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WHITE PAPER

Removing systemic barriers to equity, diversity, and inclusion: Report of the 2019 Plant Science Research Network workshop "Inclusivity in the Plant Sciences"

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Abstract

A future in which scientific discoveries are valued and trusted by the general public cannot be achieved without greater inclusion and participation of diverse communities. To envision a path towards this future, in January 2019 a diverse group of researchers, educators, students, and administrators gathered to hear and share personal perspectives on equity, diversity, and inclusion (EDI) in the plant sciences. From these broad perspectives, the group developed strategies and identified tactics to facilitate and support EDI within and beyond the plant science community. The workshop leveraged scenario planning and the richness of its participants to develop recommendations aimed at promoting systemic change at the institutional level through the actions of scientific societies, universities, and individuals and through new funding models to support research and training. While these initiatives were formulated specifically for the plant science community, they can also serve as a model to advance EDI in other disciplines. The proposed actions are thematically broad, integrating into discovery, applied and translational science, requiring and embracing multidisciplinarity, and giving voice to previously unheard perspectives.

For affiliation refer to page 12

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We offer a vision of barrier-free access to participation in science, and a plant science community that reflects the diversity of our rapidly changing nation, and supports and invests in the training and well-being of all its members. The relevance and robustness of our recommendations has been tested by dramatic and global events since the workshop. The time to act upon them is now.

KEYWORDS
diversity, mentoring, science, sponsorship, storytelling, well-being

1 | INTRODUCTION

Diverse communities and inclusive environments foster innovation, inspire creativity, and improve performance outcomes of workers in science, technology, engineering, and mathematics (STEM) (Committee on STEM Education, 2018; National Academies of Sciences E, 2018; National Academies of Sciences E, 2020; Segarra et al., 2020). However, it is necessary to identify the barriers that perpetuate disparities, including implicit and systemic biases and other contributing factors, to realize and sustain inclusivity in STEM.

The demographics in the United States are changing: an ever-larger share of the U.S. population now identifies as African American/Blacks, Hispanic/Latino(a), and Native American/Alaskan Native (AHN). However, AHNs, as well as other marginalized groups such as people with disabilities, members of the LGBTQ community, and women, remain underrepresented in STEM (Endnote[1]), a fact reinforced for some of these groups in the 2022 Science and Engineering Indicators (Burke et al., 2022). Their chronic and profound underrepresentation points to barriers that collectively hinder access to scientific training, retention, and success in technical and research programs. *The goal of this workshop was to identify those barriers and propose solutions to remove them*.

The aegis of this workshop was the NSF-supported Research Coordination Network called the Plant Science Research Network (PSRN) (NSF Award #1514765). The PSRN was formed to find common ground and create future visions under one umbrella, through participation of 14 scientific and professional societies. The PSRN organized a series of workshops from 2016 to 2020, with its penultimate workshop being "Inclusivity in the Plant Sciences," held in early 2019 and for which a summary was subsequently published (Dundore-Arias et al., 2019). The event was cosponsored by the Howard Hughes Medical Institute (HHMI) Science Education Department, which has a major commitment to diversity and inclusion in STEM fields. Forty individuals were invited to participate in the discussion and more than half identified with AHN groups. The participants were also from various professional backgrounds, institution types, at career stages ranging from undergraduate students to university administrators, and they represented the gamut of plant science disciplines. We acknowledge that not all participants were topical experts in EDI. Rather, we relied on the many dimensions of diversity in our participants to take our own journey, and thereby add to other sources and types of resources that are available.

1.1 | Shaking up the room

The workshop format was designed to avoid incremental thinking and "reinvention of the wheel." This was particularly necessary because EDI has long been recognized as an area where the plant science community has failed to make adequate progress, in spite of considerable attention being paid to it through specific funding opportunities, as well as through Broader Impacts activities across NSF awards and efforts in other agencies. Our group was guided—even provoked—to become aware of, and embrace, differences among the participants. Through the sharing of perspectives, experiences, and expertise, participants' assumptions were frequently challenged, leading to richer proposed solutions (see Supporting Information for the complete agenda).

Three speakers were invited specifically to stimulate the atmosphere and inspire participants. One was Shawn Hardnett, a high school teacher from Washington D.C. and education advocate, who helped us appreciate societal barriers to inclusion through his own story; Janell Thomas, a justice, equity, diversity, and inclusion educator, who led us through explorations of vocabulary; and Ali Na, a media studies professor working at the intersections of race, queer, and feminist studies, who helped us visualize core ideas. The impact of these provocateurs reverberated throughout the workshop and in many cases, inspired us well after our time at HHMI.

1.2 | Moving from conversation to action

As members of the plant science community, we have both the opportunity and responsibility to embrace and create a welcoming environment for current and future generations, embedding the understanding that future generations overall will look, think and dream differently than our own. *In this spirit, we propose a set of strategic recommendations that can serve as the starting point to begin reshaping the environment and culture of our community*. We commit to the actions of developing more equitable practices, implementing anti-racist and non-discriminatory policies, being welcoming and attractive to diverse researchers, and better supporting and addressing the concerns and needs of current members of our community, both AHNs and other under-resourced and under-represented individuals or groups.

Our recommendations are intended to be more sweeping and less prescriptive than, for example, small-scale and sometimes quite

successful efforts built into research grants. These are often targeted to specific situations and may not lead to durable change across disciplines. Our strength lies in the alliance of plant science practitioners, who undertook this workshop to develop momentum and build goodwill and to express their own ambition and frustration. In many cases, the PSRN member societies also have active committees organized around themes of diversity and inclusivity (Botanical Society of America, n.d.; Callis, 2020; Goeser et al., 2020; Nemhauser & Haswell, 2019) and have participated or organized other workshops around broadening participation (Friesner et al., 2021). Larger scale offshoots of this PSRN activity have also recently launched, such as the "Rooting Out Oppression Together and SHaring Our Outcomes Transparently" network (NSF RCN:LEAPS Award #2134321) (Williams & Taylor, 2021).

As this report was being drafted over some 3 years, major events shook the country and the world. One was the Covid-19 pandemic (Apuzzo & Kirkpatrick, 2020; Cohen, 2020; Dobson & Wolberg, 2020), which caused—and continues to cause—many forms of mental and physical disruption, and even as it recedes is likely to have forever altered the fabric of scientific research. Another was triggered, but not confined to the murder of George Floyd in Minneapolis on May 25th, 2020. Black Lives Matter, which predated this event (Howard University Law Library, n.d.; BBC News, 2021; Buchanan et al., 2020), and many other movements for racial and social justice were thrust to the fore. These intersect with the goals of the PSRN in promoting EDI, which must be placed in the context of this national movement and conversation. The pandemic, too, intersects with social injustice in many ways (Reyes et al., n.d.; Krishnan et al., 2020; Schumaker, 2020). At the same time, the intersections offer opportunities to consider how plant science can be a part of the response and solution to these much larger societal issues.

2 | RECOMMENDATIONS

Our group did not plan for a single future, rather we attempted to create robust plans that would be resilient to unforeseen events or cultural disruptions, exactly as proved to be the case in terms of the Covid-19 pandemic and social unrest, and as this report is being finalized, in terms of disruption to the post-Cold War international order. To do so, we used a long-term scenario visioning process, taking into account that attaining desired EDI goals will occur in environments that are both uncertain and largely out of control of the scientific community. Specifically, we considered how the funding and economics of science, the political climate, the impact of technology, public perception of science, and societal values and attitudes could create a range of possible futures.

Our recommendations (Endnote[2]) are intended to shift the system in four areas of plant science research and training:

1. **Early STEM exposure.** Raising interest in and awareness of STEM careers more effectively during early education is critical to diversifying participants over the long term.
2. **Relating to others through personal narratives.** We believe in the power of personal storytelling, which can help achieve equity when framed positively.
3. **Broadening career opportunities through shifting mentoring norms.** Early career participants should have access to multiple mentors representing different career successes, and be part of a community committed to inclusive and equitable mentoring.
4. **Calling out the barriers to participation ingrained in our institutional structures and practices.** We must work to actively break down systems and structures that continue to disadvantage participation from underrepresented groups such as implicit bias, career promotion structure, and traditional metrics to evaluate success.

These recommendations can be impactful by increasing visibility of diverse participants, promoting early STEM exposure and retention, providing inclusive and equitable mentoring and sharing the stories of the people working in plant science, as well as fostering representation along different career stages and pathways, especially of leadership in positions of influence. We envision applying these recommendations across institution types and driving meaningful change, encouraging the scientific community to implement interventions in the short-term and scaling the impact of these changes over time.

2.1 | Recommendation 1: Promoting pathways to science through early exposure to plant science

2.1.1 | The power of experiential learning

There is no substitute for implementing inclusive experiential plant science education in terms of growing new plant scientists. Experiential approaches that value learning above achievement are the most productive ways to promote engagement with an increasingly diverse pool of students. Such learning methods must be incentivized and should be enhanced through collaboration with scientists in industry and others outside academia. Scientific societies can also play a role through development of educational materials for both formal and informal education. The Covid-engendered explosion of virtual learning opportunities can be harnessed to increase the reach and sophistication of such efforts, coupled with necessary investment to mitigate the digital divide.

Along with computational resources, we must also provide teachers the needed connections and materials to showcase STEM careers. Professional societies can partner with industry groups to develop dedicated online platforms to inform students and parents, and to highlight plant science career opportunities. Misperceptions of what careers are possible in plant science are widespread, especially in the era of digital agriculture and more generally, where engineering, social science, data science, plant science and climate science, for example, are tightly interwoven. Other opportunities for career exploration, such as #BlackBotanist on Twitter (Williams et al., 2021) and the "Skype a Scientist" program (Beattie et al., 2020), can connect

students directly with scientists through social media and other online programs.

2.1.2 | Integrating mentoring and sponsorship

Research-intensive institutions should encourage mentoring networks that include "near peer mentoring" and opportunities for mentees to transition into mentoring roles (also see Recommendation 3). Shifting to a culture of mentoring will work to increase students' exposure to scientists at different levels of study. We can imagine a "daisy chain" that connects undergraduate student mentors with the K-12 classroom to facilitate hands-on lab experience, which may impact retention of undergraduates in the plant sciences through the excitement and engagement it builds. These types of linkages also provide continuity to support students as they move beyond the K-12 period, where undergraduates are in turn supported by faculty, graduate students, research associates, and institutional and professional society resources. In this light, we call attention to short- and long-term recommendations for an inclusive plant science college undergraduate classroom that have been recently developed (Butler et al., 2021).

The ability to provide the envisioned mentoring requires the development of supportive networks with cultural competency. Thus, beyond near-peer mentoring we support the concept of "sponsorship," that is, a long-term connection that goes beyond academic counseling and career mentoring (Hewlett, n.d.; Chow, 2021; Hewlett et al., 2010). For example, a sponsor may support the advancement of an individual within professional networks, help to navigate organizational structures, and open access to critical professional opportunities, doing so with a holistic understanding of their protégé's life experience. However, the lack of representation in the plant science workforce limits the ability of marginalized individuals to find and interact with role models with similar background experiences in a meaningful way, and unfortunately, mentors and sponsors from other groups may not understand cultural imperatives that are as essential to well-being and a sense of success for those individuals. Therefore, EDI training needs to be implemented as part of equitable, comprehensive, structured long-term mentoring programs.

2.1.3 | Financial resources

Properly constructed science experiences are not free. Whatever their academic level, funding that directly supports trainee housing, health care, tuition, and/or research expenses, will be required to achieve equity and therefore promote the participation of underrepresented groups. Likewise, mentors may need salary offsets for professional and curriculum development, as well as equipment and supplies, in order to provide such experiences. Often, faculty providing support for training beyond experimentation itself, for example, emphasizing outreach or mentoring, are not rewarded or incentivized, particularly at research-heavy institutions. Therefore the institutions must recast their merit structures to reward and compensate for the additional effort required, which includes the training itself, as well as implementing mentoring strategies, and spending time in meaningful interactions and conversations with the trainee and their support network. At the same time, faculty should be subject to evaluation of their success in implementing the experiential program, not just on its research output but also on the growth of the trainee.

Questions for the research community to consider are: Is further training needed to prepare researchers to take their research into the classroom? How might research funding be leveraged to support K-12 outreach programs? How do you develop resources that are broadly applicable given school district and state-specific requirements for teaching science? What can we do at a community level to increase free-choice education and learning opportunities (such as at cultural centers, museums, farmer's markets, botanic gardens)? Outreach specialists can support scientists to identify their expertise and develop modular training packages ready to be deployed in classrooms.

Funding agencies, as well as institutions, should review their approaches to these activities, which are often referred to as "broadening participation." It is currently left to applicants to determine budgetary allocations, design programs, and operate them. Panels often pay scant attention to the details of such programs, and any institutional resource contribution such as provision of recruitment and mentoring services, and there is very little collective lookback at their success. Some of this is inherent in the nature of granting programs, however agencies may consider ways to enhance the evaluation of BP initiatives at different scales, as well as guiding proposers to potentially more impactful approaches. We are not referring to programs such as INCLUDES, which is carefully managed, but rather to maximizing the potential of awardees whose grants have research as a primary outcome. This represents the majority of allocated funding, and could have the most global impact on increasing the diversity of plant scientists if proven methods were more often incorporated into their endeavors.

Getting people excited about plant science through participation will be far more durable if the potential for a fulfilling career is also visualized. Many people—young or otherwise—might be surprised to know that a "plant scientist" might be an economist, engineer, nanotechnologist, or communications specialist, as well as a lab or field researcher. They might work in law, government or for a foundation, not just for a learning institution or company. We often fail to expose these possibilities either directly through practice or during mentoring. Therefore, "experiential" learning should embrace the full range of career possibilities, rather than seeming to be a step along a typical academic path.

2.2 | Recommendation 2: Harnessing the power of personal narratives

Public understanding and perception about the possibilities and everyday relevance of plant sciences significantly influences the level of interest of potential plant scientists and the range and extent of funding available. The PSRN has previously made this observation

(Henkhaus et al., 2018; Henkhaus et al., 2020; Plant Science Research Network, 2016), and our EDI-centered workshop embraced this concept and calls for strong efforts to glamorize plant science. We choose the word "glamorize" intentionally because it connotes an emotional connection, beyond making a scholarly, technical argument as to the importance of plant science: Both are needed to increase the diversity of plant scientists.

Increasing diversity in plant scientists starts at a young age with increasing awareness of plants and their roles in culture, food, medicine and the environment and the scientific discoveries that advance human life. Plants are often discarded by our brains to simplify our visual fields, a phenomenon known as "plant blindness" (Çil, 2015; MacKenzie et al., 2019) or the preferred and more inclusive term, "plant awareness" (Parsley, 2020). Where plant science has received significant media coverage, it sometimes becomes tainted by political overtones and misinformed perspectives (genetic modification of plants, and overuse of pesticides and water pollution are examples). In order to build awareness for plants we must engage with the public, and participate in timely societal conversations, an approach which has met with some success in the area of plant biotechnology through groups such as the Alliance for Science (https://allianceforscience.cornell.edu/) (Conrow, 2021). To counter negative trends such as misinformation, we should tap into people's natural interest in food, nature, the environment, and gardening and connect them in positive and fact-based ways with hot topics in science such as climate change, biodiversity, food security, sustainability, nutrition, plant-based pharmaceuticals, genome-based insights into domestication, diverse germplasms, and crops newly adapted for bioproducts.

The recommendations below are flexible approaches that play into emerging modes of communication, especially those that appeal to and are used by diverse communities. These include storytelling (Figure 1), modular tools, and amplifying actions (Robison et al., 2020) that will equally engage the public and community scientists. Beyond this general landscape of raising visibility through cohesive action, we advance the following specific recommendations.

FIGURE 1 Stories are used to provide a much richer picture of who a person is and may improve the feeling of belonging and inclusion at work. Workshop participants discussed the importance of sharing personal anecdotes to connect as individuals. However, not everyone feels safe in the workplace to share their story. Workplaces that make space to acknowledge and celebrate our personal differences can create a richer community and engender more workplace satisfaction.

2.2.1 | Develop strong partnerships and community networks to connect with the public

In tackling the challenge of broadening participation in the plant sciences, our research and diverse career paths need to be seen as relevant and impactful, and through role models that connect with those whose participation we seek. Achieving the desired visibility of and exposure to the plant sciences at a national scale will be challenging, auguring for initial efforts at the local level that speak to those specific communities through their own institutions and focused on their specific priorities. These modular tools and stories should be deployed with an eye towards viral messaging and campaigns that can be easily picked up by the general public (memes), for example combining pop culture topics with plant science knowledge and disciplines. These will coalesce into more general themes to build the plant science brand nationally. Learning from other fields that have successfully built strong brands and are seen as more fashionable, while leveraging the rapidly evolving 21st-century social media landscape, will also be essential (Figure 2).

Partnerships will be indispensable for increasing exposure to our field. Such relationships that span K-12, higher education, government agencies, non-profit organizations and industry already exist but are atomized and therefore do not generate a sense of momentum throughout our community or in the national eye. The plant science societies can play an important role in overcoming this lack of cohesion (Madzima & GC, 2021; National Science Foundation, 2021; Segarra et al., 2020; Williams & Taylor, 2021), while they articulate why inclusion and diversity are important drivers to attract new members, and become more intentional on how they expect to retain them. Beyond the professional societies, we must create a forum for community collaboration and pooling of resources across institutions, NGOs, universities, state and federal governments, and philanthropists. This will enable the formation of community goals, vision, and a constellation of action settings.

2.2.2 | Influence the influencers

The plant science community must invest in training leaders across disciplines and sectors, with the goal of becoming more aware of issues of inequity, implicit bias, and barriers that limit participation in

FIGURE 2 Using social media to promote plants and science education. The workshop participants had a crack at developing their own social media hashtags to increase enthusiasm for plants and to increase a feeling of inclusion in science. Here, we display hashtags created by workshop participants. We encourage the use of these hashtags and recommend pairing them with interesting pictures of plants and people. Participants also toyed with designing memes (not shown). There are many plant memes found online such as "Plants have all the anthers" or "Things I do in my spare time: Buy more plants" (Fluellen, 2020) that have viral appeal with the general public and help to increase awareness of plants.

the plant sciences. We are not so much promoting mandatory awareness training, though many institutions already do so, but rather identifying and growing a new generation of diverse leadership: the role models who by dint of their own life experiences, can represent the spearhead of change. Leaders do not simply appear; their potential must be identified and realized. Where institutional leadership is diverse, it is often "assigned" to a diversity portfolio, which is insufficient and risks tokenism. Real change will occur when diverse leaders are not the exception and arise because of their broad qualifications and contributions. In terms of our recommendation here, those qualifications would include skills in science diplomacy and the ability to actively engage in the public debate and policy setting around issues of equity, diversity, and inclusion in STEM.

The focus on science diplomacy—the storytelling and local awareness referred to above—goes well beyond more general EDI training and awareness, and in fact, the effectiveness of the latter is being debated both in terms of impact and potential counterintuitive outcomes (Chang et al., 2019; Combs & Luthans, 2007; Dobbin et al., 2007). This type of diplomacy must be valued and rewarded by the institution, as it is different from the press releases, videos, and podcasts that typically accompany scientific breakthroughs, and target more familiar and attuned audiences.

2.2.3 | Train dynamic, engaging plant science communicators

Being a dynamic and engaging plant science communicator is an integral part of scientific and educational excellence. Engaging means effectively reaching out to a wider and more diverse audience of potential plant scientists in a relevant manner and learning from them by listening. As such, the plant science community should incorporate measures of excellence for faculty, students, researchers, and teachers as evidence of attendant efforts and their success. Building such capacity will entail strong collaborative partnerships with professional science communicators and media professionals, investments in faculty development, and embedding science communication into undergraduate education not only through coursework, but through social media and other modular opportunities. Every plant scientist should acquire and maintain dynamic and engaging communication skills, which may be expressed in a variety of formats depending on an individual's strengths and interests.

2.3 | Recommendation 3. Maintaining momentum through transitions

Truly broadening participation will require additional and continuous support during the many transitions that take place from K-12 to higher education, and ultimately in launching a career (Figure 3). In this context, our workshop focused on how the plant science research community can fulfill its role in providing and promoting opportunities for active engagement throughout college and beyond. If we are successful, students from marginalized groups will be connected, fully included in the culture, and valued within the research enterprise and education systems. While we recognize burgeoning efforts to address EDI across many university campuses, compatible, targeted efforts are needed in the context of plant science research that will ultimately

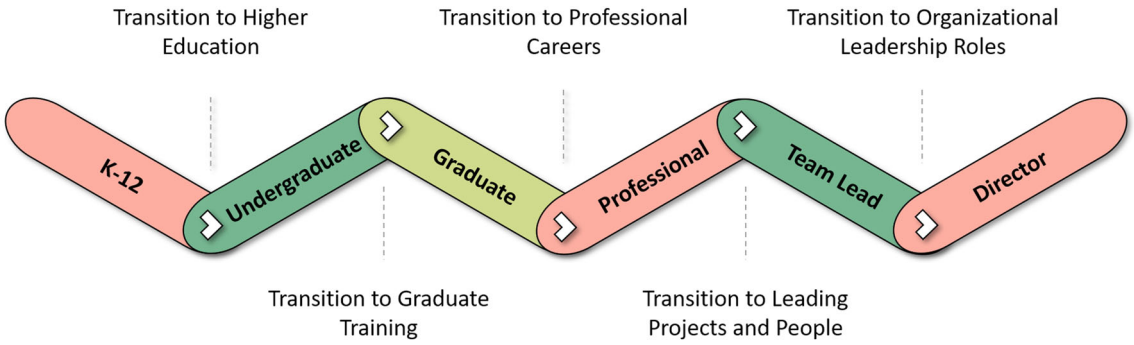

FIGURE 3 We have a responsibility to support plant scientists across transition points. Careers are journeys with many transitions (see "Pathways to Diverse Careers" 29, a training model that envisions plant science-related careers as a flexible web of possibilities). In this figure, we indicate five transition points where mentoring and sponsorship can improve retention and satisfaction. Students transitioning to higher education and/or their first professional position need support to ensure that diverse candidates are hired into technical positions. As plant scientists advance to more senior roles, we have a responsibility to ensure that diversity is maintained and that traditionally marginalized people are present and well supported in leadership positions, as discussed in Recommendation 2.

change its organization and culture, creating sustainable momentum for diversity and discovery.

2.3.1 | Implement continuous training in equity and inclusion

We recommend that continuous training in equity and inclusion, especially for influencers in the research community, is maintained to improve efficacy and relevance. Long-term impacts will enable great science, value diverse researchers, and also prioritize collaborative science, as described below. The views of workshop participants varied, however many believed that institutions are tackling the more general aspects of EDI awareness, including but not limited to bias training, antiracism, and understanding of diverse experiences. We consider this to be a foundational activity for more tactical contributions to supporting plant science education and career transitions to broaden participation in all sectors. Therefore, in spite of its overriding importance, we do not advance specific recommendations here.

2.3.2 | The concepts of mentorship and sponsorship

In previous PSRN workshops, the term "mentorship" was mainly utilized. For our purposes, "mentoring" refers to ongoing advice and consultation in the context of fulfilling a particular stage of career building, for example, during an undergraduate research experience, doctoral period, postdoctoral stage, or in a new job. "Mentors" have "mentees" with whom they are paired, and the PSRN has previously recommended normalizing the use of mentoring teams, giving the mentee additional resources that would, for example, stimulate research ideas but also identify ways to build appropriate transferable skills (Henkhaus et al., 2018).

In this workshop we were introduced to the concept of sponsorship by one of our provocateurs. *Sponsorship represents a continuity of mentoring across transitions*. For this reason, perhaps, "sponsors" are paired with "protégé," a word with the origin "to protect." "Mentor," by contrast, has its origin in advising. While we may not mean literal "protection" by a sponsor, we may mean to protect against career discontinuity or "falling between the cracks" at times when there is no specific context for advising or mentoring. We speak, for example, about "sending someone to college." Who in the career sense is taking them there, to ensure a soft landing, to ensure that their life, not just their course selection, is in order? If we wish to invite the possibilities of plant science, we must help to prepare and fertilize the ground on which our careers grow (Goeser et al., 2020; Montgomery, 2020a; Montgomery, 2020b; Pandey, 2020). Thus, sponsorship builds a bridge between academic and family life that may often be discounted and/or neglected. We believe that a failure to attend to personal and family needs is antithetical to the needs of diverse participants, even more with the "Zoom World" increasingly blurring the distinction between "work" and "life," and therefore the relevance of the "balance" we often speak of achieving.

2.3.3 | The practicalities of mentoring and sponsoring

Two elements must coexist to fulfill our goal of smoothing transitions. These are the identification and maintenance of willing mentors and sponsors, and support of them providing the needed capacity. In other words, we expect that many individuals of good will would offer to contribute their services, but are they poised professionally to do so, will they be rewarded, and how do we solicit and incorporate feedback from mentees and protégé?

Ideally, mentors or sponsors would reflect the experiences and backgrounds of their charges, and therefore be better positioned to appreciate and support their aspirations. Given that the potential pool of mentors and sponsors from underrepresented groups is relatively small—a sort of chicken and egg problem—mentors of other backgrounds who have been properly trained and understand the value

and challenges associated with equity and inclusion, should also be welcomed. All should be united in their goal to apply best practices to recruiting, training, and retaining a growing pool of underrepresented plant scientists. At the outset of these relationships, mentees and protégé should understand the importance and value of building long-time relationships with their mentors, sponsors, and peers in the plant sciences, as well as how to mentor others.

Online communities will be indispensable for building and strengthening the mentor/sponsor pool. A comprehensive network should span the full range of stakeholders including education (K-12), universities and community colleges, research institutes, industry, non-profits, and government. Some innovative approaches include creating online exchanges that connect researchers with a mentor or sponsor community (Sorkness et al., 2017). It would seem to make more sense, however, to nurture the creation of an umbrella program: the technology certainly exists to do so. This might take the form of a searchable database that allowed mutual introductions and also hosted feedback that would be suitably curated. We already do this for college courses, institutions and their subsidiary programs, and a host of components of our daily lives (movies, restaurants, services, etc.). The main barrier to creating the proposed resource is that it needs buy-in from currently fragmented ones, along with human resources and IT capacity, which could be provided initially, at least, through grant funding.

For EDI mentorship and sponsorship to succeed, it will require personal relationships, commitment to the success of the mentee or protégé, financial and professional incentives, and a consistent recognition and valuation across the plant science community. *If established researchers view the activity as a distraction and administrative burden, it will fail*. Understanding how researchers view and implement current requirements for postdoctoral mentoring plans in NSF proposals, for example, could give insight into buy-in for a larger scale effort.

2.3.4 | Value and prioritize a new vision of collaborative science

The team concept of mentoring/sponsorship fits well into our vision of how the plant science research culture must evolve. Collaborative and particularly integrative science is increasingly the most effective platform for holistic discoveries, and ultimately the science-based components of solutions to the pressing challenges facing humanity. But how science is conducted can also have a tremendous impact on the diversity of its practitioners. Thus, while collaboration itself is a venerable concept, *we call for a new vision of collaboration that leads to improved inclusivity, validates the potential of integrative research* (Endnote[3]), *and opens the door to broader viewpoints and more innovative outcomes*. This vision is closer to a team approach than the traditional construct of collaboration, where two or more largely independent methods are used to provide different forms of insight into a given question. For example, metabolomics and transcriptomics might be applied to the same biological materials, or a biologist may collect data which are then analyzed by a computational scientist. In this vein, most Nobel prizes in Medicine are awarded to collaborative groups or multiple scientists (some of whom may be competitors). In contrast, the results from an integrative team approach are mutually informative and iterative, leading to new insights, where perhaps none of the efforts alone would be considered a finished product.

This new vision of team-oriented plant science requires innovative training, modeling behavior, and successful applications of collaborative science. Perhaps most importantly, rewarding collaborative efforts must take care that they do not regress to the familiar tropes of individual achievement. It is those tropes that are for various reasons, disincentives to join plant science or barriers to career growth (some specifics are addressed in Recommendation 4). Furthermore, this vision requires bringing the entire value chain into a collaborative space to address big challenges, meaning that whether a contribution is basic, translational, applied, computational, molecular or ecological, it all lives in the same inclusive value space. When we flatten our hierarchies and join hands in discovery, we are being more inclusive and recognizing that the scientific enterprise is truly and inevitably multifaceted, and "owned" by all the participants.

These collaborative models can be facilitated through new types of cluster hiring carried out with the intent to create convergent science (Walker, 2020). This strategy, designed to stimulate team dynamics during the hiring process, must be accompanied by directly addressing the merit reward system of research in both academic and nonacademic settings (see Recommendation 4). This can be accomplished by incentivizing collaboration; for example allowing for and promoting jointly written, cross disciplinary dissertations; and recasting the review and promotion process. Rethinking collaboration can be a lever to shift the long-standing focus on the individual researcher to an emphasis on the research team. We have no illusions that this will be easily done in the face of entrenched paradigms, but its importance was forcefully argued not just in this workshop, but also in other PSRN workshops (Henkhaus et al., 2018) and elsewhere (Chapman et al., 2019; Edwards & Roy, 2017) in the scientific community.

2.4 | Recommendation 4: Recognizing and dismantling institutional barriers

Participants in this workshop, and previous PSRN workshops, often expressed frustration regarding institutional barriers to implementing recommendations (often referred to as "the system"). Many of these barriers are passive; that is, they are "how things are done" and represent longstanding practices and norms in academia. Examples most often debated were the tenure system and merit criteria, whether merit review is related to tenure, grant proposals, or to career advancement more generally. Additional systemic barriers more specific to marginalized groups include the weight often assigned to "scientific pedigree," and the perception that participation of members of marginalized groups is always the result of "equal opportunity" initiatives and not their achievements. The latter may lead to an expectation of near-perfection on the part of the marginalized individuals to avoid confirmation bias (the assumption that marginalized individuals

generally underperform), adding to pressures otherwise exerted by "the system."

The PSRN often advances team-based concepts that cut against the grain of identifiable individual achievement, which is currently a pillar of typical peer review in the plant sciences. We also call on faculty to spend more bandwidth on activities that will broaden participation, however these activities are rarely rewarded and in fact take away from what *is* rewarded: grants and publications. We have called for direct funding of trainees (Henkhaus et al., 2018), to remove pressure placed on them to support a supervisor's career rather than their own. *None of these systemic issues are simple. What is most important is to recognize these barriers for what they are: facets of a system long designed and operated by a narrow demographic group, and therefore a system that must reinvent itself if it wishes to embrace diversity*.

2.4.1 | Valuing research, teaching, and service that integrates EDI in the context of the tenure model

Our plant science community needs to address the ways in which teaching, service, and collaborative research that integrates EDI are valued (Esposito et al., 2022), while at the same time not making it an especially implicit or expressed requirement of those from marginalized groups. The current emphasis on individual research, and requirements for achieving and maintaining tenure, in many instances run counter to this strategy. That being said, the stated purpose of "modern" academic tenure is to safeguard academic freedom in teaching and research; this freedom is central to creative thought towards unhindered research and discovery. Our group does not take a position on whether academic tenure should exist: participants had a diversity of opinions that were both philosophical and contextual.

The discussion here simply recognizes the importance of academic freedom, the prevalence of the tenure model and its intersection with our recommendations. Tenure may also provide a means by which an increasingly diverse faculty can have a funding buffer to allow them to more equitably support mentoring opportunities. The question then is what can be done to raise the importance and emphasis on teaching, service, and collaborative successes? The answer may require building these activities and achievements, as well as EDI, explicitly into tenure or promotion requirements, or separating individual research and community building, to ensure both receive proper funding and attention. In order for value judgments around teaching, service, and collaborative research that integrates EDI to truly change, the plant science community must overcome biases, implicit and explicit, and judgments within the community regarding region, school, type of institution, career choices, and the qualities associated with scientific excellence. Left to its own devices, "the system" is likely to remain intact or very slowly evolve. Given that the external world is in the midst of huge cultural and political shock, *we can see this as an opportunity to harness external pressures to catalyze more than incremental change*.

2.4.2 | Diversify plant science education and expand degree tracks

Universities must value the student experience coming into and building throughout their plant science education. Plant science education, including degree programs and credential tracks, can be expanded, for example to ensure that plant science is not a fringe component of general biology majors. One could turn on its head the concept that biology is best learned from animals, and that a few specialized lectures will cover anything special about plants. "Plant blindness" is not confined to the non-academic world.

It is equally important that the tracks be clearly linked to professional development mechanisms and programs. To do this well, the plant science community must offer the opportunity for skill development that is more modular, and provide opportunities to earn credentials that enhance or build a range of professional career paths.

Diversifying educational tracks can also allow for incremental programs such that a student can achieve an associate's degree that allows them to become employable such that they can finance the next level of their education. The education tracks can be thematically organized and driven such that students are educated through addressing broadly defined "problems" to solve, or address areas of research that will demonstrably improve our local communities and broader society. There is a current model around thematic driven education: Science, Technology, Engineering, the Arts, and Mathematics or STEAM, which begins in middle school and keeps science embedded in the arts. A theme for a STEAM program could be as simple as *the importance of plants in our world*.

2.4.3 | Create and promulgate expansive, flexible, dynamic career opportunities

A significant institutional barrier to diversity in plant science is the value system associated with career aspirations. If we oversimplify for the sake of argument, we find that the aspiration to be a professor is the "highest," and anything else is an "alternative career." Among the latter, we regard industry jobs as most acceptable, since they are still research, although without the vaunted freedom of academia. Other positions, such as teaching, administration or media, are generally viewed as tertiary choices that reflect a lack of success during training. This is not a pretty picture, but it is very easy to imagine that subtle or not so subtle intimations of this sort are frequently imparted to trainees as they consider or proceed in plant science training.

Therefore, the plant science community must work to align the training and educational model with employer needs and participant interests, thus marrying an expanding set of career tracks with the expanding set of plant science training tracks. We must collaborate with industry and other employers to understand where there are shortfalls in training and help higher education and all post-high school education understand what training is needed. This can be accomplished by professional societies facilitating these communications and connections, and students then through their mentors/

sponsors and educational institutions being provided access to relevant and helpful information early in their training. *The goal is to create a system of lifelong career development support that allows plant scientists to explore career opportunities without judgment*.

As we proposed for mentoring and sponsoring (see Recommendation 3), the plant science community would be best served by a career development database that has open access, well curated resources, and built-in mechanisms to ensure the information stays relevant and timely. This must be done in an accessible format to students and scientists at any stage of their career search or development. Ideally, the resource would be designed to be tailored to different demographics or other personal criteria. The resources can include both information on careers, educational requirements, job opportunities, speakers, and people available to support career development; that is, this could ultimately be fused with the mentor/sponsor database. Clear and accurate information will also serve to facilitate conversations within families and communities about the many possibilities of plant science careers, which are often misconstrued as menial and/or poorly paid.

2.4.4 | Fund people, not projects, to reduce financial barriers

Financial barriers are one limitation, and not infrequently the primary barrier confronting potential plant scientists who would otherwise enter the educational and training systems. Mitigation strategies include equitably funding individuals through independent research grants, supporting participation in training programs, incentivizing broader participation and access to funding, and reducing the costs of higher education with a focus on underrepresented populations. In society-serving fields such as agriculture, the costs of higher education can be reduced to ensure an expanding pool of diverse plant scientists are available to tackle the many challenges posed by threats to biodiversity, climate change and food security. The plant science community can work together to reduce the barriers for students to access financial resources. The approach can include the use of stewards or concierges to help students successfully navigate the financial hurdles, connect diverse candidates to opportunities for funding, including industry financial sponsorship and independent fellowships, and lower the financial hurdles in the first place.

The aspirational target of free education may never be attained; however, supporting family medical leave for students, addressing the opportunity costs associated with a student choosing an unpaid summer opportunity over a paying job, incentivizing plant science undergraduates to complete their degrees and leadership experiences with the promise of graduate school funding, and expanding funding for undergraduate students, graduate researchers, and postdoctoral trainees regardless of citizenship status can all have a profound impact on broadening participation. *The unifying principle is that all of these ideas require shifting the paradigm from funding projects to funding people*. In doing so, the research environment shifts towards a more equitable marketplace where the experience of a trainee beyond the research itself, will be a motivating consideration for both the trainee and their primary mentor(s). We anticipate, but reject, the argument that project leaders should be in full control of trainee funding, in order to maximize the probability of success of the research. This is of course the existing paradigm, in which the majority of trainees are akin to apprentices, while a few privileged trainees with suitable pedigrees are accorded independent support. *This model may work to perpetuate "the system," but it does not work for all of us*.

2.4.5 | Increase services to support the well-being of scientists

In order for the plant science community to broaden participation, it must support and retain scientists in the face of many social barriers, including mental health. Mental health is of critical concern and was only exacerbated by the Covid-19 pandemic (Langin, 2020), during which as much as 70% of faculty reported burnout or stress (Gewin, 2021), and graduate students were similarly affected (*Graduate Student Mental Health and Well-being*, n.d.; Duffy et al., 2021; Forrester, 2021). Such stress can only be exacerbated by marginalization. Some institutions have responded by redoubling efforts to educate and support both students and faculty with knowledge, resources, and tools to destigmatize mental health and provide support to overcome personal and professional challenges, promote well-being in the workplace, and ultimately improve career satisfaction. Our impression is that the results have been uneven.

Given our ambitious vision for systemic change, setbacks and failures are inevitable. When issues of discrimination or oppression occur, the plant science community and its parent institutions must recognize these experiences and learn to create a safe and confidential means for those who experience them to seek assistance and support. That support must include consistent application of agreed upon principles of action and behavior within each institution. Otherwise, underrepresented individuals experiencing discriminatory practices, or bystanders witnessing such behaviors, will continue to fear repercussions and not report, allowing discriminatory practices to remain unchallenged. This situation can also be resolved if institutions commit to challenging these issues from the top, rather than placing the onus on the shoulders of those with that lived experience.

2.4.6 | Remove barriers to international mobility in plant science

Plants sequester carbon, and the carbon cycle knows no national boundaries. Our shared climate destiny binds us together as plant scientists and as humanity. Furthermore, human mobility has long fertilized science across the globe. Thus, while growing talent "at home" is vital, we also must promote geographic and cultural flexibility that will enrich U.S. science, but also sow innovation elsewhere. For example, international agriculture projects funded by the U.S. Agency for International Development, Fullbright scholarships, and the Bill & Melinda Gates Foundation to reduce inequity through capacity building

efforts, education, resources, and collaborations with local programs, as well as exchange programs represent examples that need to be augmented and emulated by other funding agencies (Cheney, 2020; Schurman, 2018).

International mobility and interchange have long been cornerstones of science, which itself is supportive of and influential in democracy, free speech and other aspects of open and technologically advanced societies (Davies & Horst, 2016; Sallet, 2017; Scientific Revolution, 2021). In addition, the grand challenges that plant science research addresses are global in scope and nature, as is our workforce. We as a community are highly concerned about barriers to international exchange, which extend both to people and scientific products (e.g., samples and intellectual property). *Free engagement across national barriers imparts creativity, cultural fluency and equity among stakeholders*. We believe that both the development of domestic talent, and discoveries that will change our future, all will be rooted in free exchange. This can be achieved through simplified, accessible exchange programs, and international covenants that support and incentivize collaborations, rather than viewing them with suspicion, or using exchanges as political cudgels.

We believe that the benefits of open and free scientific exchange far outweigh any risks, if the programs are appropriately constructed and managed. The last several years have seen imposition rather than rescission of barriers, where scientific innovation has been stifled by political or economic agendas. *We therefore recommend that visas for student exchanges, postdoctoral training, and faculty hiring should be readily accessible*. In the United States, the "Dreamers" are a multicultural and highly educated demographic group, motivated to contribute knowledge about plant science (Endnote[4]); barriers to their integration and participation should be permanently removed. As this report was being finalized, war broke out in Ukraine, again raising the stakes for realization of the potential of science diplomacy.

3 | TAKING ACTION: OPPORTUNITIES TO BUILD CAPACITY FOR PLANT SCIENCE

Plant scientists must take action to promote systemic change, starting by implementing and sustaining the recommendations proposed by the PSRN workshop participants, and model the leadership attributes we seek to cultivate in future generations. As practitioners of science, we must be held accountable to do the difficult work on unlearning behaviors and biases and be aware of how they contribute to systemic racism in universities, industry, government, and nonprofits. *People in positions of influence have an additional responsibility of learning to recognize those behaviors and biases, and seek positive paths for change through reward rather than punishment*. It will be important to emphasize both the human and scientific benefits of change, recognizing the diversity of frames of reference among current scientists.

When opportunities arise, we must update our traditional metrics for "success" and notions of "productivity" to be more fluid, reflecting a new way of thinking that embraces EDI. For example, each action of funding, hiring, and evaluation provides an opportunity to shift our lens. We have also emphasized the importance of systematically promoting early engagement to increase awareness of the relevance of the plant sciences, and the extremely broad range of career pathways that its participants can and should be encouraged to choose. Each conversation or media thread with a student, a parent, a reporter, is an opportunity to do so. How science defines and recognizes excellence and success, and promoting career diversity, are far from specific to the plant sciences, and we hope that other disciplines will consider our findings. Taking the above recommendations into account, we suggest three main axes for immediate action:

3.1 | Begin change with the individual

Large programs matter, institutions matter, policies matter, but without individual commitment we will persist in the status quo. In PSRN workshops it was not uncommon to hear the question, "who is going to change things?" There is no magic formula, the scale of change and its pace will depend on the commitment of each of us. We recognize the disparities in power within our community, and these different layers were represented in the workshop. Greater power means greater influence and responsibility, but all of us have some degree of power.

3.2 | Prepare the workforce for diverse careers

There are many layers to building a diverse scientific workforce. For example, administrators can work with their institutions to promote training partnerships between research institutions and local community colleges, minority serving institutions, and primarily undergraduate colleges and universities, as well as private industry and other public and non-profit organizations. After-school activities to supplement K-12 education can support teachers and parents to provide experiential activities for students.

Research institutions can partner with high school and university educators to offer summer STEM courses and internships, creating partnerships that provide value to all involved. Graduate students and postdocs participating in these activities will gain valuable science communication, inclusive teaching, and mentoring experience (Dewsbury & Brame, 2019). Teachers and college instructors will gain access to resources, new knowledge, and technologies to integrate into classroom teaching laboratories. Researchers may also develop outreach programs in collaboration with informal educational institutions such as science centers, botanic gardens, and museums. Providing hands-on science in an accessible format is crucial to reaching underrepresented demographics and establishing life-long interest in STEM research (VanMeter-Adams et al., 2014).

We also note that as we emerge from the ashes of the Covid pandemic, our tools for distance learning and participation have taken a giant leap in capacity and capability. Thus, we must expand our definition of "participation" to improve and harness the capabilities for distance engagement. While a term like "plant science metaverse" may sound futuristic today, it is all but upon us, and ripe for exploration.

3.3 | Implement experimental pilot programs to advance EDI

Making significant improvements to EDI in plant science will require institutional investments and a commitment by individuals to implement recommendations, some of which may require years to implement. Workshop participants therefore used an "Open Space" exercise to envision eight potential pilot projects, each of which are detailed in Supporting Information. These pilots cover topics such as system change, EDI awareness building, communications strategies, and career paths. For some of these pilots, appropriate funding mechanisms already exist. However, other programs will need to draw on new sources of support to support EDI in new ways. We encourage the community to make use of these pilot ideas through testing and optimization, which will help to fuel long-term success of EDI interventions in the plant sciences.

4 | IMPACT

Implementing new policies, practices, and approaches to increase equity, diversity, and inclusion is crucial to the long-term success of the plant sciences, not to mention for the future of humanity. Therefore, we have both an opportunity and responsibility to take action now. If we as a community are successful in implementing these changes, we expect that the next generation will feel represented and excited to stay connected with the field.

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CONFLICT OF INTEREST

The Authors did not report any conflict of interest.

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ENDNOTES

[1] The research community has traditionally used the term underrepresented minorities (URM) as a catchall to describe women, people with disabilities, racial and ethnic minorities, and other historically marginalized groups in science; however, there is growing support to stop using this term (Montgomery, 2020a). In this

report, we simply refer to "marginalized" groups or individuals, which are underrepresented in STEM including in plant science.

[2] A form of our recommendations was incorporated in the action plans outlined in the Plant Science Decadal Vision 2020–2030 (Henkhaus et al., 2020).

[3] We use the term "integrative research," which could include many manifestations of collaboration including cross-disciplinary, multidisciplinary, and transdisciplinary research.

[4] We use this term to describe young undocumented immigrants who were brought to the United States as children (Walters & Holpuch, 2020), who have lived and gone to school here, and who in many cases identify as American.

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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