Gender Differences in Grant Submissions across Science and Engineering Fields at the NSF

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There has been great growth in women's participation in the US academic doctoral workforce, but underrepresentation remains in all science and engineering fields, especially at high academic ranks. We obtained estimates of the numbers of professorial women and men in fields likely to seek funding from the National Science Foundation and aligned those numbers with each of six research directorates to investigate temporal trends in submission patterns. We found that women are as likely to be funded as men, but the percentage of women submitting proposals was less than expected in every field but engineering. Women are as likely as men to be employed at the most research active institutions, but women are less likely than men to self-report research as their primary work activity in almost all fields but engineering. This work imbalance ultimately limits the diversity of basic science research ideas in science and engineering.

Keywords: academia, faculty, workload equity, funding, National Science Foundation

For at least the last decade, women represent about 50% of science and engineering (S&E) bachelor degree graduates (NSF 2019). Since 2009, women's share of S&E doctorates has remained relatively stable at about 42% (NSF 2017), but there are clear differences among fields (Ceci and Williams 2011, Ceci et al. 2014). For example, some studies have found in fields with more women, such as biology and the life sciences, retention rates in academia are lower than in fields with fewer women, such as engineering (Ley and Hamilton 2008, Ginther and Kahn 2009, Shaw and Stanton 2012, Ceci et al. 2014, Miller and Wai 2015, Cheryan et al. 2017). Other studies (e.g., Xu 2008, NRC 2010) have shown virtually no difference in the retention of faculty across S&E fields (but see Kaminski and Geisler 2012, where women were shown to leave the mathematics' pipeline earlier). Despite this variation in the patterns across studies and across fields and the contentious debate about the causes of these patterns (e.g., Hill et al. 2010, Ceci and Williams 2011, Ceci et al. 2014, Bian et al. 2017, Cheryan et al. 2017, Grogan 2019), the evidence is clear that women remain underrepresented relative to men across almost all S&E fields in academia, even when controlling for demographic inertia (i.e., time lags in career stage transitions) resulting from historical inequalities (supplemental data S1; Shaw and Stanton 2012).

The National Science Foundation (NSF) is the major US funding institution supporting all major S&E fields in academia; approximately 80% of NSF funds go to academic institutions (NSF 2016). Because the NSF's scientific breadth spans fields with higher numbers of women, such as the social sciences and biological sciences, and those with very low numbers of women, such as mathematics and physics, we aimed to determine the relative difference between men and women in submission and success rates of research grant proposals across S&E fields, the temporal trends in the number of women with respect to rank and field, and whether men and women differ in self-reported time spent on research versus teaching in a typical week and whether this varies by field.

Prior studies on gender differences in grant funding. Several large-scale studies have been completed to determine whether there is gender inequity in access to research funding allocation, and the answers vary (e.g., Hosek et al. 2005, RAND 2005, Ceci et al. 2014). The US Government Accountability Office (2015) reviewed proposal success rates (defined as

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the number of awards divided by the number of proposal submissions) for men and women at six federal agencies: the NSF, the National Institutes of Health (NIH), the US Department of Agriculture (USDA), the Department of Defense (DOD), the Department of Education (DOE), and NASA. The report did not show evidence of gender disparities in proposal success rates at the NIH, the NSF, or the USDA, but at the DOD, the DOE, and NASA, there was either insufficient data to determine gender differences or evidence of disparities. Studies in the United Kingdom (e.g., Grant and Low 1997, Blake and La Valle 2000, Boyle et al. 2015, Zhou et al. 2018), Canada (CPPD 2010, Witteman et al. 2019), and Australia (e.g., Marsh et al. 2008) also showed little evidence that men and women differ in the likelihood of receiving a grant (but see Tamblyn et al. 2018, van der Lee and Ellemers 2015a, and the discussions in Albers 2015, van der Lee and Ellemers 2015b, 2015c, Volker and Steenback 2015).

Even large meta-analyses can differ in their conclusions (Bornmann et al. 2007, Marsh et al. 2009, 2011). For example, Bornmann and colleagues (2007) analyzed 21 separate studies and over 350,000 grant and fellowship applications covering the years 1987–2005 and funding institutions in North America, Europe, and Australia and concluded that men had statistically significant greater odds (7% higher) of receiving grants than did women. However, later meta-analyses using more sophisticated statistics on the same data sets found no gender biases in the peer review process after controlling for discipline, country, institution, experience, and past research output (Marsh et al. 2009, 2011). Therefore, despite some differences across agencies, countries, studies, and fields, the emerging view is one of general gender parity in access to grant funds (Ceci and Williams 2011, Ceci et al. 2014). The one thing that is almost always true, however, is that fewer women submit proposals than men (e.g., for a review, see Ceci et al. 2014; Sakai and Lane 1996, Polhaus et al. 2011, Hechtman et al. 2018).

Survey of doctorate recipients and assigning disciplines to NSF directorates. A major missing piece of data in studies in which gender disparities were examined in funding across S&E fields is the number of women in particular fields who can apply for research grants. Because no direct estimate of the numbers of women in the academic pool exist for disciplines specific to a particular NSF directorate, we gathered data from the Survey of Doctorate Recipients (SDR; www.nsf.gov/statistics/srvydoctoratework). The SDR is a biennial survey conducted since 1973 and run through the National Center for Science and Engineering Statistics (NCSES) that provides demographic, education, and career history information about individuals with a research doctoral degree in a science, engineering, or health (SEH) field from a US academic institution. SDR data are therefore limited to US-trained individuals. The SDR survey follows a sample of individuals with SEH doctorates throughout their careers from the year of their degree award until age 76. The panel is refreshed each survey cycle with a sample of new SEH doctoral degree earners. Results are used to make decisions related to the educational and occupational achievements and career movement of the nation's doctoral scientists and engineers.

We met with representatives from each of six NSF S&E directorates to align the fields funded by each directorate with the fields represented in the SDR (data S1). We excluded the health fields, because the NSF does not fund research in these areas. From the broad field of biological, agricultural, and environmental life sciences, we excluded the fine fields of food sciences and technology, nutritional science, pharmacology, and human physiology and pathology, because the NSF generally does not fund research in these areas.

We summarized the numbers of women and men employed full time in academia for each field and across ranks, and the data spanned the years 2001–2015 (figure 1, data S1). This provides the most robust estimates to date of the actual numbers of US-trained individuals in academia who could apply for funding across six NSF S&E directorates.

Submission rates and success rates. We used publicly available data from the NSF's merit review report to the National Science Board (appendix 3 of NSF 2016). In this report, the analyses were focused solely on the lead principal investigators (PIs); statistics on co-PIs and subawards were not included. The gender statuses were analyzed for the lead PIs of single proposals, as well as the lead PIs of each separate proposal of a multi-investigator collaborative proposal, where each PI could be from a separate institution. The gender status for each PI was self-reported to the NSF through their FastLane PI Information profiles; individuals are asked to choose either "female" or "male." Although we recognize that this definition of sex and gender is simplistic, our analyses are necessarily limited to the reported information. To determine the difference in success rates for women and men within an NSF directorate, we used Kruskal–Wallis rank sum tests. For all analyses, we used R version 3.4.4 (R Core Team 2018).

Type of institution and primary work activity. We analyzed two SDR variables to explore why fewer women may submit grant proposals to the NSF than could, on the basis of their presence in faculty positions in fields funded by particular directorates at the NSF: the Carnegie classification of employing institution and research versus teaching versus other activities as primary work activity. In all cases, our sampling included only full-time professorial faculty, and we excluded instructors, adjuncts, lecturers, and similar position types.

Institutions vary in the incentives for PIs to submit research grant proposals to agencies like the NSF. If there is a difference in the likelihood that men and women move to institutions of a particular Carnegie classification (e.g., *very high research*, VHR), this may explain lower grant submissions by women. To analyze their Carnegie class, we focused on the last decade (2005–2015) in order to retain a single

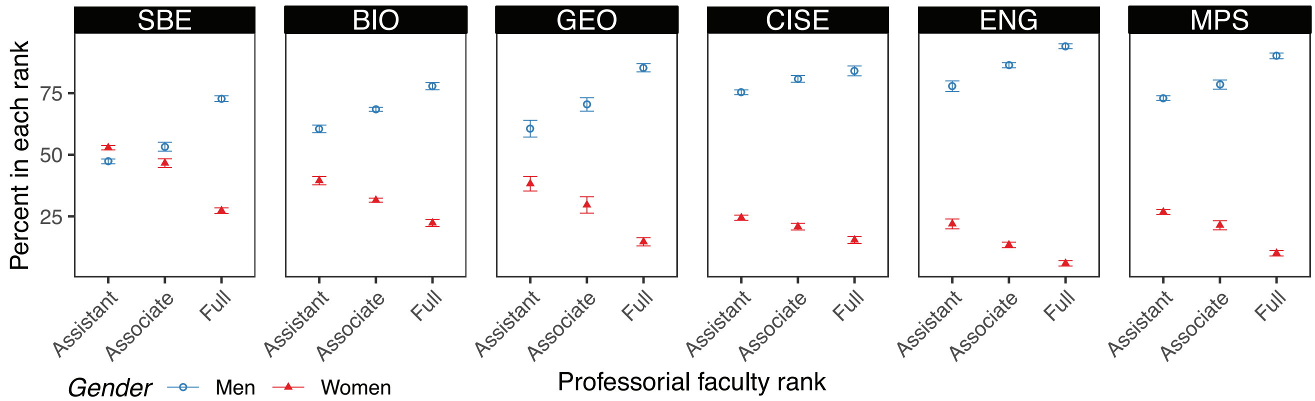

Figure 1. The relative percentages of women (triangles) and men (circles) in different professorial positions (career stages) including assistant professor, associate professor, and full professor. Each data point represents the mean value, with standard error bars, (over years 2008, 2010, 2013, and 2015; data S1). The NSF directorates include social, behavioral and economic sciences (SBE); biological sciences (BIO); geosciences (GEO); computer and information science and engineering (CISE); engineering (ENG); and mathematical and physical sciences (MPS).

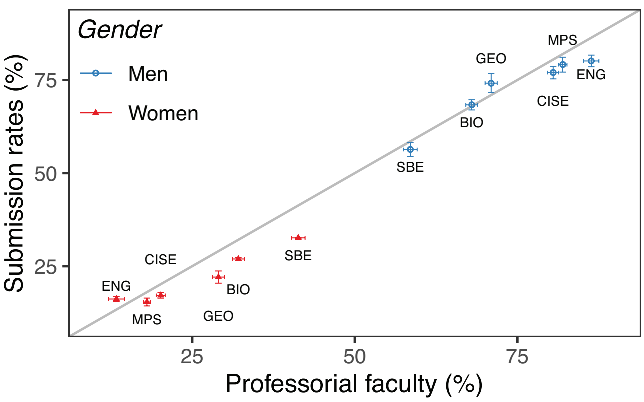

Figure 2. Relationship between grant submission rates (y-axis) and the percentage of professorial faculty (i.e., assistant, associate, and full professors; x-axis) for women (triangles) and men (circles) associated with each NSF directorate. Data on submission rates collected from NSF's merit review report (NSF 2016) and professorial faculty numbers from data S1. Each point represents the mean value, and the error bars represent the standard error, over three recent years: 2008, 2010, and 2013. (2015 data were not included because the Survey of Doctorate Recipients was redesigned that year.) The gray line represents a 1:1 ratio between submission rates and the percentage of professors in academic positions. The NSF directorates include social, behavioral and economic sciences (SBE); biological sciences (BIO); geosciences (GEO); computer and information science and engineering (CISE); engineering (ENG); and mathematical and physical sciences (MPS).

Carnegie classification, Carnegie 2005. For the other years in our analysis (2001 and 2003), SDR data were reported using the 1994 Carnegie classification, which is not fully compatible with Carnegie 2005 (VHR activity institutions under Carnegie 2005 are not identical to research I institutions under Carnegie 1994). We chose 3 years, 1 at the beginning of the Carnegie 2005 period (2006), 1 in the middle (2010), and the last year (2015), and we examined the numbers of men and women at each professorial rank (assistant, associate, and full) employed full time at VHR activity institutions.

We were especially interested in assessing the degree of difference between academic men and women in what they reported as their primary work activity and in how this varies across fields and through time, because research has suggested (for a review, see O'Meara et al. 2019) that women spend less time on research and more time on teaching and service than men. The SDR defines *primary work activity* as the activity that respondents spent the most number of hours on during a typical work week. More specifically, *primary work activity* is derived from a question in the SDR that provides its respondents with a list of over a dozen activities and asks them on which two they spent the most time, with the selected primary activities occupying at least 10% of the respondents' time. We examined those reporting research as their primary activity (supplemental data S2) and those reporting teaching as their primary activity (supplemental data S3). The SDR also offers other choices of primary work activity, which we grouped together in an *other* category (supplemental data S4). We used the percentage and standard error associated with the SDR estimates for each year within a given directorate to determine whether men and women reported different primary work activities using a z-test with $\alpha = .10$.

Major findings and temporal trends

Submissions are lower for women than men. We found that fewer women submitted proposals than could have, given how many women are in the professorial academic pool (figure 2, data S1). This is true, to varying degrees, for all

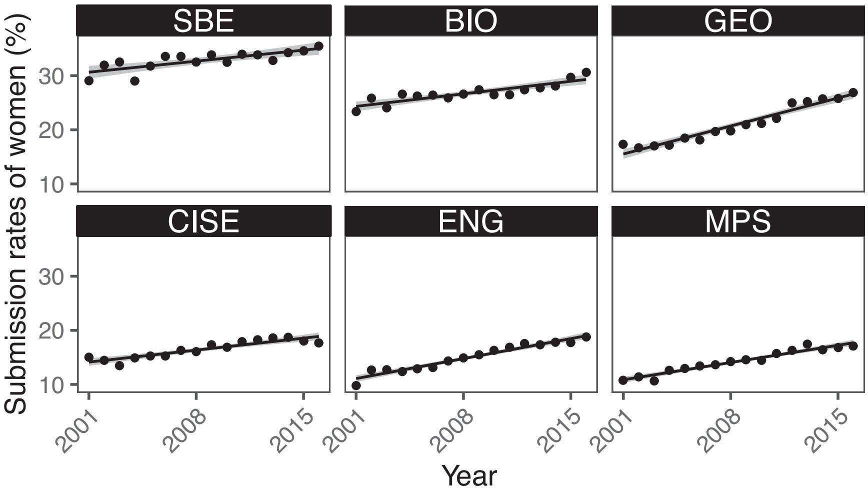

Figure 3. Submission rates of women across directorates at the National Science Foundation. Submission rates of women by year (2001–2016) for each directorate including social, behavioral and economic sciences (SBE); biological sciences (BIO); geosciences (GEO); computer and information science and engineering (CISE); engineering (ENG); and mathematical and physical sciences (MPS). Solid lines represent linear relationships with 95% confidence intervals (gray shaded area) and points represent each year.

directorates except for engineering. On the other hand, men generally submitted at the rate they are represented in the pool (i.e., they fall on or near the 1:1 line in figure 2) except for engineering, where they show lower submission rates but represent over 80% of the academic scientists in those fields (figure 1).

Looking at temporal trends, submission rates by women have increased in almost all NSF directorates, although the trajectories vary from relatively steady but slow improvements in biology to significant gains in the geosciences over the same time period (figure 3). In terms of the funding success of submitted grants, women are as likely to receive research funds as men in all directorates (table 1).

We found no evidence that women are more likely to be at schools with fewer incentives for research (supplemental table S1). Although there are some instances (fields or ranks) in some years (e.g., full professors in biology in 2015) where a higher proportion of men than women are employed at VHR Carnegie classified schools relative to other types of institutions, there are no consistent trends for any field at any rank (supplemental table S1). We did find, however, that women report that they spend more hours in a typical week teaching rather than conducting research, whereas men report that they spend more time conducting research than teaching (supplemental data S2, S3). The exception to this pattern is, once again, engineering (figure 4a, 4b). Furthermore, in recent years, women are more likely than their male counterparts to report that they primarily perform other activities (neither teaching nor research; supplemental data S4). It is worth emphasizing that these differences are for professorial faculty; the patterns are not conflated by position type (supplemental data S1–S4).

General insights on work inequities

As women have been increasing their academic representation in S&E, new gender disparities come to light. Although our data suggest that women maintain equal success at receiving NSF research funding as men (table 1), we also show that fewer women submit research grant proposals as a PI relative to their representation in academia, especially in fields with more women (figure 2). Why is this so? We chose to focus on two often-cited hypotheses: Women tend to be employed at less research-intensive institutions so may have fewer incentives to submit NSF-type research grants, and women spend less time on research than men (Bellas and Toutkoushian 1999, Porter 2007, Link et al. 2008, Misra et al. 2011, Babcock et al. 2017, Guarino and Borden 2017, O'Meara et al. 2017, Eagly 2020). In the present study, we are the first to use the SDR to provide a robust, large-scale, and comprehensive data set to explore these hypotheses.

We found the first hypothesis, that women tend to be employed at less research-intensive institutions, to be unsupported (but see Eagly 2020). Our data show that in general women with research doctorates in S&E are as likely as men to be at VHR schools (supplemental table S1). It is worth noting that in 2015 at the assistant professor stage, only engineering showed a significant difference between the genders, and it was in the opposite direction: a higher proportion of women (44%) than men (34%) were employed at VHR-activity institutions than at less research-intensive schools (supplemental table S1).

We did, however, find support for the second hypothesis. Despite the significant increase in the numbers of women in the S&E professoriate over the last 20 years, women are still much less likely to report that research is their primary work activity in comparison to men (Foley et al. 2019), but this varies considerably by field (figure 4a) and the disparity is especially evident in the social, behavioral, and economic sciences and in math and physical sciences. Some studies have shown that a possible reason for this gender difference is that women are asked (and accept) more often than men to participate in teaching, service, mentoring, or other less research-heavy activities (Mitchell and Hesli 2013, Babacock et al. 2017, O'Meara et al. 2017, 2019). Women are also more likely than men to be employed in teaching-intensive positions within universities (see Eagly 2020 but also NSF 2019, which shows that S&E doctorate holders frequently self-identify as *both* research faculty and teaching faculty).

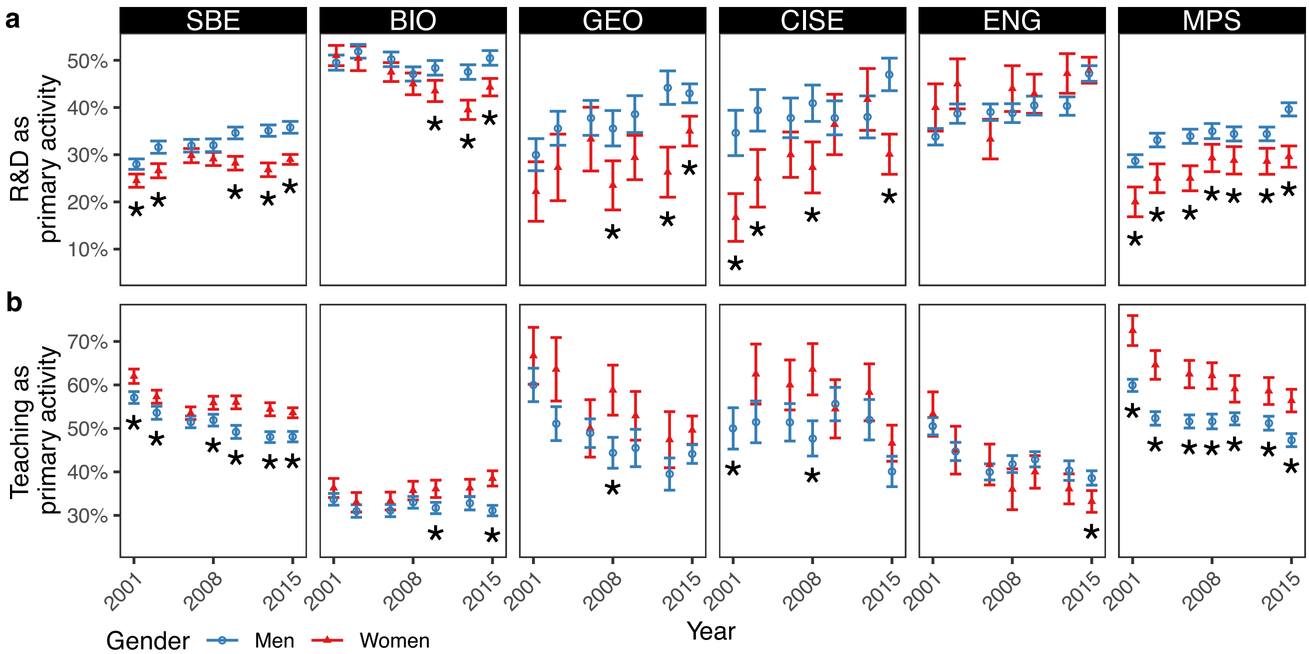

Figure 4. Differences between the proportion of men (blue circles) and women (red triangles) who report their primary work activity in a typical week according to the Survey of Doctorate Recipients from 2001 to 2015. (a) The percentages of each gender who report research as their primary work activity. (b) The percentages of each gender who report teaching as their primary work activity. Primary work activity is derived from SDR question A31: "On which two activities in question A30 did you work the most hours during a typical week on this job?" Question A30 presents a selection of 14 work activities. Respondents are asked to indicate which work activities "occupied at least 10 percent of your time during a typical work week on this job." SDR estimates are based on a sample of the population and may differ from actual values because of sampling variability or other factors. As a result, apparent differences between the estimates for two or more groups may not be statistically significant. Statistically significant comparisons between the genders in a given year, determined by z-tests, are at the 90% confidence interval and marked with an asterisk (*). The value for CISE women in 2001 (4b) is 83% but not reported in order to keep the scale bar at a level where the differences are clear for all NSF directorates. The NSF directorates are listed from left to right in order of those with more women to those with fewer women and include social, behavioral and economic sciences (SBE); biological sciences (BIO); geosciences (GEO); computer and information science and engineering (CISE); engineering (ENG); and mathematical and physical sciences (MPS).

If women are more likely than men to be instructors or lecturers this would exacerbate gender differences in reported work activities; however, we emphasize that our analyses excluded these position types, focusing only on the full-time professoriate.

It is also true that irrespective of institution type, field of study, or position, there are many impediments that can disproportionately plague women in science and contribute to reduced time for research. These range from implicit or explicit bias, harassment, stereotype threat, less access to institutional resources, the motherhood penalty, caregiving for elderly parents, lower salaries, to lack of mentors at higher academic ranks (NAS et al. 2007, Shen 2013, NASEM 2018). This inequity in work activity could lead to less productivity in research because of there being less time available, and therefore it is important for institution administrators to promote equitable workload and activity rotations among all faculty and protected time for research (O'Meara et al. 2019).

Conclusions

Women remain underrepresented relative to men in all fields of S&E, although the disparity varies by field and career stage (figure 1). Funding patterns are paradoxical in that fields with more women (such as the biological sciences) show fewer grant submissions, and women report less time spent on research per week, than those in fields with more male-biased representation such as engineering (figure 2), although grant success is equal for women and men in all directorates at the NSF. These results mirror recent work analyzing gender differences in publication productivity and career longevity of over 1.5 million authors (Huang et al. 2020), where annual productivity is essentially equal for men and women across all fields, but the gender gap in total productivity (across a publishing career) is much higher in fields with more women (e.g., approximately 35% in biology versus approximately 12% in engineering; see Huang et al. 2020 figure 3a). Huang and colleagues (2020) conclude this is because of a lower retention of women in active research at

Table 1. Success rate of submitted proposals to the NSF across six S&E directorates over all years of the study (2001–2016) and separately for more recent years (2010–2016).

Directorate	Proposal success rate 2001–2016		Proposal success rate 2010–2016	
	χ_1^2	*p*	χ_1^2	*p*
SBE	3.411	.065	0.494	.482
BIO	0.818	.366	0.331	.565
GEO	2.750	.097	1.800	.180
CISE	2.876	.090	2.551	.110
ENG	**7.161**	**.007**	2.976	.085
MPS	1.365	.243	2.159	.142

Note: ENG is the only directorate where women were more likely to receive funding than men (in bold). Source: Data from NSF (2016). NSF directorates are listed from top to bottom in order of those with more women to those with fewer women and include social, behavioral and economic sciences (SBE); biological sciences (BIO); geosciences (GEO); computer and information science and engineering (CISE); engineering (ENG); and mathematical and physical sciences (MPS).

all career stages (19.5% higher risk of leaving academia each year), relative to men, especially in fields with more women.

Less time for research translates into fewer grant submissions which could lead to delays in promotion, depending on university evaluation criteria, and compound gender inequities in academia. We suggest university administrators and mentors carefully assess workloads of their faculty to ensure gender equity and transparency in teaching and service, as well as increase the incentives for research activities and protected time for research, especially for women, and at all career stages. This is especially true because even with equal time for research, women and marginalized groups still face bias and inequities inherent in our culture that can negatively affect mental health and retention (NASEM 2018). Funding agencies are also responsible for ensuring that grants are fairly reviewed and distributed without bias, and the good news is that when women submit research proposals, they are as likely as men to be funded by the NSF in every field. Therefore, those administrative and policy efforts that aim to enable research, retain women, and advance them to the highest academic ranks, will ultimately be critical to narrowing the gender gap in S&E and, notably, as important as the more common singular focus on early career scientists (Holman et al. 2018, Huang et al. 2020).

Supplemental material

Supplemental data are available at *BIOSCI* online.

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