissenters within the Patriarchy. They broke their silence, and the movement slowly grew. Scientists began forming coalitions, talking and supporting each other in forming pockets of resistance. They questioned the power inequities. Why are most Patriarchs white? Why are most of them men? Over many decades the negotiations continued. Women scientists and scientists of color rose in the power structure. The collective consciousness was now male, female, and multicolored. But it was still supreme. It was privileged. The Pursuit for Truth continued, although new Truths emerged—Truths from the perspective of women, from the black, brown, yellow, red and the white. The world had become a better place.

ENDING 3: A POSTMODERN FANTASY

The story of Snow Brown spread like wildfire. The Land of the Blue Devils was ablaze with anger and rage. The Wise Matriarch and a number of budding Patriarchs stormed the Department of the Pursuit of Scientific Truth and took it over. The mirror was brought down. The Room of Judgment was transformed into the Room of Negotiation. In their first meeting after all this occurred, the scientists sat together. "We need a different model," they said. They dismantled the positions of the Supreme White Patriarch, the Emeritus Patriarch, the Associate Patriarch, the Assistant Patriarch, and the Young Patriarch. "We will be self-governing," they decided. They debunked the myth that truth was a monolithic entity. "Truth is a myth," they said. "One person's truth is often privileged over someone else's. This is dangerous. The Patriarchs privileged their worldview over all others. This distorts knowledge and makes an accurate description of the world impossible." Together they decided they could help each other in reconstructing science and rewriting scientific knowledge. The House of the Seven Detergents was dismantled, and the detergents were rendered invisible. The new Department of Scientific Endeavor was very productive. Its faculty and students solved many problems that had eluded the world for years. They became world renowned, and their model was adopted far and wide.

If you are ever in the forests in the Land of the Blue Devils and come across the voice of an old-school scientist arguing vociferously, you know you have stumbled across the ghosts of Snow Brown and the Seven Detergents.

CHAPTER 3

State of Knowledge about the Workforce Participation, Equity, and Inclusion of Women in Academic Science and Engineering

Diana Bilimoria and Xiangfen Liang

We include science, technology, engineering, and mathematics (STEM) fields as well as the social and behavioral sciences (SBS), under the overall rubric of science and engineering (S&E). The inclusion of women in S&E is directly connected to the future composition of the nation's S&E workforce and to the continued development of a globally competitive marketplace for talent.

THE PARTICIPATION OF WOMEN IN THE SCIENCE AND ENGINEERING WORKFORCE

In the past 20 years, the proportion of women and minorities in S&E occupations has increased considerably. As indicated in Figure 3.1, college-educated women constituted 27% of S&E occupation holders in 2007, up from 22% in 1990 (Science and Engineering Indicators 2010, Figure 3.27, pp. 3–32). The proportion of women with doctoral degrees in S&E occupations was 34% in 2007, up from 23% in 1990. Among workers whose highest degree is S&E bachelor's, the share of women has risen to above 60% in social sciences and life sciences in the recent cohort 2002–2005 (National Science Foundation 2010, Figure 3.29). Similarly, among workers whose highest degree is S&E doctorate, women also remained a higher percentage in the recent cohort (2002–2005), especially in social sciences (about 60%) and life sciences (about 45%) (National Science Foundation 2010, Figure 3.30).

In the STEM professional workforce, women were 19% of all managers and 15% of top-level managers in business or industry compared with 34% of all scientists and engineers in business or industry in 2006 (National Science Foundation 2009). They constituted 8% of engineering managers and 11% of natural sciences managers. Only in medical and health services were women more than half of managers (National Science Foundation 2009).

The workforce participation of women in the STEM professions is considerably larger at lower rungs in the corporate hierarchy–41% of qualified scientists, engineers, and technologists are women–yet, over time, 52% of these women quit their jobs, not in a steady trickle, but during their mid to late thirties (Hewlett, Luce, Servon, et al. 2008). These authors provide a fivefold explanation of this massive brain drain: hostile macho cultures, isolation from being the lone woman on a team or site, systems of reward that emphasize risk-taking, extreme work pressures, and lack of clarity about career paths (Hewlett, Luce, Servon et al. 2008).

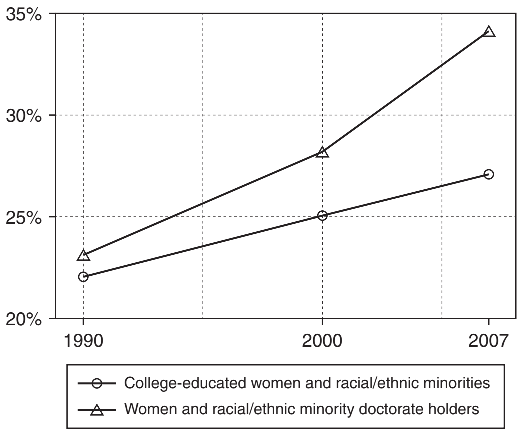

Figure 3.1 Women and racial/ethnic minorities with college or doctorate degrees in science and engineering occupations: 1990, 2000, 2007.

Source: Adapted from Figures 3–27 and 3–28, Science and Engineering Indicators 2010 (p.33), National Science Foundation.

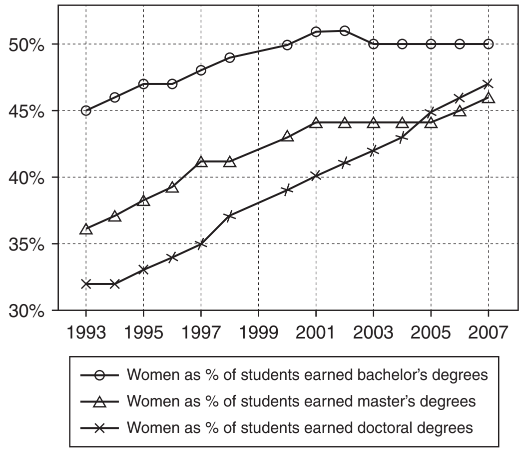

Figure 3.2 Women as a percentage of students by earned degree in S&E: 1993–2007.

Source: Data drawn from Appendix Tables 2–12, 2–26, 2–28, Science and Engineering Indicators 2010, National Science Foundation (www.nsf.gov.statistics/seind10).

THE PARTICIPATION OF WOMEN STUDENTS IN S&E FIELDS

Women also made considerable progress in obtaining S&E degrees over the years. Figure 3.2 presents the representation of women by earned degree from 1993 to 2007. In 2007, 485,772 students earned bachelor's degrees in the United States, and half of them (244,075) were women, up from 45% (165,720 out of 366,035) in 1993. Since 2000, half of the S&E bachelor degree's recipients have been women. At the graduate-school level, women students constituted 46% (54,925 out of 120, 278) of S&E master degree's recipients in 2007, up from 36% (30,971 out of 86,425) in 1993. The percentage of female students who earned S&E doctoral degrees also increased, up from 32% in 1993 to 47% in 2007.

According to Science and Engineering Indicators 2010 (National Science Foundation 2010), women earned 58% of all bachelor's degrees since 2002 and about half of all S&E bachelor's degrees since 2000, but major variations persist among fields. In 2007, men earned a majority of bachelor's degrees awarded in engineering, computer sciences, and physics (81%, 81%, and 79%, respectively) while women earned half or more of bachelor's degrees in psychology (77%), biological sciences (60%), social sciences (54%), agricultural sciences (50%), and chemistry (50%). Fields with marked increases in the proportion of bachelor's degrees awarded to women from 1993 to 2007 are earth, atmospheric, and ocean sciences (from 30% to 41%); agricultural sciences (from 37% to 50%); and chemistry (from 41% to 50%), However, women's share of bachelor's degrees in computer sciences, mathematics, and engineering has declined in recent years.

Women's participation in graduate S&E fields has also increased, Women made up 42% of S&E graduate students in 1993 and 50% in 2006, although large variations among fields persist. In 2006, women constituted the majority of graduate students in psychology (76%), medical/other life sciences (78%), biological sciences (56%), and social sciences (54%). They constituted close to half of graduate students in earth, atmospheric, and ocean sciences (47%) and agricultural sciences (48%) and more than one-third of graduate students in mathematics (37%), chemistry (40%), and astronomy (34%), Their percentages in computer sciences (25%), engineering (23%), and physics (20%) were low in 2006, although higher than in 1993 (23%, 15%, and 14%, respectively) (National Science Foundation 2010).

In 2009 women's share of engineering degrees hovered around 20% at all degree levels—17.8% of bachelor's degrees, 23% of master's degrees, and 21.2% of doctoral degrees. The percentage of women awarded doctoral degrees in engineering increased from 15.9% in 2000 to 21.2% in 2009 (Gibbons 2009). However, there is large variance by field: women's percentage of doctoral degrees varied from 12.6% in nuclear engineering to 37.7% in biomedical engineering (Gibbons 2009).

In brief, the number of female students and PhD recipients in S&E fields has been increasing in recent years. However, as the numbers presented in the next section show, these increases do not reflect corresponding increases in the number of female faculty in STEM areas, particularly at higher ranks, prompting many to refer to this phenomenon as a 'leaky pipeline' of faculty in these fields.

THE PARTICIPATION OF WOMEN FACULTY IN ACADEMIC S&E FIELDS

The job market of academic S&E disciplines has changed substantially in the past few decades. Full-time faculty positions have been declining, and postdoctoral and other full-time nonfaculty positions (e.g., research associates, adjunct appointments, and lecturers) have been increasing since the early 1970s (National Science Foundation 2010). The full-time faculty share of all academic employment was 72% in 2006, down from 88% in the early 1970s; the full-time nonfaculty share rose from 6% in 1973 to 13% in 2006; and postdocorates rose from 4% in 1973 to 9% of all academically employed S&E doctorate holders in 2006 (Science and Engineering Indicators 2010, Table 5.6, pp. 5–20). Along with these movements, women have gained an increasing share of the academic workforce composition. In 2006, 33% of all S&E doctorate holders employed in academia were women, up from 9% in 1973 (Science and Engineering Indicators 2010, Table 5.9, pp. 5–22). Women doctorate holders constituted more than half of part-time positions in academic S&E during 1993 and 2006.

In academic S&E fields, women hold a larger share of junior faculty positions than senior positions. In 2006, women constituted 25% of full-time senior faculty (full and associate professors) and 42% of full-time junior faculty (assistant professors and lecturers). Despite these gains, women are significantly more likely to hold nontenure-track positions (30% of full-time women faculty compared to 18% of men), are appointed to tenure track positions in most fields in far lower proportions than their representation in the candidate pool of doctoral degrees granted in the last decade, and are less likely to be tenured faculty than men, especially in doctoral institutions where "full-time women faculty are only half as likely as men to have tenure" (West & Curtis 2006, 10). Importantly, the percentage of women with S&E doctorates (including social and behavioral sciences) who are full-time full professors increased from 14% in 1999 to 20.6% in 2008; however, the percentage of under-represented minority S&E doctorate holders in full professor positions remained relatively flat, from 4.5% in 1999 to 5.7% in 2008 (National Science Foundation 2011).

Figure 3.3 shows the relative status of women doctorate holders by academic positions held. Overall, women doctorate

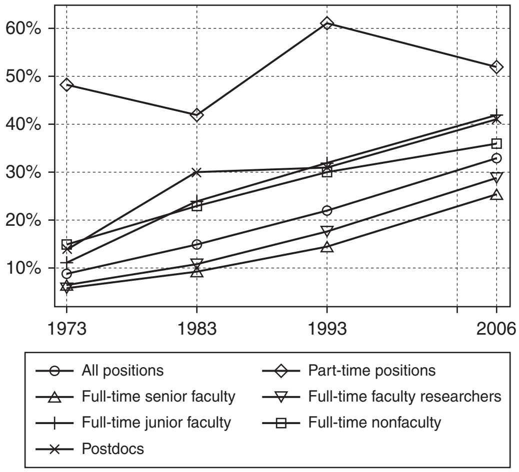

Figure 3.3 Women as a percentage of S&E doctorate holders by position in academic employment: selected years, 1973–2006.

Source: Drawn from Tables 5–9, p. 5–22, Science and Engineering Indicators 2010, National Science Foundation.

Notes: Academic employment limited to U.S. doctorate holders employed at 2- or 4-year colleges or universities. Senior faculty includes professors and associate professors. Junior faculty includes assistant professors and instructors. Full-time non-faculty includes positions such as research associates, adjunct positions, lecturers, and administrative positions. Part-time employment excludes those employed part-time because they are students or retired.

holders have made encouraging progress in occupying academic positions but they are under-represented at senior faculty positions, and moderately represented at the junior faculty positions.

Analyses of the workforce participation of women faculty reveal under representation in several STEM fields. Leboy (2008) noted that since close to half of the top ten National Institutes of Health–funded academic health centers in 2006 had no women among their junior tenure-track faculty in their biochemistry and cell biology departments, a young woman might get the impression that her shot at a faculty position in these schools would be difficult, if not out of reach. In schools of engineering, women constituted 12.7% of the tenured or tenure-track faculty in 2009 (up from 10.4% in 2004)—21.6% of assistant professors (17.9% in 2004), 14.5% of associate professors (12.4% in 2004), and 7.7% of full professors (5.8% in 2004) (Gibbons 2009). By field, the percentage of women tenured or tenure-track faculty in 2009 varied from 6% in mining engineering to 22.1% in environmental engineering (Gibbons 2009).

Academic chemistry exhibits very similar patterns of the underrepresentation of women, even though relatively more women complete doctoral degrees in chemistry. In 2003–2004, women held only 12% of all tenure-track faculty positions and only 21% of assistant professor positions at the top 50 chemistry departments (Nolan, Buckner, Kuck, & Marzabadi 2004). The American Chemical Society reported that the percentages of full-time, female, doctorate faculty members at PhD-granting universities, master's granting institutions, baccalaureate institutions, and two-year colleges were 13%, 20%, 26%, and 32%, respectively (Nolan et al. 2004).

The estimated total number of full-time faculty in mathematical sciences for 2004–2005 was 20,224, of which 5,302 (26%) were females (Kirkman, Maxwell, & Rose 2005). The number of females as a percentage of full-time faculty varied considerably among the groups in 2004, from 12% for doctoral-granting departments in private institutions to 32% for master's-granting departments. In fall 2004, the percentage of women in mathematical sciences was generally higher in statistics (26%) than in the doctoral mathematics groups (18%). Similarly, the percentage of tenured faculty who are women was highest in departments granting either a master's or a baccalaureate degree only (21%), and lowest in doctoral-granting departments (9%). Women in mathematical sciences accounted for 52% of non-doctoral full-time faculty, and 4%

of the part-time faculty in 2004. The percentage of tenured/tenure-track women faculty in mathematical sciences over the period 1998–2004 remained relatively stable (Kirkman et al. 2005).

Among S&E doctorate holders with academic faculty positions in four-year colleges and universities, females are less likely than males to be found in the full professor positions and more likely to be assistant professors (National Science Foundation 2011). This is consistent with findings from Nelson (2007), who examined the percentage of male and female tenured and tenure-track faculty in several disciplines, including S&E, at the top 50 U.S. educational institutions, based on research expenditures: few female full professors in S&E with the percentage of women among full professors ranging from 3% to 15% in different fields. Nelson (2007) also noted that in all but computer science, the rank of assistant professor has the highest percentage of female faculty. In converse, the rank which has highest percentage of male faculty is typically that of full professor, and that is the rank held by the majority of male faculty as well. Fewer differences in rank exist between male and female faculty in early-career stages in S&E, but greater differences tend to appear between 15 and 20 years after receipt of the doctorate.

Research also indicates that women are underrepresented in senior academic ranks and faculty leadership positions such as presidents, chancellors, provosts, deans, and chairs (Hollenshead 2003). This may be related to the difficulties women faculty in STEM face in academic career advancement (e.g., due to gender stereotyping and lack of mentoring) and the fact that they may not obtain the same levels of professional recognition for their scholarly work as do their male colleagues. In a comprehensive study of almost 60,000 faculty members at 403 academic institutions, Astin and Cress (2003) reported that male faculty attained tenure in a shorter amount of time than female faculty in all fields, with the exception of engineering. Other research has shown that women are less likely than men to receive tenure or promotion in STEM fields (Rosser & Daniels 2004). It has also been pointed out that the gender gap in compensation may be due in part to gender differences in rank, field (Astin and Cress 2003), and promotions (National Science Foundation 2003). As Astin and Cress (2003, 58) note, "At research universities, 25% of men are in the more highly paid fields of physical science, mathematics/statistics, and engineering combined, compared to 6% of women. Likewise, more than twice as many women (33%) as men (16%) are in the less financially lucrative fields of education, health science and humanities combined."

EDUCATIONAL ATTAINMENT AND WORKFORCE PARTICIPATION OF MINORITIES IN ACADEMIC S&E

Underrepresented minorities (blacks, Hispanics, and American Indians/Alaska Natives as a group) and Asians/Pacific Islanders earned 17.4% and 8.7% of S&E bachelor's degrees in 2008, up from 15.9% and 8.2% in 2000 (National Science Foundation 2011). Underrepresented minorities (URMs) earned 7.2% of S&E doctorates to U.S. citizens and permanent residents in 2008, up from 6% in 2000, while Asians/Pacific Islanders earned 5.8% of S&E doctorates in 2009, down from 6.2% in 2000. URM and Asian shares of S&E bachelor's and doctoral degrees have risen slightly or flattened over the last decade; more importantly, they remain a small proportion of the total (National Science Foundation 2011). Underrepresented minorities constituted 10% of all scientists and engineers in business or industry in 2006, 7% of top-level managers, and 6%–13% of managers in most S&E fields (National Science Foundation 2009).

The data regarding URM faculty in S&E are also disturbingly low. The 2010 report *A National Analysis of Minorities in Science and Engineering Faculties at Research Universities,* a comprehensive demographic analysis of tenured and tenure track faculty in the top 100 departments of science and engineering disciplines, shows that minorities are significantly underrepresented in the academic S&E pipeline (Nelson & Brammer 2010). The report concludes, "Our data reveal that URMs among our science and engineering faculty are shockingly underrepresented despite increased general growth in their representation among B.S. and Ph.D. recipients. As expected, compared to their share of the U.S. population, URMs are underrepresented at almost every point in the academic pipeline. In most disciplines, there is a drop in representation at each point measured, with a gradual decrease up to the rank of 'full' professor, where the lowest representation is found; this reflects an increase in recent hiring in those disciplines. However, in some disciplines, the representation of Blacks, Hispanics, or Native Americans, among assistant professors (the most recently hired rank) is lowest and occasionally zero" (Nelson & Brammer 2010, 18). These data provide evidence that the academic pipeline is leaky for racial/ethnic minority faculty as well.

The case of Asian Americans in academic S&E careers is a particular problem of underrepresentation (Chen & Farr 2007). While Asian Americans are a population minority (about 5%) in the United States, they are overrepresented among students and professionals in S&E, holding more than 15% of all S&E doctoral degrees (National Science Foundation 2003). As faculty at many research universities, Asian Americans are not considered to be underrepresented; rather, they constitute minorities who are not underrepresented. The *glass ceiling* is a concept reflecting the workplace barriers to workforce participation and advancement facing specific minority groups. Chen and Farr (2007) delineate four criteria for a glass ceiling: (a) the inequality represents a demographic difference (e.g., gender or race/ethnicity) that is not explained by other job-relevant characteristics of an employee (e.g., education, training, discipline, location), (b) the inequality is greater at higher levels, (c) the inequality is one of opportunity and not merely an inequality in proportions of people at high levels, and (d) the inequality increases over the trajectory of a career. These authors analyzed data over the period 1993–1999 and found the existence of a glass-ceiling effect for Asian Americans (both men and women) at all stages of their S&E careers, and confirmed the effect for all women (regardless of race) in S&E (Chen & Farr 2007). Xie and Shauman (2003) found that women immigrant scientists are more severely disadvantaged than native-born women scientists in employment and advancement, unlike male immigrant scientists in comparison with their native-born counterparts; this gender difference was attributed to differences in the migration paths taken by men and women—men scientists more likely to be primary immigrants and women scientists more likely to be secondary immigrants.

In summary, multiple sources and historical data reveal the long-standing and consistent underrepresentation of women in S&E fields. Most problematic is the low proportion of women faculty at higher levels in the academic hierarchy.

UNDERREPRESENTATION AND INDIVIDUAL DIFFERENCE EXPLANATIONS

The concept of *underrepresentation* is itself subject to multiple interpretations

(Stewart, Malley, & LaVaque-Manty 2007). Underrepresentation may mean that women should participate in every activity in society in rough proportion to their numbers in the population (about half), or it may mean that women should be expected to participate on university faculties in rough proportion to their attainment of doctoral-level degrees. Underrepresentation may occur in terms of many dimensions such as tenure status, rank or position, and leadership opportunities (Stewart et al. 2007).

Two concepts illustrate various dynamics of underrepresentation: token or solo status, and critical mass. The literature on *tokens or solos*—individuals who are the sole representatives of their group (e.g., by race, gender, rank, or tenure status)—suggests that they are perceived and treated differently than others in a work setting (Kanter 1977; Yoder & Sinnett 1985; Yoder 1991; Niemann & Dovidio 1998). Solos are more likely to be subject to stereotyping, scrutiny, and negative judgment (Thompson & Sekaquaptewa 2002), and experience greater internal stress (Bilimoria & Stewart 2009). When individuals constitute a "significant minority" and not tokens, they begin to be viewed through more individualistic and less stereotyped lenses. The phenomenon of solo and minority women faculty in academic STEM departments is widespread, especially in top research universities.

A second related concept is that of *critical mass*. The theory of critical mass suggests that a meaningful representation of women in a group facilitates their individual differentiation (thereby helping them evade token treatments, reduce performance pressures, and escape role entrapment) and increases the possibility of their forming alliances and coalitions to alter the prevailing culture (Kanter 1977). Critical mass is linked to positive educational and career outcomes. For example, Latinos/Latinas student success was found to be higher at community colleges in which they constitute more than half of students and more than a third of the faculty (Hagedorn, Chi, Cepeda, & McLain 2007). Defining critical mass departments as those with more than 15% women faculty and departments with token status as having less than 15% women faculty, Etzkowitz, Kemelgor and Uzzi (2000) found that women faculty in critical mass departments reported relationships with significantly higher levels of social support and identity enhancement, more network contacts, and more reciprocation from network contacts as compared with women faculty in departments with token status.

Similar to the definition of a critical mass of students as defined by the American Educational Research Association, Elam, Stratton, Hafferty, and Haidet (2009) suggested that a critical mass of faculty may be defined as a contextual benchmark that allows an institution to exceed token numbers within its faculty body and to promote the robust exchange of ideas and views that is central to an institution's mission. Etzkowitz, Kemelgor, Neuschatz, Uzzi, and Alonzo (1994) identified a strong minority of at least 15% as necessary fulcrum to move toward critical mass. While the specific operational definition and the contextual benchmark of a critical mass of women faculty in academic S&E is yet to be specified (Elam et al. 2009), in the field of corporate governance it has been empirically determined that while a lone woman can and often does make substantial contributions and two women are generally more powerful than one, in a small-group setting such as a corporate board it takes three or more women to achieve a critical mass that can cause a fundamental change in deliberation processes and enhance corporate governance (Kramer, Konrad, & Erkut 2006; see also Erkut, Kramer, & Konrad 2008). This study found that having a critical mass of women directors is good for corporate governance in at least three ways: different views and perspectives of multiple stakeholders are likely to be considered, difficult issues and problems are considerably less likely to be ignored or brushed aside, and discussions are more open and collaborative.

Varied explanations have been offered for the continued underrepresentation of women and girls in science and engineering fields, constituting a "culture-to-biology spectrum" (Ceci & Williams 2007, 20). At the biological-differences end of the spectrum is the proposition that girls have lower cognitive skills (specifically, certain mathematical and spatial rotation abilities) than do boys—and that these nuanced deficiencies ultimately lower women's chances of success at ensuing stages of their academic S&E careers. While specific sex-based cognitive skill differences have been cited by some to explain the low proportions of women and girls in scientific and engineering research careers (see Ceci, Williams, & Barnett 2009), it is beyond the scope of the current study and the present review to deeply delve into some of the highly nuanced merits of such arguments; we focus instead on the institutional level cultural and structural causes of women's underrepresentation and the institutional remedies that more readily yield possibilities of improvement in women's workforce participation, equity, and inclusion. Nevertheless, we acknowledge here, then Harvard University president Lawrence Summer's 2005 citation of possible innate gender differences at the extreme right end of the distribution of mathematical and spatial cognition abilities (coupled with a dismissal of rival socialization, stereotyping and unconscious bias, and institutional-barriers explanations) as sparking considerable interest and debate over the biological causes of women's underrepresentation in science.

Many have strongly refuted cognitive-difference explanations for the dearth of women in S&E on the following grounds. First, girls' scores in mathematics achievements in other countries refute arguments about the possible innate nature of observable differences in the U.S.—girls in Japan and Singapore outperform boys in the U.S. on math tests, to the extent that "The cross-national differences dwarf the sex differences" (Valian 2007, 29). Second, U.S. girls have considerably improved their scores on mathematics measures as well as their performance in undergraduate and graduate STEM fields over the past decades, indicating that the gap is not immobile (e.g., Xie & Shauman 2003). The American Association of University Women's 2010 report *Why So Few? Women in Science, Technology, Engineering and Mathematics* provides a summary of evidence that recent gains in girls' mathematical achievement demonstrate the importance of culture and learning environments in the cultivation of abilities and interests (Hill, Corbett, & St. Rose 2010). As this report states, "Thirty years ago there were 13 boys for every girl who scored above 700 on the SAT math exam at age 13; today that ratio has shrunk to about 3:1. This increase in the number of girls identified as 'mathematically gifted' suggests that education can and does make a difference at the highest levels of mathematical achievement" (Hill, Corbett, & St. Rose 2010, xiv). Third, it appears that specific kinds of spatial cognition training can elevate girls' (and boys') spatial skills (Newcombe 2007), and both test scores and career choices can be positively influenced by removal of internalized stereotypes and biases. Believing in the potential for intellectual growth, in and of itself, improves test scores and intentions to pursue STEM careers; internalized negative stereotypes about girls' and women's STEM abilities can be overcome by improving the classroom environment and individual training (Steele & Aronson 1995; Spencer, Steele, & Quinn 1999; Nguyen & Ryan 2008; see also Dweck 2007, 2008).

Other individual level differences may contribute to women's employment decisions and success, particularly their demonstration of psychosocial abilities such as self-confidence, political skills, and propensity to engage in negotiations, as compared with men's. A recent study of more than 1,300 intramural postdoctoral researchers at the National Institutes of Health documents a self-confidence gap (in the expectations of success) between women and men postdoctoral researchers (Martinez et al. 2007). This survey found that women are more likely to quit at the postdoctoral researcher to principal investigator (PI) transition on account of two reasons: (a) family responsibilities—spending time with family, plans to have children, affordable child care, travel, and proximity to spouse's workplace were some of the considerations that were weighed more heavily by women, whereas salary was more important to men, and (b) self-confidence—although men and women rated themselves equally when it came to professional skill, men were significantly more confident that they could obtain a PI position and become tenured than were women (Martinez et al. 2007). The causes of women's less optimistic outlook about their future success as PIs were not examined in this study. Rather, the investigators urged future research to examine "whether this lower confidence originates from foreseen future challenges that affect women more than men—such as child-bearing, child care, and/or a less favorable professional environment—or whether they indicate that women underestimate their professional ability" (Martinez et al. 2007). An interview-based study of 31 women engineers found that "persistent" women engineers (those who stayed in the engineering workforce for an average of 21 years) versus those who opted out (those who left the engineering workforce after an average of 12 years) demonstrated more self-efficacy in dealing with work-related issues, were more other-oriented, were more likely to adapt to the masculine engineering culture, were more engaged in engineering-related learning and professional growth, and perceived themselves as having alignment between their personal and career aspirations (Buse, Perelli, & Bilimoria 2010). In another study of 3,700 women engineering-degree holders, Fouad and Singh (2011) found that women engineers who were more self-confident in their abilities to navigate their organization's political landscape and juggle multiple life roles reported being highly satisfied with their jobs as well as their careers.

Political skills involve an individual's behaviors to gain information regarding formal and informal work relationships and power structures within an organization (Chao, O'Leary-Kelly, Wolf, Klein, & Gardner 1994). They reflect the ability to get things done by understanding and working through others outside of formally prescribed organizational mechanisms (Ferris, Davidson, & Perrewé 2005). Higher levels of political knowledge and influence behaviors are associated with increases in annual salaries (Judge & Bretz 1994) and supervisor ratings of job performance (Ferris et al. 2005). However, women are less likely than men to engage in or use organizational politics, possibly due to a perception of incompetence, lack of confidence, and distaste for political activity, preferring to rely instead on formal mechanisms of influence, sometimes at the cost of career progression (Arroba & James 1988; Mann 1995). Similarly, sex differences in the propensity to negotiate have been employed to explain various career outcomes (e.g., Babcock & Laschever 2003; Babcock, Gelfand, Small, & Stayn 2006). However, while women may be less likely to engage in negotiation behaviors, there may be good reasons for this—recent