GENDER MATTERS

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Evidence shows that patterns of inequity in physics drive talented women out of the field. Here's what physicists can do to overcome them.

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In a seminar for teaching assistants, one male and one female TA stand up; the professor in charge tells the room that the male TA will get more respect from students. A woman talks to her undergraduate adviser about her desire for a PhD in physics; he replies, "You know physics is hard. Are you sure you want to try to do that?" A physics major asks a senior male professor for advice on getting into a good doctoral program; he suggests that she flirt more at conferences. In his letters of recommendation for students applying to graduate school, a professor consistently describes his male students as "brilliant" and "outstanding" while praising the women for being "conscientious" and "hardworking"; his male students are accepted to more competitive doctoral programs.

All of the stories in the opening paragraph are examples of the kinds of comments and situations that, taken in aggregate, can combine to create an environment that is unwelcoming for aspiring female physicists. While other sciences have made strides toward more diverse demographics, physics has lagged behind (see figure 1). Demographic data consistently show that our field is 75% male and 75% white, and the growing consensus is that this is a problem.[1]

In this article we highlight a few of the many studies that show systemic bias against women in physics, examine implicit bias, and consider stereotypes about women and about physics. We then turn our attention to what physicists can do to improve the situation, particularly in how they structure their courses and talk about physics with their students. Finally, we highlight some resources offered by the American Physical Society and other professional organizations to help make physics a more welcoming home for women.

Patterns of inequity

Studies on the causes of gender imbalance in the sciences have documented persistent problems facing women in science careers. Women are especially underrepresented in physics because of a complex interaction of factors, including an unusually chilly climate for women, worse policies and resources for female faculty, and pervasive cultural stereotypes about the inaccessibility and masculine nature of physics. Much of the past several decades of research on gender barriers in STEM fields has been summarized in the report *Why So Few? Women in Science, Technology, Engineering, and Mathematics*.[2] It provides a thorough but accessible description of findings about women in science, from primary school up through career levels. Some current research is also showcased in the August 2016 *Physical Review Physics Education Research*, a special issue focused on gender in physics.

For the purposes of this article, we will highlight a few key studies that illustrate the challenges facing women in the sciences, particularly physics. In a 2012 paper, social psychologist Corinne Moss-Racusin and her collaborators documented systemic hiring biases among science faculty. They found that search committees judge male candidates more competent, offer them higher salaries, and plan to mentor them more than they would mentor women with identical application materials.[3] Those biases affect women scientists' job prospects, pay, and access to support networks.

Even after securing a faculty position, women often do not have equal status. An international survey found that women physicists report less access to the resources they need to perform research and attend conferences. For example, even in highly developed countries, 46% of women had lab space compared with 52% of men, 52% of women had research funding while 60% of men did, and 57% of women had travel money compared with 64% of men.[4] Those differences remained constant even when accounting for age and position type (see the article by Rachel Ivie and Casey Langer Tesfaye, Physics Today, February 2012, page 47).

Furthermore, surveys and studies have found that female physicists, particularly graduate students, frequently encounter microaggressions—small interactions that may seem innocuous individually but present a picture of gender bias when viewed in a pattern. The stories that opened this piece are all drawn from real experiences, and all are examples of microaggressions. The professors in the stories may not have intended to be hostile, but when female physicists are subjected to such comments on a regular basis, the cumulative effect is isolating and demoralizing.

In a survey of graduate students in physics and astronomy, science education researcher Ramón Barthelemy and colleagues found that three-quarters of the female-identified graduate students they interviewed experienced microaggressions during their graduate study. Examples included being called out as the only woman in a class, being persistently assigned secretarial roles in lab, being denied difficult tasks, hearing crude jokes, and feeling they were seen as potential sexual conquests rather than colleagues (see figure 2). Even small incidents of bias can build up and create self-doubt, result in less ambitious goal setting, or, in some cases, lead to post-traumatic stress syndrome. They can make women feel alone and separated from their male classmates and colleagues, particularly if they are ignored in the lab and classroom, treated as secretarial help, and left out of social gatherings.[5]

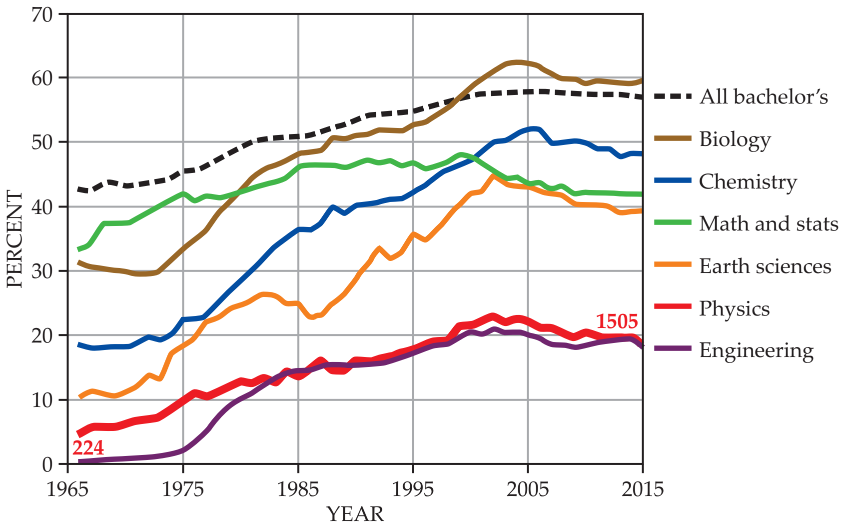

FIGURE 1. STEM BACHELOR'S DEGREES EARNED by women in the US, 1965–2015. Women now earn nearly 60% of all bachelor's degrees in the US but make up just 20% of physics majors, and that number has remained static over the past 20 years. (Courtesy of the Integrated Postsecondary Education Data System and the American Physical Society.)

Examining implicit bias

What's causing those persistent problems for women in science? The truth is that cultural biases influence all of us, even data-driven scientists, more than we like to imagine. Tests of implicit bias—the ease with which we link different images or ideas at a faster-than-conscious level—show that most people find it easier to associate women with the humanities and men with math and science.[2] Crucially, those attitudes extend across gender and ethnicity. They are even present among people who consciously hold egalitarian beliefs—people who would strongly agree that students should pursue STEM careers regardless of gender. Our unconscious biases have real influence over the level of encouragement we give to a student, the words we choose when writing a recommendation letter, or the overall competence and promise we see in a job candidate.

Women scientists must contend with cultural biases that portray science as a masculine field. In one recent study, participants were shown pictures of 40 men and 40 women. The subjects were asked how masculine or feminine they considered the person in the photograph, and then they were asked to guess whether each person was a scientist or an elementary school teacher. Subjects said that more feminine-looking women were much less likely to be scientists and much more likely to be teachers. The pictures of men rated more masculine in appearance, in contrast, were slightly more likely to be identified as scientists. In fact, all 80 people pictured were STEM faculty members.[6]

In physics especially, television shows such as *The Big Bang Theory* express and reiterate cultural stereotypes that physicists are not only men (and overwhelmingly white), but a particular kind of man: straight, awkward around women, disdainful of

STANDOUT WORDS (more often used to describe men)		GRINDSTONE WORDS (more often used to describe women)	
Excellent	Terrific	Hardworking	Assiduous
Superb	Fabulous	Conscientious	Trustworthy
Outstanding	Magnificent	Dependable	Responsible
Unique	Remarkable	Meticulous	Methodical
Exceptional	Extraordinary	Thorough	Industrious
Unparalleled	Amazing	Diligent	Busy
Most	Supremely	Dedicated	Work
Wonderful	Unmatched	Careful	Persistent
		Reliable	Organized
		Effort	Disciplined

"STANDOUT" WORDS AND "GRINDSTONE" WORDS in letters of recommendation. Standout words, which portray a candidate as talented and exciting, are most often found in letters of recommendation for men. Grindstone words, which create the impression that a candidate works hard but is not intellectually exceptional, are more often used for women. (Adapted from ref. 9.)

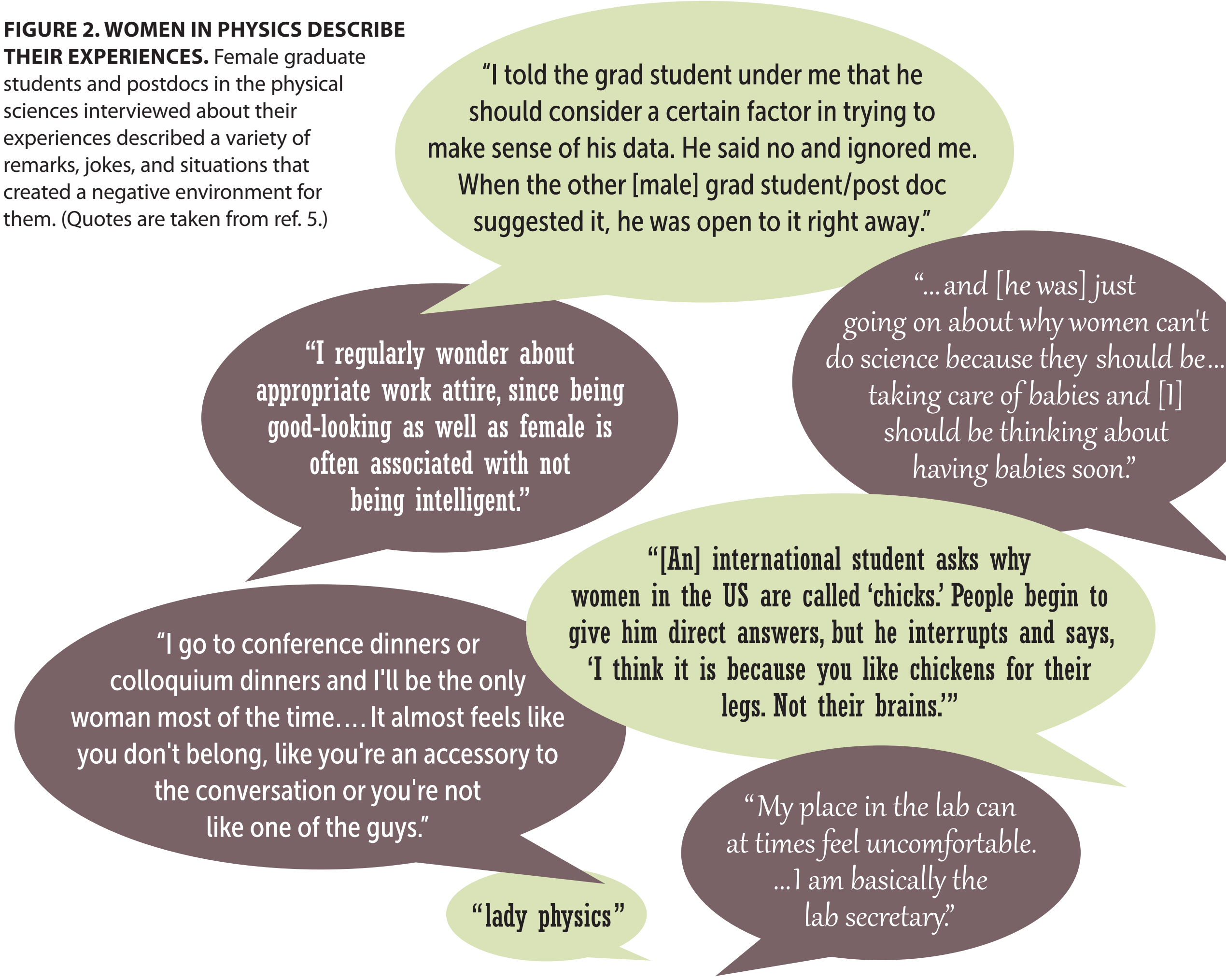

FIGURE 2. WOMEN IN PHYSICS DESCRIBE THEIR EXPERIENCES. Female graduate students and postdocs in the physical sciences interviewed about their experiences described a variety of remarks, jokes, and situations that created a negative environment for them. (Quotes are taken from ref. 5.)

social skills, and effortlessly brilliant. That final trait reflects a larger pattern across STEM subjects and the humanities. The belief that "raw intellectual talent" or "brilliance" is the main prerequisite for a field is negatively correlated with the representation of women in that field, with philosophy occupying an analogous position to physics in terms of its association with brilliance and its poor representation of women.[7] Celebrating the image of the distracted, abrasive, and socially inept genius also reinforces the male-coded stereotype of what a physicist "should" look like. Women are aware that they do not fit the stereotypical image of a physicist; across various studies, female scientists report modifying their behavior to either blend in with male peers or fight for recognition.[8]

Ironically, implicit bias may be causing graduate and postdoctoral mentors to unintentionally contribute to some of the hiring bias described by Moss-Racusin's group. In a 2007 study, psychologists Toni Schmader and Jessica Whitehead and chemist Vicki Wysocki examined recommendation letters for chemistry and biochemistry faculty positions. They found that letters written for men were more effusive than letters written for women. Letter writers were more likely to use words like "outstanding," "amazing," and "unmatched" to describe men and more likely to use words like "dependable," "hardworking," and "careful" to describe women (see the table on page 42). That effect persisted even when candidates' number of publications, fellowships, and other markers of research success were considered.[9] As a result of that discrepancy, female candidates seem both more boring and less intellectually promising than their male competitors.

What physicists can do

Physicists can work in classrooms, departments, and hiring processes to be part of the solution. First of all, they can look to the atmosphere of their courses, especially at the introductory level, to make sure women are not being inadvertently discouraged. The physics education research community works, in part, at improving the teaching and learning of physics. As part of that community, the three of us work not only on gender issues, but also on research about student understanding, cognitive load and spatial reasoning skills, reformed classrooms, and community formation in introductory physics courses. We have found that innovative improvements to classroom instruction can enhance a department's ability to develop and retain talented female students.

A study by psychologist Karyn Lewis and coauthors found that women majoring in physics often feel that they do not "fit in" or "belong" in the discipline. Women believe they must earn their place in STEM by demonstrating exceptional ability, and are more likely than men to switch majors if they receive a C or even a B in an introductory course.[10] Improving physics

FIGURE 3. SCALE-UP CLASSROOMS AT FLORIDA STATE UNIVERSITY (LEFT) AND VIRGINIA TECH (RIGHT). In SCALE-UP classrooms, students sit at round tables and work in small groups, which encourages them to collaborate with classmates and remain active and engaged with the material. Studies have shown that such courses improve learning outcomes, especially for students from underrepresented groups. (Photos by Scott Baxter, Florida State University, left, and by Virginia Tech, right.)

pedagogy can give those students the tools they need to persevere and succeed.

The curricula for the Student-Centered Activities for Large Enrollment Undergraduate Programs (SCALE-UP) and the Investigative Science Learning Environment (ISLE) developed at Rutgers University are two examples of innovative STEM courses that have improved outcomes for underrepresented students.[11] With SCALE-UP and ISLE, students don't just passively take notes and try to apply the concepts to problem sets outside of class. They work together in groups during class and stay active, involved, and engaged throughout the lecture (see figure 3). SCALE-UP classes have been shown to improve learning outcomes for all students, and they give particular support to women and other traditionally underrepresented populations. Similarly, female students in ISLE courses pass their first-year physics classes at the same rate as their male classmates, even when they enter with low math placement scores. Students learn more in ISLE classes and pass them at a higher rate, and the gap in both test scores and grades between white men and other groups of students narrows.

Even those of us who do not teach in SCALE-UP or ISLE-type classrooms can make a difference with interventions designed to overcome gaps caused by student mind-sets. Lewis's team makes several research-based recommendations that physics educators can follow to help women gain a sense that they belong in physics. The team's recommendations go beyond curriculum and pedagogy choices to how instructors and mentors talk about, and think about, physics. First, professors can identify and temper cues that perpetuate the stereotype of the geeky scientist. Jokes about how physicists have no social skills, how they work too many hours a week to have a social life, and how they are all familiar with every iteration of *Star Trek* can be isolating for students who do not see themselves in those stereotypes.[10]

Second, professors can emphasize the role of hard work in scientific success rather than praising effortless brilliance. This recommendation builds on the work of Stanford University psychologist Carol Dweck, who developed the related idea of "fixed" and "growth" mind-sets.[12] People with fixed mind-sets think their intelligence is a fixed trait, while people with growth mind-sets think they are capable of getting smarter. A student with a fixed mind-set might believe that if a class is hard for them, they are simply not smart enough to do well and nothing can be done about it. On the other hand, someone with a growth mind-set who encounters a difficult task interprets it as a chance to grow and change. They will be able to work through a challenge and eventually succeed.

Professors with fixed mind-sets can also inadvertently discourage students from trying to overcome their challenges. Instructors who think, for example, that some people "just aren't good at math" may think the best way to help students who perform poorly is to guide them through dropping the course or changing their major. Professors with growth mind-sets, however, are more likely to encourage their students to improve on poor results.[10]

Professors can also talk about their own struggles with learning and with belonging. If they struggled to learn certain topics in physics themselves, and if they remember how they

overcame those difficulties, they should share those stories. Doing group work during class can also help create a sense of belonging; students who see each other struggle and learn will realize that it is normal to take more than an instant to comprehend a concept or solve a problem. If students know each other and their professors better, they may see that concerns about belonging are normal and not a reason to leave the field.[10]

Finally, professors can and should consider the broader social context that their classrooms connect to. Culturally, many physicists take pride in the abstract and theoretical nature of their field. There is nothing wrong with showing excitement for understanding the fundamental laws of the universe, but they do physics a disservice if they do not also recognize its applications to medicine, engineering, and other fields that produce daily benefits to society. Students approach their classes with a range of intellectual, pragmatic, and emotional motivations, and professors limit both the appeal and the long-term potential of physics when they neglect the practical or altruistic goals it can support. Acknowledging real-world applications and advances can help to connect dry classroom material with a longer-term vision that students have for their postcollege careers.[10]

Resources for departments

The American Physical Society (APS) has excellent resources to help physics departments evaluate and improve their work with women and minority students.[13] You can schedule a site visit from APS's Committee on the Status of Women in Physics (CSWP) or Committee on Minorities in Physics to get a thoughtful, private evaluation of the climate of your department and, as necessary, suggestions for change. If you are in a department with a graduate program, you might undertake a self-assessment developed by the CSWP to see whether your graduate program in physics is female friendly. The assessment is also a resource for undergraduate students who are choosing a graduate program. (The self-assessments from more than 150 schools are available on the APS website at www.aps.org/programs/women/female-friendly/.)

Physics departments should also look at work by physicist Barbara Whitten and her coauthors to see what characterizes physics departments that excel in graduating female students (see the article by Barbara Whitten, Suzanne Foster, and Margaret Duncombe, PHYSICS TODAY, September 2003, page 46). Whitten's group identifies several key steps departments can take to recruit and retain female majors. Most of the suggestions are practical and inexpensive, and they can make large differences in the lives (and retention) of students of any gender. Examples include supporting collaborations such as study groups—ideally with dedicated lounge space—and adding student-relevant topics such as jobs and postgraduate opportunities to the list of seminar topics.[14]

Additionally, the papers by Whitten and her colleagues suggest policies that support female faculty members, such as spousal hires and inclusive family leave, a commitment that would also help many graduate and undergraduate students. In aggregate, those kinds of changes send a message to students that the department is a place where they can have space to grow intellectually, find their feet professionally, and seek advice for the academic and life challenges that inevitably arise over the years of seeking a college degree. Unfortunately, the absence of that message is not neutral; it is itself a message that physics only welcomes students who are materially secure, raised in prestigious school districts, and freely able to divert family time to work.

Departments can also encourage faculty members to read the study by Schmader and colleagues on letters of recommendation, including the helpful appendix listing words they classified as standout, grindstone, and other labels (see the table on page 42).[9] Professors can do all of their students a great service by ensuring that they write letters that accurately speak to their students' full potential and relevant skills.

Being aware of patterns in letters of recommendation can also help faculty members serve more fairly and carefully on hiring committees. The Women in Science and Engineering Leadership Institute of the University of Wisconsin–Madison has published a guide for search committees.[15] The authors discuss how to ensure that your applicant pool is diverse and that the applicants are reviewed and interviewed fairly. They also talk about how to look for unconscious biases and give instructions about how to guard against letting those biases and assumptions influence decisions about which candidates to interview and hire.

In light of recent disturbing high-profile cases of STEM faculty members sexually harassing students and colleagues, we all need to work to ensure that harassment in physics is not tolerated, no matter how prominent or famous the harasser. Our professional societies are starting to step up by drafting codes of ethics and antiharassment policies (see PHYSICS TODAY, June

2016, page 30). Physics departments can reinforce such efforts with something as simple as a website. Many department or research group websites post about recent news in the physics world. One way to show support is by highlighting stories and reports about combating harassment in academia.

One recent statement about sexual harassment in the sciences came from an NSF-funded workshop held in September 2016. Participants drafted a set of principles for addressing harassment, including the following one: “Science and education are social endeavors. Professional societies, academic departments, organizations that fund research, and government agencies should have a comprehensive code of conduct to guide ethical behavior in the conduct of research, which includes treatment of people as well as data.”[16]

Simply put, research always involves people. To ensure an intellectually vibrant and diverse future for our discipline, we must find ways to work together using practices that support inclusion rather than exclusion in our classrooms and labs.

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