



# Women in immunology: 2020 and beyond

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**Women have been at the forefront of tremendous achievements in immunology in the past decade. However, disparities still exist, limiting upward potential and further advancements. As four NIH intramural women scientists who care deeply about scientific progress and the progress of women in our field, we review ongoing challenges and discuss potential approaches to help advance the promotion of women in the sciences.**

Welcome 2020! As we herald in this new decade, we celebrate the many and important contributions of women in science, specifically in immunology. Women have been at the forefront of critical discoveries—from deciphering immune cell differentiation and function to the development of groundbreaking technologies, novel diagnostics and innovative therapies. At the US National Institutes of Health (NIH), we are proud to have a great scientific environment and outstanding women immunologists who have made key advances in the areas of the microbiome<sup>1–5</sup>, imaging<sup>6,7</sup>, responses to infectious diseases<sup>8–28</sup>, autoimmunity<sup>29–32</sup>, cancer immunology<sup>33–35</sup>, genomics<sup>36–41</sup>, understanding primary immunodeficiencies and other genetic disorders<sup>42–45</sup>, mucosal immunology<sup>46</sup>, allergy<sup>47</sup>, vaccines<sup>48–50</sup>, immunometabolism<sup>51–53</sup>, development<sup>54–56</sup>, cellular and systems biology<sup>57–59</sup>, therapeutics<sup>60–67</sup> and a host of related areas too numerous to mention. Women have also been trailblazers in the field of education, bringing forward-thinking reforms to the training of our PhD students and clinicians, with many efforts focused on the advancement of women in science, technology, engineering and mathematics (STEM) fields. In the past decade, women have increasingly risen to positions of leadership across the field as laboratory directors, institute directors, university presidents, foundation and society presidents and biotech CEOs, among others. We have pioneered innovative visions while bringing improved balance to the workplace.

However, while women have brought exceptional and vital contributions, recent data argue that significant gender-based disparities remain in the sciences<sup>68</sup>. Despite the fact that women are well represented as trainees at the doctoral and postdoctoral levels (<https://nces.nsf.gov/pubs/nsf19304/data>)<sup>69–72</sup>, trajectories for women then diverge, with a lower proportion of women achieving tenure as well as promotion to professor-level and leadership positions<sup>70–73</sup>. Disparities continue in compensation<sup>74,75</sup>, funding<sup>76,77</sup> and recognition<sup>78</sup>. For instance, women's representation as academic grand rounds speakers is significantly lower than the nearly 50% female medical student enrollment; in a recent study, only 22.4% of extramural non-trainee speakers were women<sup>79</sup>, and between 2013 and 2014, male academics were found to have given over twice as many colloquium talks compared to their female colleagues at one of the top 50 US universities<sup>80</sup>. Furthermore, while female representation as first authors of articles has increased significantly in the past two decades, their representation as senior authors has not shown the same degree of advancement<sup>81,82</sup>. Such disparities are greatest in high-impact journals<sup>83</sup>. Gender disparities also continue to exist in invited commentary authorship, with the odds of invitation being 21% lower for women<sup>84</sup>. Women authors are

less likely to present their submitted manuscripts as 'excellent' or 'novel'<sup>85</sup>, and one journal editor observed to us that she was struck by how few women rebutted manuscript rejections compared to men (C. Dunbar, past editor-in-chief of *Blood*, personal communication). At *eLife*, acceptance rates for manuscripts with male last authors were found to be higher than for female last authors; this difference was exacerbated when the reviewing team was all male<sup>86</sup>. These differences may contribute to the underrepresentation of women in the top echelons of science. Even within a single entity such as the NIH, different institutes and centers vary widely in the ratios of tenured woman and men, as well as the representation of women in leadership positions, with the same disparities as seen in academia.

Why do the careers of women scientists not progress on par with those of their male counterparts? The underlying causes that result in such disparities and inequities in advancement opportunities for women in science are not always clear, and, as for any complex problem, solutions may not always be apparent. But we are optimistic that solutions exist.

Indeed, given that women and underrepresented groups are not only vital contributors to scientific progress, but also that diverse voices are critical for advances in innovation and discovery, the stakes for the future of science are high. On the basis of prior experiences, we believe that fairly straightforward changes can translate to a significant impact. An adjustment in the review process for Hubble Telescope observing proposals to a dual-anonymous review process (rather than non-anonymous review) was critical for increasing the success rate of proposals submitted by female principle investigators, resulting in parity with male principal investigators<sup>87</sup>. Similarly, during the 1970s, many major orchestras adopted blind auditions. While the cause and effect may be less clear<sup>88</sup>, the percentage of women in elite orchestras has dramatically increased since that time<sup>89</sup>. Can we use these examples to set up our own experiments to promote equality in the scientific arena?

As four women scientists who have worked at the NIH and elsewhere, and who care deeply about the progress of science and the advancement of women in science, we wish to draw from our collective experience to address the question: how can we create exemplary work environments, giving every female scientist the opportunity to achieve her fullest potential? Although we do not all necessarily agree on how to get there, we nonetheless offer our diverse views in the hope of stimulating new efforts to achieve a bright future for women in science in 2020 and beyond. To achieve this goal, we propose a three-pronged approach, which involves: (1) equalizing resource allocation, (2) optimizing mentorship and

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providing advocacy, and (3) challenging stereotypes and beliefs emerging from a patriarchal culture.

We believe that the first critical component for the success of women scientists is the equalization of resources. This includes funding, both at the time of hiring as well as following tenure, and establishing a model to promote sustainability of resources. Resources provided in start-up packages do not include just monies for supplies and expenses but also include funds for personnel and space allocation. Thus, resources have both quantitative and qualitative features. For example, a conscious effort to place new principal investigators in similar physical laboratory and office spaces may prevent the potential for disparities in space to impact, even slightly, a woman's potential to recruit the best postdocs. Establishing programs that help provide personnel to sustain scientific efforts when members of the research team are out on maternity and paternity leave is another example of 'resource allocation' that would promote the steady advancement of scientific efforts yet not diminish the desire to recruit or mentor young women. Indeed, resource allocation and programming that allow flexible work schedules have been shown to facilitate the advancement of women who have to navigate critical periods for job applications and the tenure process while balancing life and family goals<sup>90</sup>.

Equalization of resources also requires a strong commitment to parity in the percentages of women in leadership positions, particularly since these positions are often associated with the allocation of discretionary funds. As women are underrepresented in leadership positions, external reviews evaluating the distributed monies as well as the process of allocations may be needed to equalize resources and evaluate implicit biases that influence decision making. Several organizations and institutes have recently reported on their efforts to improve female recruitment, retention and advancement<sup>85,91–94</sup>. From these reports a common theme emerges: any change focused on efforts supporting women in science must come from the leadership. One such mechanism could be to have a designated director for women in science at all academic institutions, institutes and or individual departments who would have access to data and provide oversight on resources, recruiting and retention to promote equity

across the board. Many universities and academic institutions have already established advisory committees, and at the NIH such committees include the NIH Equity Committee (<https://diversity.nih.gov/programs-partnerships/nih-equity-committee>) and the Woman Scientist Advisors Committee, which specifically promotes the interests of women scientists (<https://oir.nih.gov/signs/woman-scientist-advisors-wsa>). Some NIH institutes have used a mechanism of expanding the numbers of laboratory chiefs (equivalent to a department head) and deputy directors to bring more women into leadership roles. Even though one solution may not fit all, there seems little reason why each institute cannot carry out experiments to determine the optimal paths towards the standardization of equal resource allocation and promotions for women and men scientists.

Our second critical prong includes mentoring and advocacy. There are several components of a robust, effective mentoring environment. First, if we succeed in promoting women, we will have models for our younger generation to look up to. This is also particularly true for all underrepresented groups, where again, having models for one's future is an important step in setting up future generations. Beyond providing role models, mentors can provide essential advice on career steps, including, but not limited to (1) assistance in writing manuscripts, grant proposals and job applications; (2) performing mock interviews; (3) promoting optimal communication by critiquing seminar and meeting slides; (4) helping women at transition stages negotiate start-up packages with maximum resources; (5) providing advice on the journals to which a manuscript can be submitted to ensure that women are not underselling their discoveries; (6) supporting the writing of rebuttal letters in the event of rejections and reviews that are considered to be unfair; (7) ensuring that women scientists are optimally prepared for discussions with department heads, colleagues and editors when difficult or complex conditions arise; (8) protecting women from sitting on an exorbitant number of committees (evaluation, animal use, communal platforms, and so on) that take time away from scientific discovery and publication; and (9) supporting optimal management of the life–work balance. These activities are all essential components of scientific success. This type of concrete advice—

provided by both female and male mentors, including department chairs, senior investigators and professional coaches who may bring outside, objective perspectives—could help promote the early careers of young women scientists as well as the advancement of women in more senior positions.

Within this second prong, advocacy plays an important role. As department chairs and leaders, it is important that both men and women actively promote and advocate for the women in their divisions. In some NIH institutes, each tenure-track investigator has a yearly meeting with his or her scientific director to assess progress and plans. Codifying such events so that starting investigators are guaranteed at least twice yearly formal discussions and ensuring that chairs and directors allot equal time to the success of their tenure track investigators is an important way to normalize and equilibrate access to the top. Women should also not be at a disadvantage if they do not participate in informal social gatherings. Finally, this prong requires the active nomination of women for awards, speaking engagements, panel discussions and promotions and, importantly, advocacy of their candidacy on nominating committees. Recognizing and celebrating the value of the work of our fellow women scientists can provide increased visibility and help instill confidence and success in our women trainees and junior and senior faculty. At NIH, there are efforts to promote many of these components of successful mentoring through, for example, mentoring committees for tenure-track investigators; the Woman Scientist Advisors Committee; the Distinguished Scholars program, aimed at building a community within the intramural program (<https://diversity.nih.gov/programs-partnerships/dsp>); and the Office of Scientific Workforce Diversity, led by Dr. Hannah Valantine (<https://diversity.nih.gov>), as well as individual and institute-specific efforts. Some senior scientists have also publicly announced that they will no longer speak in all-male panels, or 'manels' (<https://www.nih.gov/about-nih/who-we-are/nih-director/statements/time-end-manel-tradition>). These critical aspects of support need to be provided throughout one's entire career.

Our third critical prong requires a shift in our culture—a change in the metrics that we use to evaluate promotion and advancement. We would like to raise the following question: do gender disparities exist, at least in part, because the currently used metrics for promotion and recognition, established largely by men, end up awarding male-biased strengths? The hiring, tenure and promotion of women scientists should be based on outstanding achievements. However, the criteria for what constitutes an exceptional contribution may not always be readily apparent, particularly in the context of existing disparities. For example, two studies argue that bibliometrics tend to result in a bias against women senior-authored articles due to decreased acceptance rates, as discussed above, as well as an under-citation of women in reference lists<sup>86,95</sup>.

Furthermore, the present standards may not place adequate value on the unique assets that women bring to the table—distinct strengths that are equally important to the advancement of scientific knowledge and education. Although we recognize the danger of generalizations, from our experience, women are often more collaborative and less confrontational, actively contributing to team science. Additionally, they are often more engaged in mentoring the next generation of scientists and serving the scientific community. These are indisputable strengths. However, on the basis of our experiences, we find that these strengths are often perceived as weaknesses and may indeed impede the ability of women to advance on the basis of traditional metrics. Recent studies have shown that in mixed-gender co-first authorships, male authors were more likely to be in the first position<sup>96</sup> and female authors were more likely to delegate corresponding authorship to one of their coauthors<sup>97</sup>. Information is still needed on the percentages of women who participate in co-senior and co-corresponding authorship; per the data presented above, we hypothesize that women

outweigh men in their percentage of shared senior authorship. However, being more collaborative and agreeing to equal first or co-senior authorship on a paper may affect the perceptions of those on evaluation committees. As personal examples, having shared co-senior authorship on publications, we have found ourselves in the position of needing to defend our leadership roles. Yet we think coauthorship (as on this Perspective) is an important enterprise that should be valued and promoted.

Being less confrontational may mean that starting salaries and packages are less frequently negotiated by women than men. Women also apologize more often for perceived offenses that a male colleague may not have noted, frequently changing how a woman is viewed<sup>98</sup>. Moreover, women are more likely to devote more of their time to teaching, participating in clinical activities or serving on committees and taking notes—activities that all take time away from the ability to focus on research goals and the advancement of academic careers. We tend to self-promote less frequently, a characteristic that contributes to fewer downstream citations from our research publications<sup>95</sup>. Conversely, while assertiveness is often viewed as a positive attribute in “ambitious” male scientists, we have found that the same attribute in women is often deemed “aggressive.” Indeed, the ‘tightrope’ analogy is an apt description of the predicament<sup>99</sup>.

Perhaps the ultimate message is that we need to create environments where there is value placed on distinct strengths, and particularly, the strengths that women and other underrepresented groups bring to the table. The critical value diversity adds towards scientific contributions is not debatable. If we create an environment that does not leave room for disparities and where there is a proactive effort to appreciate and harness women's strengths, we believe that achieving parity is possible. The NSF ADVANCE program has started such efforts by creating institutional transformation program awards that are aimed at creating a more “diverse and capable science and engineering workforce” ([https://www.nsf.gov/funding/pgm\\_summ.jsp?pims\\_id=5383](https://www.nsf.gov/funding/pgm_summ.jsp?pims_id=5383)). We also argue that it will be critical for our male colleagues to actively join us at the table as we identify and challenge the biases in our culture; we invite our colleagues to partner with us in addressing inequalities, as well as to celebrate our accomplishments and our strengths.

Will these efforts make a difference? Will eliminating disparities in resource allocation, in the context of a dedicated commitment to mentorship and challenging our mindsets, make a difference in the success of women scientists over this next decade? We don't know. But by carrying out some thoughtful experiments, we might identify conditions that will lead to solutions. As scientists, we pride ourselves on our creativity and our ability to think outside the box. Harnessing these energies will benefit us all and will increase discoveries by all scientists. And so we end by applauding the amazing discoveries made by women immunologists over the last decade and toast the many exciting discoveries and accomplishments to come.

Received: 21 January 2020; Accepted: 24 January 2020;  
Published online: 24 February 2020

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## Acknowledgements

The authors thank Cynthia Dunbar, Brigitte Widemann, Carl Hashimoto, Hannah Valentine, Carol Thiele, Meredith Shaffer, Deborah Citrin and Tom Misteli for critical reading. Funding was provided in part by the Division of Intramural Research, National Institute of Allergy and Infectious Diseases (S.K.P. and P.L.S.) and National Cancer Institute (N.N.S. and N.T.), National Institutes of Health. The content of this publication does not reflect the views or policies of the Department of Health and Human Services, nor does the mention of trade names, commercial products or organizations imply endorsement by the US Government.

## Competing interests

The authors declare no competing interests.

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