Elite male faculty in the life sciences employ fewer women

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Women make up over one-half of all doctoral recipients in biology-related fields but are vastly underrepresented at the faculty level in the life sciences. To explore the current causes of women's underrepresentation in biology, we collected publicly accessible data from university directories and faculty websites about the composition of biology laboratories at leading academic institutions in the United States. We found that male faculty members tended to employ fewer female graduate students and postdoctoral researchers (postdocs) than female faculty members did. Furthermore, elite male faculty—those whose research was funded by the Howard Hughes Medical Institute, who had been elected to the National Academy of Sciences, or who had won a major career award—trained significantly fewer women than other male faculty members. In contrast, elite female faculty did not exhibit a gender bias in employment patterns. New assistant professors at the institutions that we surveyed were largely comprised of postdoctoral researchers from these prominent laboratories, and correspondingly, the laboratories that produced assistant professors had an overabundance of male postdocs. Thus, one cause of the leaky pipeline in biomedical research may be the exclusion of women, or their self-selected absence, from certain high-achieving laboratories.

women in STEM | gender diversity

Between 1969 and 2009, the percentage of doctorates awarded to women in the life sciences increased from 15% to 52% (1, 2). Despite the vast gains at the doctoral level, women still lag behind in faculty appointments. Currently, only 36% of assistant professors and 18% of full professors in biology-related fields are women (3). The attrition of women from academic careers—known as the leaky pipeline problem (4)—undermines the meritocratic ideals of science and represents a significant underuse of the skills that are present in the pool of doctoral trainees.

A variety of factors has been suggested to influence the leaky pipeline in science, technology, engineering, and math (STEM) fields. Early career aspirations and choice of undergraduate major are significant departure points for women in certain disciplines (5, 6). For instance, women are awarded only 19% of bachelor's degrees in physics and 18% of bachelor's degrees in engineering, and correspondingly fewer women go on to graduate school in those subjects (1). In contrast, women are awarded >50% of both bachelor's and doctoral degrees in biology, suggesting that major leaks in the pipeline occur at later points in professional development. Gender differences in individuals' personal aspirations may explain some attrition from the academy (7). For instance, in surveys of graduate students and postdoctoral researchers (postdocs), women tend to rank work–life balance and parenthood-related issues as more important than men do, and the perceived difficulty of raising a family while working as a tenure-track faculty member causes more women than men to leave the academic pipeline (8–12). Such preferences are likely constrained by societal factors: male postdocs are more than two times as likely as female postdocs to expect their spouse to make career sacrifices for their benefit (8). Additionally, female scientists with children are significantly less likely to be hired for tenure-track jobs than those without children, whereas male scientists with children are more likely to be hired for tenure-track jobs than male scientists without children (13). Thus, a complex mixture of both free and constrained personal choices may contribute to the leaky pipeline in STEM fields.

In addition to the impact of gendered preference differences, the scarcity of female faculty may be, in part, because of persistent discrimination against women in science. Unlike systems of *de jure* discrimination, which were common until the middle of the 20th century and often explicitly excluded women from certain career paths, discrimination in the present day more often results from de facto differences in the treatment of men and women. Such behavior is linked to the problem of cumulative (dis)advantages: small differences in access to scientific goods (i.e., resources, mentoring, public visibility, etc.) may spiral over time, leading to significant divergence in achievement over the course of a career (14). These biases have been documented in both correlational and experimental studies of academic science. For instance, Moss-Racusin et al. (15) sent science faculty identical resumes for a laboratory manager position in which only the name and gender of the applicant were changed. The applicant with the male name was judged to be more competent and hirable and offered a larger starting salary than the female applicant.

How these gender biases affect the advancement of women in science is poorly understood. Moreover, in a field like biology—where women are well-represented at the doctoral and postdoctoral levels—it may be easy to assume that issues of gender are unimportant at early career stages. However, not all doctoral and postdoctoral positions are equivalent: vast interlaboratory differences exist in terms of reputation, mentoring, access to funding and equipment, networking possibilities, and more. Scientists who receive their training in particular laboratories may be at a disadvantage when applying for grants or faculty positions if their

Significance

Despite decades of progress, men still greatly outnumber women among biology faculty in the United States. Here, we show that high-achieving faculty members who are male train 10–40% fewer women in their laboratories relative to the number of women trained by other investigators. These skewed employment patterns may result from self-selection among female scientists or they may result from conscious or unconscious bias on the part of some faculty members. The dearth of women who are trained in these laboratories likely limits the number of female candidates who are most competitive for faculty job searches.

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principal investigator (PI) is less well-known or if their laboratory tends to produce fewer high-impact publications. We hypothesized that the steep decline in the representation of women at the postdoc-to-PI transition could be in part explained if the most prestigious PIs tended to predominantly train young male scientists. In this study we therefore sought to explore the link between gender, laboratory choice, and future academic employment. We found that women are significantly underrepresented at the graduate and postdoctoral levels in the laboratories of high-achieving male scientists, whereas elite female faculty show no such gender bias in their laboratories. We are unable to ascertain to what degree these differences result from self-selection among female trainees or gender biases among male faculty members. Nonetheless, this skew in laboratory employment represents a novel—and possibly corrigible—aspect of the leaky pipeline in life science research.

Results

A Survey of Employment by Gender at Top-Ranked Programs in the Life Sciences. To examine the gender distribution of biomedical scientists in academia, we collected information on the graduate students, postdocs, and faculty employed in 39 departments at 24 of the highest-ranked research institutions in the United States (*SI Materials and Methods* and Table S1). We focused on departments that study molecular biology, cell biology, biochemistry, and/or genetics. For each faculty member, we determined their gender, academic rank, and if available, the year in which their doctorate was received. We then used their laboratory website or a departmental directory to find the names of graduate students and postdocs currently working in their laboratories. We attempted to assign a gender to each graduate student and postdoc, using the internet and social network searches when a name was ambiguous. Lastly, we used three different criteria to define faculty whose laboratories we hypothesized would be the most prestigious: those who were funded by the Howard Hughes Medical Institute (HHMI), were members of the National Academy of Sciences (NAS), or had won at least one of seven different major research awards (e.g., the Nobel Prize or the National Medal of Science) (*SI Materials and Methods* and Table S2).

In total, we obtained information on 2,062 faculty members in the life sciences (Table 1). Within this sample, 21% of full professors and 29% of assistant professors were women. The gender distribution of the faculty members that we classified as elite was approximately proportional to the gender distribution of full professors, as 25% of HHMI investigators, 18% of NAS members, and 16% of major award winners were female. Among the trainees that we counted, 49% of 4,143 graduate students and 39% of 4,904 postdocs were women. We note that the percentages of female postdocs and assistant professors in our sample are below national averages (39% vs. 43% and 29% vs. 36%, respectively), suggesting that the leaky pipeline might be comparatively worse at top-ranked research institutions (3, 16). Alternately, the subfields from which we harvested might be slightly more male-biased than other fields, like ecology, that also fall under the spectrum of the life sciences (16).

Table 1. A survey of biology laboratories in the United States

Category	Male	Female	Total
Faculty	1,557	505	2,062
Professor	1,023	276	1,299
Associate professor	269	121	390
Assistant professor	265	108	373
HHMI investigators	113	38	151
NAS members	210	47	257
Major award winners	53	10	63
Faculty with one or more trainees listed	982	358	1,340
Postdoctoral researchers	3,013	1,891	4,904
Graduate students	2,120	2,023	4,143

Elite Male Faculty Employ Fewer Female Graduate Students and Postdocs. We next examined the gender distribution of trainees on a per-laboratory basis. On average, male PIs ran laboratories that had 36% female postdocs and 47% female graduate students (Fig. 1*A*). These values were significantly lower than values that we observed in laboratories headed by women, who employed on average 46% female postdocs and 53% female graduate students (Fig. 1*B*) ($P < 0.0001$ for both comparisons, Wilcoxon rank sum test). Thus, male professors run laboratories that have about 22% fewer female postdocs and 11% fewer female graduate students than their female colleagues do (Fig. 2).

We then tested our data to determine if the most prestigious PIs trained fewer women. Surprisingly, for each comparison, male PIs who were funded by HHMI, were elected to the NAS, or had won a major research award employed significantly fewer female postdocs than the corresponding pool of other male PIs (Fig. 1*A*). For instance, male HHMI investigators ran laboratories that had, on average, 31% female postdocs, whereas men who were not HHMI investigators employed, on average, 38% female postdocs ($P < 0.0001$, Wilcoxon rank sum test). This difference translates to a 19% deficit in the employment of female postdocs relative to their representation across all laboratories (Fig. 2*A*). In contrast, female professors who had achieved the same career milestones showed no evidence of a gender bias. Women who were HHMI investigators ran laboratories that employed 48% female postdocs compared with 46% female postdocs among those who were not funded by the HHMI (Fig. 1*B*). Similar results were obtained when we examined women who were members of the NAS or had won a major research award.

At the graduate student level, we observed an analogous, although less substantial, skew in employment by gender. Male NAS members and major award winners ran laboratories with about 41–42% female graduate students compared with 47–48% among other male professors (Fig. 1*A*). This disparity represents 14% and 17% deficits in the employment of female graduate students by NAS and award-winning laboratories, respectively, relative to their representation across all laboratories (Fig. 2*B*). However, there was no difference at the graduate student level between HHMI- and non-HHMI–funded male PIs (Fig. 1*A*). Among female faculty, major award winners actually trained slightly more female graduate students than non-award winners, whereas HHMI funding and NAS membership did not affect the number of female graduate students employed by female professors (Fig. 1*B*). Thus, elite male PIs, but not elite female PIs, tend to employ fewer female trainees than other faculty members who have not achieved certain career milestones.

Our dataset also included 24 Nobel Laureates in Medicine/Physiology or Chemistry. Male PIs who had won a Nobel Prize ($n = 22$) ran laboratories that had, on average, 24% female postdocs and 36% female graduate students, which represents a 39% and 27% deficit, respectively, relative to the pool of trainees (Fig. S1). The paucity of female Nobel Laureates prevented a meaningful comparison using this criterion, although we note that both female Nobel Laureates in our sample ran laboratories in which female trainees outnumbered male trainees at the time of our survey.

These results led us to consider the distribution of trainees across all laboratory types. We found that female trainees were much less likely to work for an elite PI, particularly at the postdoctoral level (Fig. S2). Combining faculty of both genders, men were about 17% more likely to do their graduate training with a member of the NAS, 25% more likely to do their postdoctoral training with a member of the NAS, and 90% more likely to do

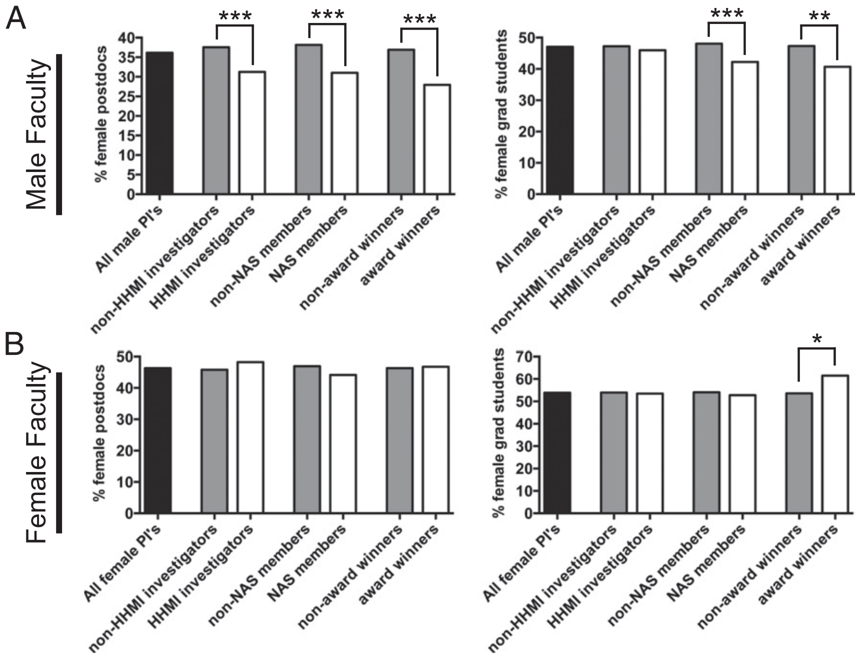

Fig. 1. The gender composition of elite biology laboratories in the United States. The weighted average percentages of female trainees in laboratories with (*A*) male PIs and (*B*) female PIs who have achieved certain career milestones are displayed. Major career awards that were counted for this survey are listed in Table S2. **P* < 0.05; ***P* < 0.005; ****P* < 0.0005 (Wilcoxon rank sum test).

their postdoctoral training with a Nobel Laureate. Thus, the gender skew in employment results in fewer women being trained in the laboratories of elite investigators.

Other Factors That Affect the Gender Skew in Biology Laboratories. We next sought to identify other characteristics of PIs that correlate with altered gender distributions. Nearly every faculty member who had achieved one of the career milestones that we counted held the rank of professor; thus, our results could be explained if older faculty in general trained few women. In fact, men who were full professors tended to employ fewer female postdocs but more female graduate students than men who were assistant professors (Fig. S3). Women who were full professors also trained fewer female postdocs than assistant professors did, but there was no difference in graduate student employment between women with different academic ranks. Nonetheless, when we restricted our analysis to only faculty holding the rank of full professor, we still observed a significant deficit in women trained specifically by elite male PIs (Fig. S3).

Among different STEM disciplines, the representation of women generally decreases in more math-intensive fields (3, 17). We focused our analysis on departments of cell and molecular biology (Table S1), but our dataset does contain biophysicists, computational biologists, and other investigators who take a more quantitative approach to biological questions. HHMI investigators whose listed discipline was biophysics, computational biology, or systems biology and NAS members whose primary section was Biophysics and Computational Biology were found to employ particularly few female trainees (Fig. S4). However, even with these faculty members excluded, the remaining male HHMI investigators and NAS members trained fewer women than other male PIs did (Fig. S4).

Lastly, we built various linear models from our dataset using either the weighted percentage of female postdocs or the weighted percentage of female graduate students in each laboratory as the dependent variable. For simplicity, we collapsed the three career achievements that we scored into a single categorical variable (elite status). As expected, among male faculty, elite status was negatively correlated with the percentage of female postdocs in a laboratory ($P < 0.0001$) (Table S3). This relationship remained true even when several other explanatory variables were added, including faculty rank, years since a faculty member had received his or her PhD, and total number of trainees in a laboratory (Table S4). As a single independent variable, years since PhD was moderately negatively correlated with the percentage of

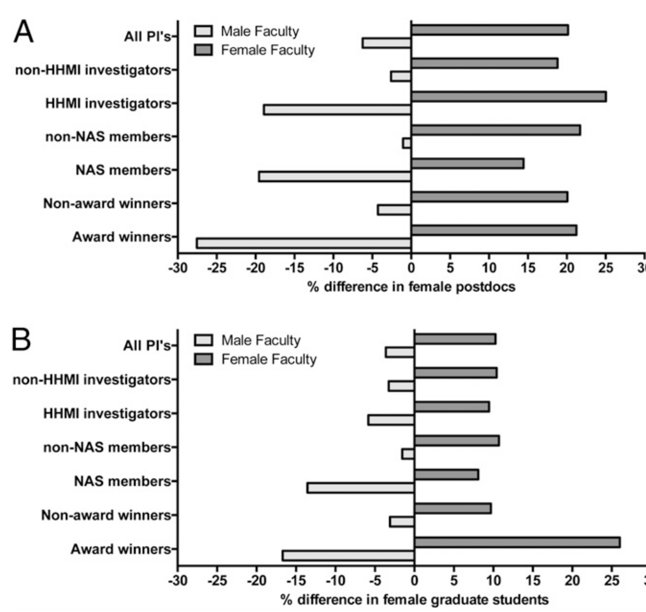

Fig. 2. Elite male PIs employ fewer women. The percent differences in (*A*) female postdocs and (*B*) female graduate students employed by PIs who have achieved certain career milestones are displayed. The axis at $x = 0$ represents employing female trainees at a rate proportional to their representation among all laboratories in this survey.

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female postdocs in laboratories with male faculty members ($P <$ 0.045), but this effect disappeared when other variables were included in the model (Tables S3 and S4). This observation suggests that a faculty member's age is not a significant determinant of the gender makeup of their laboratory, and both young and old elite professors employ few women. Laboratory size was also negatively correlated with the representation of female postdocs both as a single variable and in multivariable models. Regression against the percentage of female graduate students in each laboratory revealed similar, although less robust, results. In multivariable models, elite status was associated with a significantly lower percentage of female graduate students trained by male faculty (Table S4). However, years since PhD correlated with an increasing representation of female graduate students, whereas laboratory size was not significantly correlated in either direction. Finally, we constructed equivalent linear models for female PIs, but we failed to find a single variable that was significantly associated with differential representation of female trainees in these laboratories.

Laboratories That Produce Assistant Professors Employ More Male Postdocs. In the current funding environment, there is intense competition among postdocs for scarce tenure-track positions as assistant professors (18, 19). We sought to determine how postdoctoral laboratory choice and gender influenced this process. Using curriculum vitae, websites, and publication records, we determined the prior employment of 311 of 373 assistant professors from the 39 departments that we surveyed. Of these, 276 assistant professors were postdocs before their faculty appointments, and 144 of them completed their postdoc in 1 of 118 laboratories that we had surveyed. (Assistant professors who did not complete postdocs primarily held clinical positions or were independent fellows before their faculty appointments.) Accordingly, we examined the characteristics of these feeder laboratories that have successfully trained postdocs who won recent faculty job searches at top universities.

The PIs of feeder laboratories were significantly more likely to be HHMI investigators, NAS members, or have won a major research award relative to the pool of all PIs (Fig. 3*A*). For instance, 13% of the professors in our dataset were members of the NAS, but 58% of feeder laboratory professors were NAS members ($P < 0.0001$, Fisher exact test). Our above analysis suggested that these feeder laboratories may therefore have skewed gender ratios. Indeed, these laboratories had 14% fewer female postdocs than nonfeeder laboratories did (Fig. 3*B*) ($P <$ 0.0001, Wilcoxon rank sum test). Both male and female faculty, considered separately, who had trained new professors employed fewer female postdocs than those who had not, although for female faculty, the percentage was still higher than the representation of female postdocs across all laboratories (Fig. 3 *B*–*D*). Because 71% of the assistant professors in our sample were male, these results could represent a form of selection bias. However, when we examined only the feeder laboratories in which female assistant professors had trained, we found that these laboratories still employed disproportionately few female postdocs (Fig. 3*B*). We conclude that PIs who successfully train new assistant professors employ an overabundance of male postdocs.

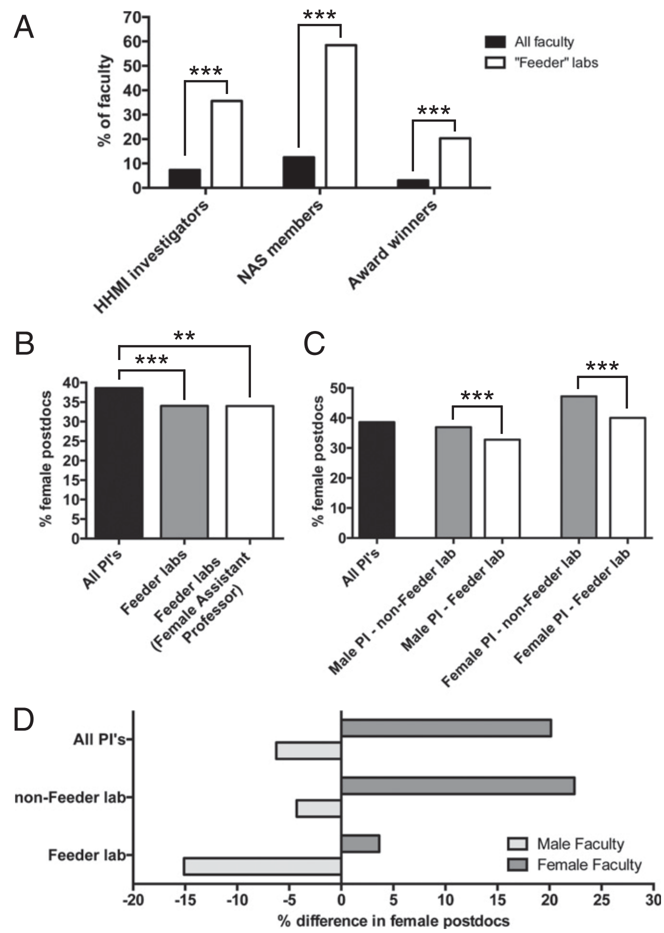

Fig. 3. Feeder laboratories train fewer female postdocs. (*A*) The percentages of all faculty members (black bars) and faculty members who have recently trained new assistant professors (white bars) who have achieved certain career milestones are displayed. ***$P < 0.0005$ (Fisher exact test). (*B*) The percentages of female postdocs employed in different laboratories are displayed. The black bar represents all PIs, the gray bar represents PIs who have recently trained at least one new assistant professor of either gender, and the white bar represents PIs who have recently trained at least one new female assistant professor. **$P < .005$; ***$P < 0.0005$ (Fisher exact test). (*C*) The percentage of female postdocs employed in different laboratory types subdivided by the gender of the PI is displayed. ***$P < 0.0005$ (Fisher exact test). (*D*) The percentage differences in female postdocs employed by different PIs are displayed. The axis at $x = 0$ represents employing female postdocs at a rate proportional to their representation among all laboratories in this survey.

Discussion

Our results show that male faculty in general, and elite male faculty in particular, train fewer female graduate students and postdocs relative to their representation in the pool of trainees at top universities. These findings are robust to considerations of faculty rank, age, and laboratory size and cannot be explained by the exclusion of women from a small number of math-intensive laboratories. Because the majority of assistant professors in our dataset conducted their postdoctoral research under the supervision of one of these high-achieving PIs, the limited number of women trained in these laboratories reduces the number of female candidates who would be most competitive for faculty job searches.

Notably, our current data do not show conscious bias on the part of male PIs who employ few female graduate students and postdocs. It may be the case that women apply less frequently to laboratories with elite male PIs. Unfortunately, data on this question are difficult to collect, because applying to do research in a laboratory is an unregulated and largely informal process. Interested graduate students and postdoctoral candidates typically e-mail PIs with whom they seek to work, and faculty members can easily ignore or delete requests when they so choose. Milkman et al. (20) have shown that faculty members across a host of disciplines, including the life sciences, respond to e-mails from prospective graduate students written under male names significantly more frequently than they respond to e-mails written under female names. Nonetheless, self-selection among female graduate students and postdocs may still contribute to the gender skew that we have documented. By graduate school, fewer women than men perceive themselves to be on an academic career track (10, 21). Some women, in particular, may not apply to the most prestigious laboratories if they do not believe it to be important for their professional development. Additionally, in certain circumstances, women underrate their own skill sets (22–24), which could lead some to self-select away from elite laboratories.

A lack of applications from women could also reflect specific issues with a laboratory or PI. Female PhDs frequently cite marriage and childbirth as reasons to opt out of scientific careers (12); faculty members who are reputed to be hostile toward maternity considerations could be implicitly discouraging women from applying to their laboratories. More insidiously, 16% of women employed in the academy report that they have experienced work-related sexual harassment (25), and the tolerance of sexual harassment in a laboratory could further decrease the number of female applicants. Regardless of the cause, we believe that PIs who receive few applications from female trainees ought to increase their efforts to proactively recruit talented women and should ensure that their laboratories are safe spaces for female scientists. A more formalized process of applying to work as a graduate student or postdoc could also serve as a check against PIs who routinely fail to hire women.

Alternately, differences in quality between the male and female applicant pools could contribute to the gender gap in elite laboratories with male PIs. We note, however, that female investigators at the top of their respective fields run laboratories with just as many women as other female PIs (Fig. 1*B*). Additionally, women win competitive fellowships for graduate and postdoctoral training at frequencies that are proportional to their representation among all trainees: about 55% of National Science Foundation graduate fellowships, 45% of Helen Hay Whitney postdoctoral fellowships, and 41% of Jane Coffin Childs postdoctoral fellowships are awarded to women (26–28). These observations argue against a sizeable gap in applicant quality between male and female trainees in the life sciences.

Thus, in addition to the aforementioned factors, we suggest that gender bias may contribute to the decreased employment of women in laboratories with elite male PIs. Several recent studies have shown that gender bias remains an endemic problem in academic science. For instance, in several European countries, faculty promotion decisions are made by randomly chosen review committees. The promotion chances of female candidates are significantly decreased if they are assigned to an all-male review committee, whereas their promotion chances are equivalent or nearly equivalent to men's chances if they are assigned to a mixed-gender committee (29, 30). Similar results have been reported in the private sector: men tend to underrate women's job performances (31), whereas having more women in supervisory roles is associated with the increased hiring and promotion of other women (32). In an academic context, graduate student and postdoc employment decisions are often made unilaterally by the single PI who runs a laboratory. It may be the case that, in the most competitive laboratories, male PIs knowingly or unknowingly underestimate the qualifications of female applicants and instead hire more men in their place. Because mixed-gender hiring committees more accurately assess the qualifications of female applicants in a variety of settings (29–31), male PIs could potentially benefit by soliciting feedback on applicants to their laboratories from female postdocs or affiliated faculty members.

Irrespective of the cause of the gender disparities in elite laboratories, its consequences significantly shape the academic ecosystem. Our data show that these laboratories function as gateways to the professoriate: new generations of faculty members are predominantly drawn from postdocs trained by high-achieving PIs. However, these feeder laboratories employ a disproportionate number of men (Fig. 3). According to the theory of cumulative disadvantage, persistent inequalities in achievement can result from small differences in treatment over a prolonged goal-oriented process (14). In controlled studies, women in academia receive less favorable evaluations, receive lower salary offers, and are ignored by faculty more frequently than men (15, 20). Access to training in certain laboratories may be another level at which women are disadvantaged. The absence or exclusion of female trainees from elite laboratories deprives them of the resources, visibility, networking opportunities, etc. that could facilitate their professional development. These differences may contribute to the leaky pipeline by shunting women toward laboratories that provide fewer opportunities for advancement in academic science.

Conclusions

The continued underrepresentation of women in the academy slows the progress of discovery by artificially excluding individuals with the ability to make significant contributions to the scientific enterprise. It is our hope that this work, along with the growing body of related evidence showing gender bias in the academy (15, 20, 29, 30), will elicit an increased awareness of the ways in which gender continues to play a role in shaping the career trajectories of young scientists. Recognition of gender disparities as a persistent problem can aid in the fair evaluation of women in hiring decisions and trigger active steps by individual PIs to recruit more talented women to their laboratories. Such steps can ensure that, in the future, an individual's gender will not hinder their ability to engage in scientific research.

Materials and Methods

The name, gender, and rank of PIs from 39 biology departments at 24 academic institutions were collected (Table S1). Graduate students and postdocs who worked for each faculty member were identified from public departmental listings or their laboratory's website. Current HHMI investigators were downloaded from www.hhmi.org and matched with faculty in our database. Members of the NAS were downloaded from www.nasonline.org and matched with faculty in our database. Winners of major research awards (listed in Table S2) through 2013 were downloaded from their respective websites and matched with faculty in our database. Additional details on our survey methodology are presented in *SI Materials and Methods*.

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