Advancing equity, diversity, and inclusion: a how-to guide

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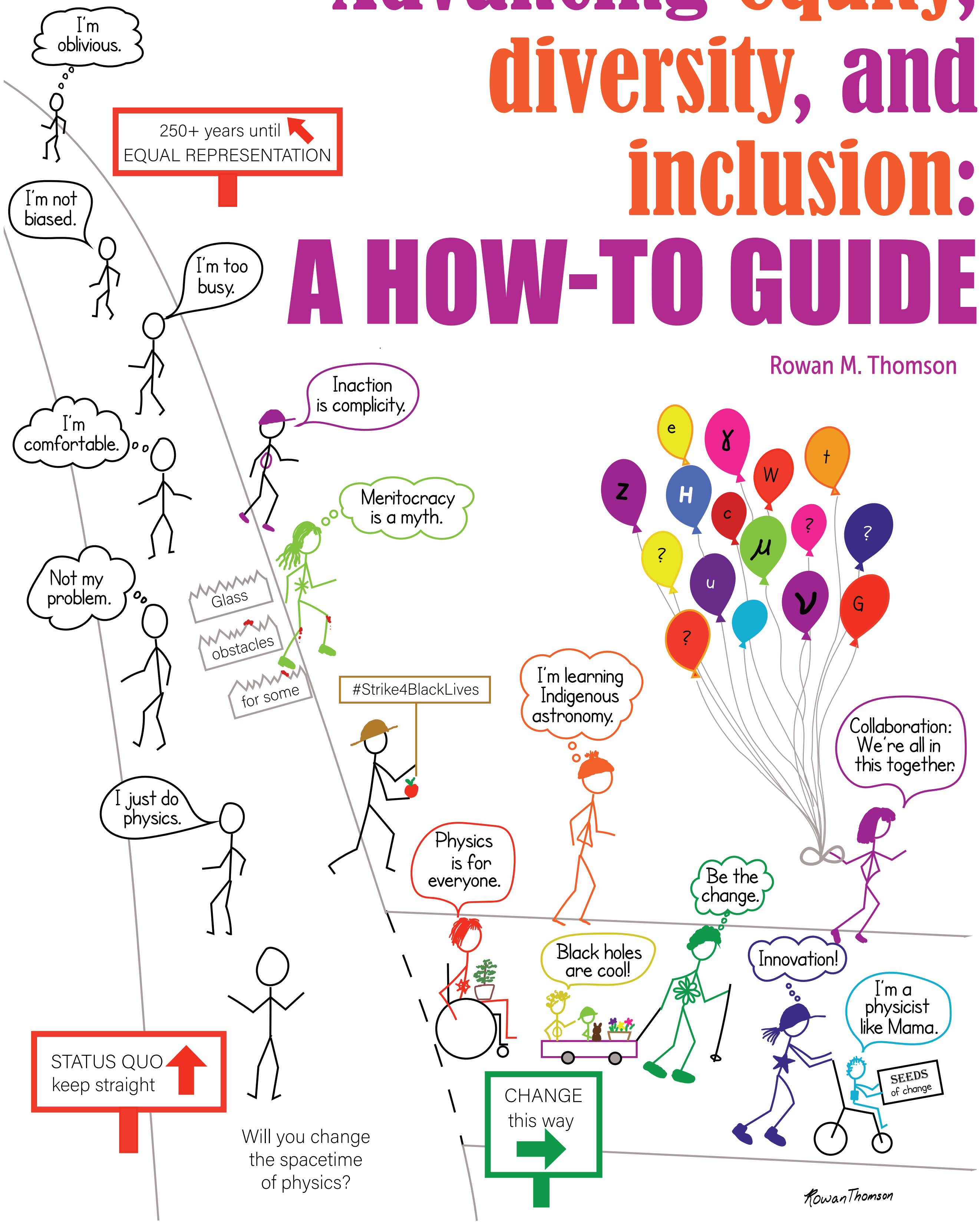

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Physics remains one of the least diverse fields in science. Here's how individuals at all career stages can contribute to fostering an inclusive environment for everyone.

Looking around the lunchroom on my first day at my first job in physics—as a summer student in a Canadian national laboratory—I was shocked to see that almost all the scientists present were white men! I loved that job and was thrilled to be paid to do physics, but I was disappointed in the lack of diversity at the lab. I expected that things would get better as I continued in my career. Surely, I thought, the diversity of the general population would begin to be reflected in physics. But 20 years later, my optimistic expectation has proven naive. The lack of diversity in physics is still striking. Moreover, the issues in the field go beyond representation. Insidious inequities, pernicious discrimination, and systemic barriers continue to prevent the inclusion of everyone in physics.

The numbers confirm that many groups are underrepresented in physics: Data from a recent NSF report demonstrate that among recent PhDs awarded in physics, Black, Hispanic, and Indigenous people, women, and individuals with disabilities are underrepresented by factors of about two to five.[1] The representation of individuals in physics identifying as lesbian, gay, bisexual, transgender, queer, intersex, asexual, and additional identities (LGBTQIA+) has received less attention, but those groups are certainly underrepresented too.[2,3] And representation gaps seem set to persist for a long time. To take just one example, currently only 13% of senior authors of articles in physics are women. That number is rising by only 0.1% per year—at that rate, it will take 258 years to come within 5% of gender parity![4]

What factors lead to those disparities in representation? What are the challenges faced by equity-deserving groups? Why should physicists be motivated to effect change? What can physicists do to help the field improve? This article is a call to action for all physicists to work together on concrete and sustained efforts to advance equity, diversity, and inclusion (EDI; see the box on page 46) through awareness, collaboration, and engagement.

Awareness: Molehills and mountains

Both academic research and lived experience have shown that individuals from underrepresented groups face a pattern of barriers that can be conceptualized as "molehills"—namely, challenges that may be individually surmountable but that add up over time to create a substantial cumulative effect.[5] Even a single molehill may be sufficient to deter an individual from entering the field or to motivate their departure. Individuals who do persist face disadvantages that compound over time. The summative effect of molehills creates a mountain that members of underrepresented groups must overcome (see figure 1). The result is a loss of talent, a lack of recruitment, and other inequities that hamper the full realization of human potential in physics.

Young children are often described as little scientists, but their joy for experimentation and discovery may be adversely affected by negative stereotypes and cultural beliefs. Gender identity, sexuality, and race or ethnicity are strong and persistent social bases for stereotyping. Students with disabilities also face accessibility barriers—particularly the high financial costs of disability accommodations in STEM (science, technology, engineering, and mathematics).[6] All of those obstacles result in enrollment gaps in physics among underrepresented groups.[2]

The sense of belonging felt by students with diverse backgrounds is important in determining their persistence and success. Factors affecting that sense can include their peer group, the presence of role models, and the pedagogical approaches used by instructors.[2,7] Perhaps the biggest negative factor those students face is discrimination or exclusion because of their race, ethnicity, gender identity, socioeconomic class, disability status, or sexual identity. Given that today's student body is more diverse than ever—16% of physicists ages 17–25 identify as LGBTQIA+—such discrimination may have a significant effect on overall retention.[3]

Individuals who have been sexually harassed are particularly likely to feel like they don't belong.[7] One recent survey of attendees at a US conference for undergraduate women in physics revealed that 74% of the 455 respondents had experienced sexual harassment. Most of them probably experienced gender harassment, which comprises a range of put-down behaviors, including sexual and sexist remarks and inappropriate jokes. Gender harassment is often deemed less severe than similar types of behavior, but it, too, has serious ramifications. Its pervasiveness is alarming.[7]

Other research indicates that scientists who identify as members of multiple marginalized groups, like women and people of color who are also part of the LGBTQIA+ community, face greater risks of harassment.[2,3] Members of those groups are also likely to face microaggressions, subtle and often unconscious actions that express prejudicial views toward marginalized people. Microaggressions negatively affect individuals' experiences in the field and the likelihood of whether they will ultimately choose a career in physics.[2,8,9]

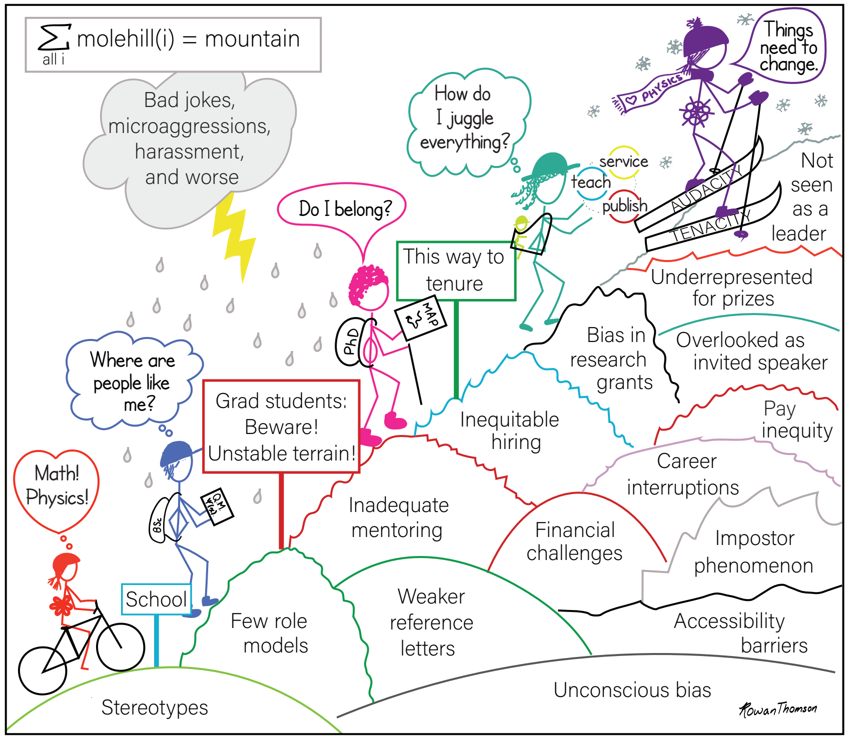

FIGURE 1. AWARENESS. "Many molehills make a mountain."[5] Members of underrepresented groups in physics experience disadvantages that have a substantial cumulative effect.

Myth of equity

The gender, race, and ethnicity of graduate students entering the job market have been shown to influence perceptions of their abilities and have ramifications on both their hirability and the salary they are offered.[10] In one recent study, a curriculum vitae (CV) was created for a hypothetical doctoral student applying for postdoctoral positions. Eight versions of the CV were produced. All were identical except for the name, which was changed to reflect gender (female or male) and race (Asian, Black, Hispanic, or white). A total of 251 physics and biology professors at eight large US research universities were each sent one of the CVs and asked to rate the candidate for competence, hirability, and likability.

The physics faculty had more gender bias than their counterparts in biology. Although they rated the female candidates as more likable, they ultimately viewed male candidates as more competent and hirable than female candidates. Race and ethnicity affected ratings too: White and Asian candidates were rated as more competent and hirable than Black and Hispanic candidates. Black female and Hispanic male and female candidates were rated lowest in hirability, which demonstrates how race and gender intersect in physics.

Biases undermine the advancement of individuals from underrepresented groups.[5] They are shortcuts formed by our brains based on our culture, experiences, and external influences. Such automatic associations make information processing more efficient, but they are often incorrect.[11] Biases are labeled as unconscious or implicit to indicate that we may be unaware of their role in distorting our decisions. Common biases relate to gender identity, race, ethnicity, age, sexual identity, religion, and disability.[2,5,11] Sometimes called second-generation discrimination,[8] biases may underpin the disadvantages faced by individuals from underrepresented groups, including receiving inadequate mentoring, unequal pay, weaker reference letters, and fewer speaker invitations; having fewer citations; being overlooked for prizes; and not being seen as a leader.[2,5]

A strong indication of the bias encountered, for example, by scientists identifying as women comes from a recent study that considered 24 000 grant applications received by the Canadian Institutes of Health Research.[12] For years the funding agency has awarded project grants, which are allocated mainly on the proposal's scientific merit. But in 2014 it introduced a new award, the foundation grant, intended for research leaders and based on the "excellence" of the candidates who applied.

The study compared the success rates of male and female principal investigators for both types of grants. They found that female applicants were 0.9% less likely than men to succeed at winning project grants. But when the foundation grants were introduced and reviewers were explicitly instructed to focus on researcher excellence, that gap widened to 4%. Although that number may sound small, it is not: Only about 10% of such grant applications are successful. The authors concluded that gender gaps in grant funding stem not from the quality of women's proposals but from the tendency of reviewers to evaluate women less favorably when they are principal investigators. Because most research begins with winning a grant, that bias damages both individual careers and the collective potential for scientific excellence.

Physicists like to believe that the field is meritocratic and that it grants power and resources to individuals in accordance with their abilities, talents, and achievements. But as quantita-

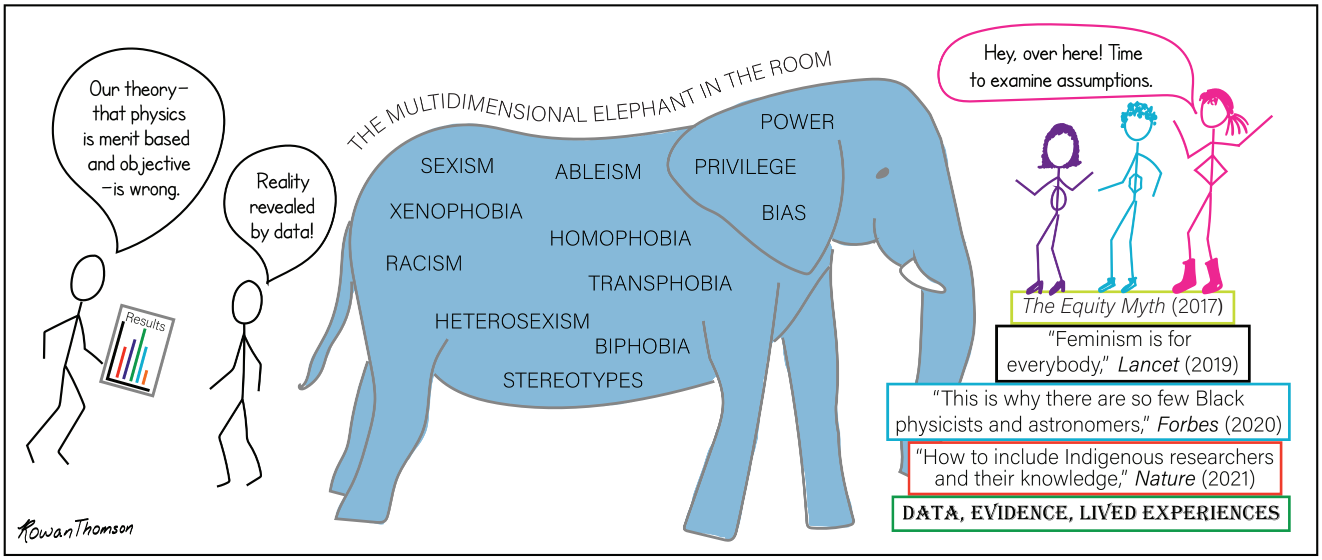

FIGURE 2. CONFRONTING IDEAS WITH DATA. Mounting evidence demonstrates that contrary to what some may choose to believe, the field of physics is not a meritocracy.

tive scientists, we must follow the data, which clearly demonstrate that our so-called meritocracies are not so meritocratic. In fact, they often reinforce the privilege of those who are already established in the field[11] (see figure 2).

Impetus for change

The "business case" is sometimes cited as a motivation for diversity initiatives. The term comes from the private sector, where it describes how employers can improve their business opportunities and gain economic and competitive advantages by employing the broadest possible field of talent.[13] In the scientific world, there is analogous evidence that diverse teams of researchers are smarter and more creative. One recent analysis focused on gender diversity in teams and determined that it is positively linked to collective problem solving, that diverse teams more effectively draw on each member's expertise and help members overcome biases, and that diversity broadens the range of research questions that a group might choose to address.[14] Because the majority of physics research is conducted by teams, the business case presents a good argument that diversifying physics would open the door to new discoveries.

The trouble with the business case is its implication that inclusivity needs to be justified. Why does it need to be shown that including underrepresented groups adds value?[13] Requiring proponents of diversity to demonstrate its positive effects implicitly sets the bar higher. After all, teams of white men are not asked for a business case to justify their team's composition.[11] The potential for scientific excellence in a fully equitable, diverse, and inclusive system remains not just unrealized but unknown.

Powerful voices for change have emerged in the physics community (see the Commentary by Ann Nelson, PHYSICS TODAY, May 2017, page 10, and the #BlackInPhysics Week essay series, PHYSICS TODAY online, 26 October 2020 and 25 October 2021). Those individuals have courageously shared their experiences and stories of persistence in the face of adversity, and their ideas illuminate paths forward. And in 2020 a task force chartered and funded by the American Institute of Physics (the publisher of PHYSICS TODAY) released a comprehensive report, *The Time Is Now: Systemic Changes to Increase African Americans with Bachelor's Degrees in Physics and Astronomy* (see PHYSICS TODAY, February 2020, page 20).

International human rights treaties commit governments worldwide to take measures to address stereotyping and eliminate inequities. Restrictions in access to STEM education and careers impose a limitation on a person's right to full participation in society and are thus a matter of human rights as defined by those treaties.[6] In short, advancing EDI is a moral imperative: We must focus on action (see figure 3).

Collaboration and innovation

Now that we are fully aware of the magnitude of the problem, let's put advancing EDI at the top of the list of open questions in physics and address it as we would any other challenge: through collaboration (see figure 4). That makes advancing EDI into an innovation challenge, which is something that we are very familiar with. As physicists, we know how to experiment, collect data, try different tactics, and learn from our successes and failures—all of which are needed to advance EDI. "Experimental" (real-life) evidence has shown that the "perturbation" (incremental) approach to EDI that the field has taken up to now has failed. That must motivate us to disrupt the established ways of doing things and make systemic changes. Only then will the field of physics achieve equity.[8]

To do our part in that field-spanning collaboration, we must each engage in concrete and sustained actions to effect change—which need to be made part of all things physics. In the following list, I present eight ways that physicists can help to advance EDI. The ideas are expressed in general terms, and their implementation should be tailored to each specific context. Because some ideas are more relevant at certain points in a physicist's career, I have indicated appropriate career stages for each of them. They are intended to stimulate reflection and spark action, but the list is by no means exhaustive. Think of it as a starting point.

Adopt EDI as core values (everyone). EDI must become an integral part of our field's spacetime. Committing to the principles of EDI means that we need to use them as a guide for all our activities as physicists. Making that commitment to address them implicitly acknowledges the field's ongoing deficiencies in EDI. It affirms "inclusive excellence" as a guiding principle—namely, the philosophy that true excellence is unattainable without EDI.[2,15] It emphasizes that all physicists need to be mobilized in collective and intentional actions to advance EDI and that each physicist must take personal responsibility for change. And it underlines the importance of adopting a culture of care in physics that emphasizes respect, honesty, compassion, and fairness.

Practice allyship (students, early-career physicists, and onward). Physicists who come from more privileged groups should become allies, which involves speaking up in support of individuals from underrepresented groups, amplifying their voices, and calling out bias and discriminatory actions and behaviors. Anyone can be an ally; many universities and other organizations offer allyship training.[9,15] As allies progress in their careers, they may expand their work to help members of marginalized groups dismantle oppressive structures and enact sustainable institutional and societal changes. Practicing allyship requires concerted and sustained efforts to disrupt cycles of injustice.

Serve as a role model or mentor (students, early-career physicists, and onward). Physicists of all identities need role models and mentors who can show that people from diverse backgrounds can flourish in the field. Being a role model involves sharing stories of personal and scientific trajectories with less senior members of the field, including early-career physicists, students, and even children. A physicist at any stage of their career can be a role model: Undergraduate physics students can be effective role models for high schoolers and younger children, who may more readily relate to them than more senior physicists.

Mentors provide guidance, support, and opportunities to nurture the development of others. Peer mentoring is highly effective and can take place at all career stages. Upper-year students can help their first-year counterparts; senior postdoctoral fellows can mentor new postdocs; and senior faculty can assist junior professors.[6] Both formal and informal mentoring programs typically pair a more senior physicist mentor with a junior mentee. Such programs should be explicitly inclusive of underrepresented groups, such as the LGBTQIA+ community,[3] because members of those groups often have a difficult time finding appropriate mentors. Strategies for being an inclusive mentor[2,6] include listening actively, being approachable, reflecting on biases, working toward cultural responsiveness, creatively addressing issues faced by the mentee, and being supportive of the mentee as they navigate obstacles and transitions.

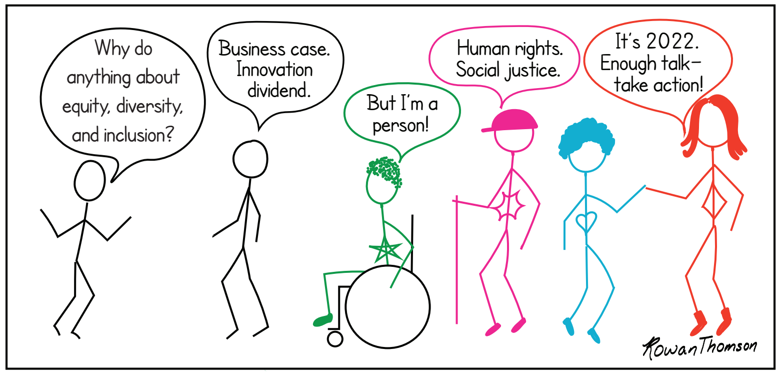

FIGURE 3. ENOUGH TALK—TAKE ACTION. There are compelling reasons to advance equity, diversity, and inclusion. It's time to end the discussion and focus on innovative solutions.

Teach equity, inclusivity, and accessibility (instructors). Students can become agents of change if we expand the curriculum to incorporate topics relating to EDI. One way of doing that is by developing courses dedicated to EDI. Biologists have already begun to incorporate such classes into their curriculum: In a recent article, Amy Reese describes a course she developed that focuses on how women's and men's scientific work have been treated differently throughout history. In the course, she also discusses how the scientific community has dealt with individuals from such marginalized groups as racial minorities, the LGBTQIA+ community, and those with disabilities.[16] Adapted for physicists, such a course would empower students with the tools to recognize, challenge, and change persistent inequities.

Another example of diversifying the curriculum would be an astronomy course that uses "two-eyed seeing" as a guiding framework—namely, one that weaves Indigenous astronomical practices together with Western scientific principles (see, for example, the Native Skywatchers initiative at https://nativeskywatchers.com). Such a class would provide an opportunity for students to learn about Indigenous history, ways of knowing, decolonization, and reconciliation.

EDI considerations and education may also be incorporated into traditional courses. Several of my colleagues and I at Carleton University recently released a toolkit for instructors that aims to make the classroom more inclusive, diversify science education, and incorporate EDI in all courses (see https://science.carleton.ca/toolkit). It provides ideas for actions both small and large that instructors can take to advance EDI in their teaching.

Along similar lines, Abigail Daane, Sierra Decker, and Vashti Sawtelle present a set of activities that instructors can use to teach racial equity in introductory physics courses.[17] They acknowledge that instructors may be hesitant to tackle sensitive topics in the classroom but note the importance of addressing and not ignoring them. Student responses to the activities have been generally pos-

CONCEPTS OF EQUITY, DIVERSITY, AND INCLUSION

▸ **EQUITY:** Treating people of all identities and backgrounds fairly and respectfully with regard to opportunities, access, treatment, power, outcomes, and resources.

▸ **DIVERSITY:** Embracing differences, which may include race, ethnicity, gender identity or expression, family status, disability status, sexual orientation, age, and socioeconomic situation.

▸ **INCLUSION:** Intentionally creating welcoming and respectful environments and systems in which inequities in power and privilege are addressed and everyone is given an opportunity to flourish.

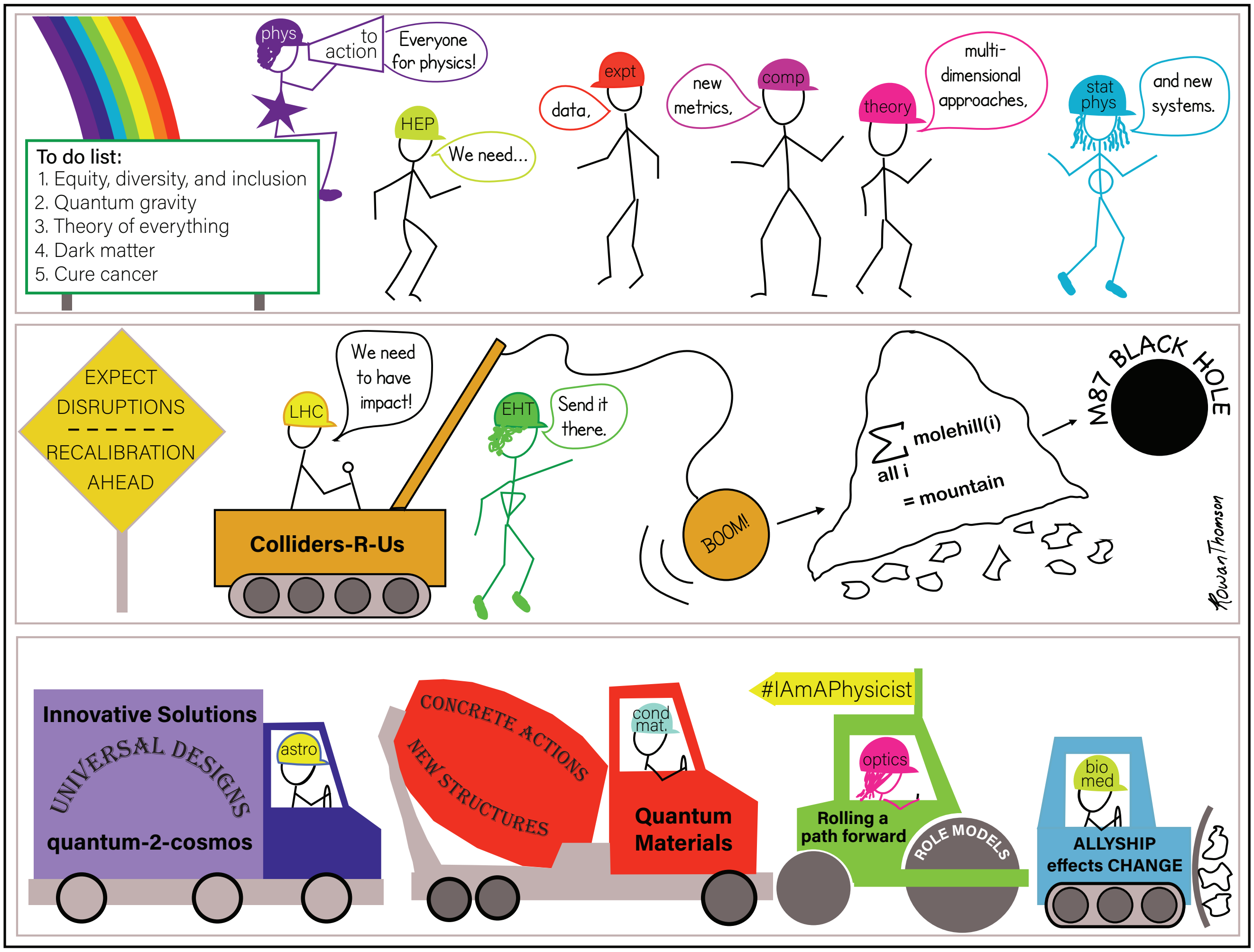

FIGURE 4. COLLABORATION. All physicists need to work together to advance equity, diversity, and inclusion.

itive. Instructors can preempt resistance from students by pointing to published data on the physics field's glaring EDI deficiencies and thereby emphasizing the importance of integrating EDI into courses.

Changing the curriculum, adopting inclusive teaching practices, and supporting students' development of a physics identity all promise to improve student recruitment, retention, and overall success (see the article by Jennifer Blue, Adrienne Traxler, and Ximena Cid, PHYSICS TODAY, March 2018, page 40). Physics graduates will then be prepared for a professional work environment in which awareness of EDI is the new cultural norm.

Train in EDI (early-career physicists and onward). All professional physicists should engage in ongoing EDI training as part of their career trajectory. A first step is building one's awareness of current EDI deficiencies. Learning about the framework of intersectionality, for example, can help physicists understand how different facets of an individual's personal identity interact with privilege and dominant belief systems in STEM and society.[15] Developing foundational skills, such as cultural sensitivity, knowledge of inclusive language, and strategies to deal with problematic interactions, will help physicists build inclusive, respectful, and welcoming environments.

For example, training to improve Indigenous cultural awareness might involve learning about the impacts of colonialism, appropriate language, and the experiences of Indigenous students, scientists, and elders.[8] Training to better support the LGBTQIA+ community, on the other hand, might involve learning how to use gender-neutral pronouns, create safe spaces, and develop strategies to make classrooms and events welcoming.

Creating an environment where everyone can thrive requires recognizing and addressing discrimination in all its forms. Microaggressions are especially challenging to identify and address because they are subtle and nuanced.[8] In a 2019 paper, Derald Wing Sue and several coauthors introduce a strategic framework for disarming racial microaggressions that incorporates the "microintervention" strategies they developed for targets of microaggressions, for white allies, and for bystanders.[9] The framework has four goals: To make the "invisible" visible, to disarm the microaggression, to educate the offender, and to seek support or intervention from an external party. Sue and his colleagues' microintervention strategies should be adapted for other targets of microaggressions, including women, LGBTQIA+, and physicists with disabilities.[9]

Organize inclusive scientific meetings (senior physicists). Women and other members of underrepresented groups are

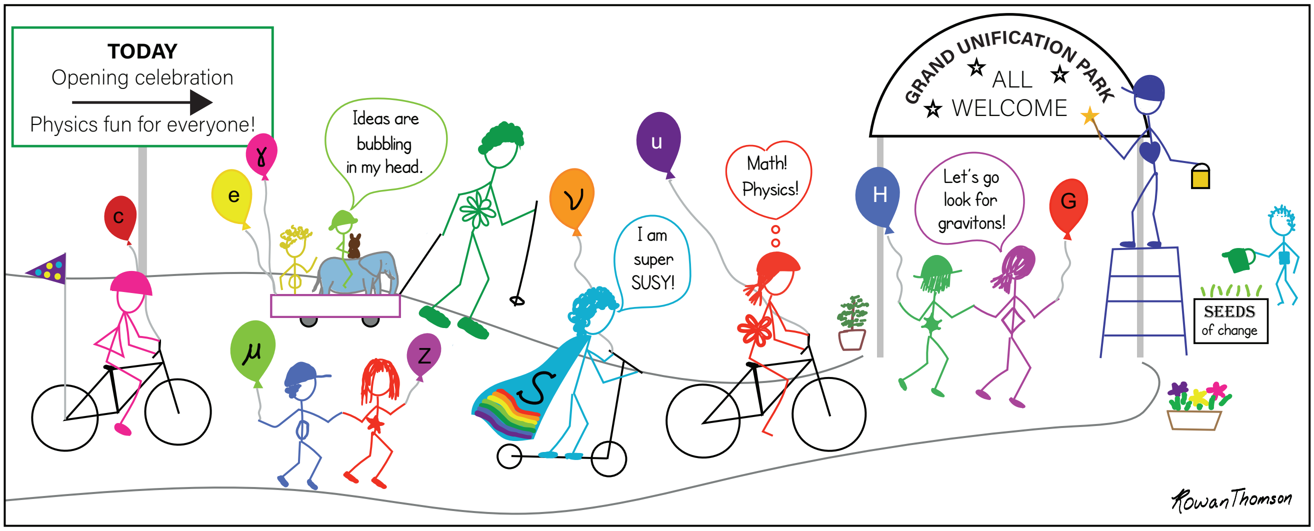

FIGURE 5. ENGAGEMENT. Physicists can be leaders in effecting broader change toward a more equitable and inclusive society.

often overlooked as invited speakers at conferences, workshops, and seminar series. Seeking balance in representation enriches the development of highly qualified personnel, enhances the career progression of researchers, and spurs research and innovation. Specific practices that organizers of scientific meetings can use to encourage EDI include collecting data on diversity at meetings and conferences, publicly reporting that data, mandating that a proportion of speakers come from underrepresented groups, ensuring that the organizing committee is diverse and informed, building databases of diverse speakers, responding to resistance, accommodating speaker needs, and being family friendly.[18] Organizers should also adopt a code of conduct that supports respectful and ethical behavior and creates a safe environment for all.[3,18] Conference participants should pledge to proactively check if the conference has a policy to ensure a diverse set of participants and speakers before accepting an invitation to speak.

Planning an inclusive event means being aware of inclusive design principles and budgeting accordingly, which might include covering costs related to captioning, dietary restrictions, accessible facilities, childcare, nursing rooms, and travel and registration (for students and low-income attendees).[18] Organizers should make EDI sessions part of the conference's core programming. In addition to having their travel and accommodation costs covered, EDI-focused speakers should be provided with honoraria to explicitly recognize the value of their contributions.

Integrate EDI into committee work (senior physicists). All physics committees must intentionally integrate EDI into their activities (see the Commentary by Alexander Rudolph, PHYSICS TODAY, June 2019, page 10). Committee members should undergo appropriate EDI training and be made aware of strategies to mitigate bias, and members of underrepresented groups should be present on such panels. Inclusive recruitment and hiring actions can include the following:

▶ Drawing candidates from underrepresented groups with job advertisements that appeal to a broad applicant pool.

▶ Critically examining the criteria, evaluative metrics, and their relative weight before reviewing applications and interviewing candidates. That should include recognition that traditional metrics place individuals from underrepresented groups at a disadvantage because they fail to account for their unequal starting points and career barriers.

▶ Considering holistic core competencies to ensure that recruits have the potential to succeed in all facets of physics, from mentoring and teaching to innovation and research. Hiring committees for faculty positions should, for example, evaluate candidates' abilities to integrate EDI best practices into research teams and teaching.

▶ Using structured interviews and a standardized rubric for admission and hiring.

▶ Fostering collegiality among committee members so that they collectively work to mitigate biases.[2,6,8]

Leaders need to be aware of the burden often placed on members of underrepresented groups to fulfill service roles. Many of those roles are less visible and are done without compensation. Senior physicists should implement strategies that ensure an equitable distribution of labor, which might include strategically assigning individuals from underrepresented groups to serve on important committees, such as hiring and award selection; limiting other service activities, such as taking minutes or ordering lab supplies; monitoring total time spent on service; and shifting responsibilities to ensure fairness.

Celebrate and raise the visibility of diverse physicists (senior physicists). Are diverse physicists visible in your organization, community, and society? Or are imbalances perpetuated by a lack of diversity in the images on classroom walls, on departmental websites, and in the names of buildings, research chairs, and awards? Are diverse physicists included in textbooks and classroom examples? We need to overhaul outdated images and textbooks and find balance in the naming of theorems, buildings, and awards. Annual events such as the International Day of Women and Girls in Science and Black in Physics Week provide natural venues for celebrating the contributions of underrepresented groups. Social media can also be invaluable, as demonstrated by such viral hashtags as #NativeInSTEM, #IndigenousSTEM, #POCinSTEM, #IAmAPhysicist, #WomenInSTEM, and #HispanicinSTEM.

Leaders can champion the advancement of protégés from underrepresented groups, provide them with access to opportunities, connect them with networks, and help propel them into leadership positions. They can also use their privileged positions to nominate outstanding physicists from underrepresented groups for prestigious prizes.[2,5]

Engagement with society

Physics does not take place in a vacuum; it exists within the context of the broader society. The inequities and injustices experienced by physicists from underrepresented groups exist across the globe. But we need to try and ACE EDI: With growing *awareness* of barriers (see figure 1) and *collaborative* work to address them (see figure 4), all physicists can *engage* in debunking societal stereotypes and drive change in our communities, cities, and countries (see figure 5). We cannot settle for the status quo: We must take ambitious strides toward a more equitable future. Underrepresented groups deserve to be full members with equal opportunities and rights not just in physics but in all organizations, communities, and societies. As we work to integrate EDI in physics, let us spread a culture of care and inclusive excellence beyond the confines of our field so that everyone can flourish.

This article is dedicated to my family, with thanks for their ideas to improve the cartoons, and it is also in memory of Chris. Additionally, I acknowledge support from the Natural Sciences and Engineering Research Council of Canada, the Canadian Institutes of Health Research, and the Canada Research Chairs Program.

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