Inequality in science and the case for a new agenda

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The history of the scientific enterprise demonstrates that it has supported gender, identity, and racial inequity. Further, its institutions have allowed discrimination, harassment, and personal harm of racialized persons and women. This has resulted in a suboptimal and demographically narrow research and innovation system, a concomitant limited lens on research agendas, and less effective knowledge translation between science and society. We argue that, to reverse this situation, the scientific community must reexamine its values and then collectively embark upon a moonshot-level new agenda for equity. This new agenda should be based upon the foundational value that scientific research and technological innovation should be prefaced upon progress toward a better world for all of society and that the process of how we conduct research is just as important as the results of research. Such an agenda will attract individuals who have been historically excluded from participation in science, but we will need to engage in substantial work to overcome the longstanding obstacles to their full participation. We highlight the need to implement this new agenda via a coordinated systems approach, recognizing the mutually reinforcing feedback dynamics among all science system components and aligning our equity efforts across them.

diversity | equity | inclusion | structural racism | new agenda

> *The system of cooperation and competition, secrecy and openness, rewards and punishments that has characterized science from its inception is both social and internal to science itself.*
>
> *David Hull (1)*

According to Hull, the process of science is characterized by two extreme views (1). The internalists hold that the scientific process is characterized by rational evaluation of observations, hypotheses, and experimentation. This means that, in the end, what counts as scientific fact results from the cogency of the arguments deployed and the weight of evidence supporting them. On the other end of the extreme are the externalists, who hold that a wide variety of factors impact the process of science, particularly social forces and idiosyncratic personal motives. The latter perspective acknowledges that the process of science, and scientists themselves, are part of a social order. Historically, social orders are maintained through the distribution of rights, the generation of interests, and coercion. In a just society, the rights of individuals would be protected, the interests of constituent groups would be balanced, and the use of coercion would be discouraged. However, our societies are structured on group-based hierarchies, established very early in the evolution of our species (2). Social dominance based upon age, gender (patriarchy), identity, class, and socially defined race have been persistent features of human societies, and our science system derives from those societies.

Inequality and the Scientific Enterprise in Historical Context

Our view of the scientific process falls somewhere in between the internalist/externalist positions. The objectivity and integrity (or lack thereof) of the scientific process is maintained by both individual scien-

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tists and communities of scientists. However, scientists are not persons with ideal intellects or moral virtues; they are imperfect human beings influenced by the societies in which they are raised and the social groups in which they live and work. This means that their decisions to pursue particular research problems and their professional behaviors are influenced by their social biases, personal ambitions, and social group norms. Thus, it is obvious that the composition of the community of scientists may have potent effects on individual scientists as well as the outcomes of the scientific enterprise (viewed as the collective efforts of the scientific community).

A common example of how societal context may misdirect the results of scientific research is that of genetics in the Soviet Union from the 1930s to the 1960s. While often cited, the dynamics of the suppression of Mendelian genetics is not well understood. A key character in these events was Trofim D. Lysenko (1898–1976). Lysenko had an uneven training in biology, particularly in the scientific method (3). His most important discovery was that some plants required a period of low temperature to develop to flowering stage (vernalization). On the basis of this observation, he devised a method to accelerate the development of wheat. Lysenko's lack of training in general biology led him to propose theories of plant development that simply did not hold up to experimental test. He attempted to demonstrate the validity of his theories of vernalization on his father's farm and made claims of success in increasing wheat yield that could not be verified. Lysenko publicized these results at a time when Stalin's government was beginning its first 5-y plan to collectivize and improve Soviet agriculture, and in the midst of an acute grain shortage in the country. The ministers of Soviet agriculture judged him favorably when he instituted large experiments on thousands of hectares in close cooperation with the peasants.

Lysenko was viewed as a hero because his research was rooted in trying to feed people. By 1935, he had become a public figure. However, by this time, Soviet scientists were fully aware of his lack of scientific knowledge and inadequate experimental techniques (4, 5). His opposition to Mendelian genetics and the chromosomal theory of inheritance was thoroughly ridiculed at a scientific congress in Moscow in 1936. When the Stalinist purges of the late 1930s decimated wide sectors of Soviet society (6, 7), the scientific community was not spared. In 1934, Vavilov, head of the All-Union V.I. Lenin Academy of Agricultural Science was removed, and, in 1937, his successor A. I. Muralov was also purged. Lysenko was named head of the institute in 1938.

Lysenko's rejection of Mendelian genetics was not rooted in Lamarckism, although his ideas on the importance of environment over genetic determinants of phenotype was consistent with a Lamarckian world view. He actually saw himself as a Darwinist, protecting evolution from an overemphasis on genetics. He was, of course, wrong, but so were many other geneticists. Prominent members of this community, such as Charles B. Davenport and R. Ruggles Gates, had adopted both genetic determinism and eugenics. These individuals were not "fringe" elements of their respective scientific communities; they and their views on genetic determinism, race, and eugenics were well within the mainstream (8). The dispute between the genetic and environmental determinist camps came to a head at the seventh International Congress of Genetics held in Edinburgh in 1939. The congress issued the *Genetico* manifesto (authored primarily by American scientists) that condemned Nazi race theory, called for effective birth control and emancipation of women, stressed the importance of social and economic change, and condemned racism against ethnic minorities. In the end, the scientific errors of Lysenko occurred due to both a failure of the internal checks of science combined with external societal forces that were invested in this false science being true. The same is also the case for eugenics and other socially relevant aspects of evolutionary biology.

The development of an integrated discipline of evolutionary biology during the neo-Darwinian revolution of the early 20th century did not quell racism within the discipline. In the 1920s, the American Association for the Advancement of Science (AAAS) Committee on Evolution included the eugenicists Edwin Grant Conklin, Henry Fairfield Osborn, and Charles Davenport (9). This was because—just 100 y ago—the inferiority of certain human races was considered as solid a scientific fact as gravity. For example, in 1962, a year after the United Nations Educational Scientific and Cultural statement on race, the anthropologist Carleton Coon worked with his cousin Carleton Putnam to help justify ongoing racial segregation in the United States. Coon's ideas were popularized by segregationists, and he corresponded with his cousin over the relevance of his "science" for the segregationist agenda. He also argued vehemently with evolutionary geneticists such as Theodosius Dobzhansky concerning the validity and application of this theory (10).

Hull's exegesis of externalist and internalist influences on science becomes all too real in examples such as these. The rise of race science in the United States is one of the most powerful examples of how the exclusion of entire groups from the scientific enterprise can warp its outcomes. Indeed, the history of evolutionary biology, pursued largely by White males until only recently, is replete with racialized arguments for biological determinism (11). We shall not retell that history here except to say that, at every point along its growth, it was supported by powerful leading figures in American science and society. For example, while Thomas Jefferson would not have been considered a scientist in the modern sense of the term, his views on nature, particularly those of the inferiority of the "Negro" race, had powerful impacts on American society. By the mid-19th century, polygenism was a prominent force in creationist biology and, along with its alternative, monogenism (with degeneracy), supported the belief in the inferiority of the Negro. This sentiment was well expressed by Supreme Court Justice Roger B. Taney in his decision in the Dred Scott Case (8).

In addition to powerful individuals, powerful institutions are also germane, as reflected in the historical emergence and composition of national science organizations. The AAAS was founded in 1848, and the polygenist Louis Agassiz was a founding member [as well as an original member of the National Academy of Sciences (NAS) in 1863 (12)]. The Swiss-born Agassiz ingratiated himself with the American public by inserting himself into the race issues of the time (13). Agassiz was convinced that Africans represented an inferior and separate species of human, and he was only for the abolition of slavery as a means to export those enslaved back to Africa. It goes without saying that there were no African American, American Indian, Latinx, or female members of the original AAAS or NAS. To date, the AAAS has not had a female CEO, and the NAS has had one. Neither AAAS nor NAS has ever had a Black CEO. The first "Black" member of the NAS was David Blackwell, elected in 1965. In 2005, there were only four Black members, and, among the most recent inductees of the NAS, there were nine

Blacks (14–16). The NSF has had two Black directors and two female directors in its history. The NIH has had one female director and zero Black directors. The duration and persistence of this power vacuum at the highest levels of the scientific enterprise is both astonishing and expected, demonstrating the sheer strength of legacy. Notably, these organizations have diversified of late, and are now actively engaged in the formidable work of institutional transformation and reinvention—including diversification of leadership, workforce, membership, and fellows; development of new equity policies and departments; creation of programs to support and resource the diversification of STEM; integration of equity experts; and mobilization of scientists and science policy makers for evidence-based strategies to broaden participation. While too early to discern outcomes, we are at a potentially historic turning point for the realignment of the US science system relative to our society (17).

This section has focused primarily on racism within science, but there are just as many historical examples of science used to defend and/or perpetuate sexism, exclude or marginalize persons with disabilities, pathologize nonheteronormativity, and disenfranchise other members of society (18–22). Numerous historical research agendas have purported to demonstrate the inferiority of women to men—emotionally, neurologically, intellectually, and psychologically—in ways that blatantly genderize "intelligence differences" for example. The uses and misuses of science to reinforce ideas of homosexual abnormality are also legion and have caused profound harm. Thus, we argue that the history of science cannot be divorced from our society's foundational history of patriarchy, White supremacy, and oppression of any and all subjugated groups.

Consequences and Costs

> *Not everything that is faced can be changed, but nothing can be changed until it is faced.*
>
> —*James Baldwin (23)*

The historical forces discussed above have led to a science system within the United States that remains restricted to an exclusionary subset of society. That fact influences literally everything else about science: who participates in science, who sets research agendas, who benefits from science, and the degree to which scientific outcomes are accepted by the public (17). Recent studies and reports document the limited demographics of today's scientific enterprise, and there is little indication that the representation of racial minorities in the scientific workforce has changed significantly over the last century (24). Two-thirds of full-time employed scientists and engineers are White, and one-half are White men. Women make up 51% of the total US population yet are underrepresented in science and engineering careers (38.5%), are paid less, and experience attrition rates (19.5%) that are much higher than for men as they move up the career ladder. We acknowledge many caveats and nuances regarding these numbers. For example, they vary significantly depending on subdiscipline (e.g., majority male in physics, engineering, computer science; majority female in psychology, healthcare; nearly at gender parity in the biosciences). Further, there is a continuing need to disaggregate data on race, gender, and ethnicity by educational stages, career stages, subdisciplines, more detailed identities, and other factors. Overall, however, the general picture is indisputable: a deep lack of racial, ethnic, identity, and gender diversity in the scientific community as compared to the population of the United States, with disadvantaged groups that do make it into the system being paid less, promoted less often, and disproportionately leaving STEM careers.

Many excellent efforts and investments have been made to correct these deficiencies, yet the exclusionary legacy of racism and sexism endures (25), infecting all major components of today's science system—from precollege STEM education, to the culture and norms of the scientific workforce, to scientific progress and knowledge production, to the translation of scientific and technological advances to society and policy. We focus on those four areas in the following four sections, while acknowledging that there are many more to address. While the fundamental problem crossing over these components is clearly systemic inequity, inequity manifests in numerous unique ways (e.g., unequal access, conscious and unconscious bias, unhealthy power dynamics, biased research agendas, devaluation of diversity). Importantly, today's unequal science system in which racialized populations and women are underrepresented cannot be solely attributed to historical legacy—unequal access, harassment, exclusion, and bias are active issues in science today, and newer problems are now emerging (e.g., resistance and backlash in the face of calls for change and accountability).

Precollege and Higher Education in STEM. The persistence and pervasiveness of racial inequality in the US education system has deep roots (26, 27). STEM education remains unequally available to the US public, and "science deserts" persist across socioeconomically and racially disadvantaged areas. For Native Americans, unequal access to education has obviously existed since the very beginning of this country's founding. For Black Americans, these roots date back to enslavement when it was illegal to teach enslaved persons to read and write. Even with the coming of emancipation and expansion of education in the late 19th century, access to education was unequally distributed in ways that maintained the prevailing social hierarchy. For certain segments of the US population, including girls and women, formal schooling was simply perceived as unnecessary, and they were therefore denied educational opportunities.

The Supreme Court ruling in *Plessy v. Ferguson* in 1896 affirmed the state- and local-level racial Jim Crow laws erected after the Civil War under the principle of "separate but equal." One consequence of such laws was a system of segregated and separate schooling in the South that was anything but equal. Vastly different amounts of money were spent on the education of White and Black children, and different expectations for their futures prompted different curricular offerings. Higher education was similarly separate and unequal. Initially, colleges with a mission to educate previously enslaved Blacks were little more than vocational/secondary schools in terms of their coursework. They were founded largely in the South in the late 1860s and 1870s. Another wave of Black institutions was established in the 1890s to take advantage of support from the second Morrill Act whose funding required educational access for Blacks either within existing White institutions or in separate Black institutions. However, higher education for Blacks did not benefit from the Morrill Act of 1862 that provided the lion's share of the support for America's land-grant institutions; it was these colleges and universities that were advantaged and that ultimately became the research powerhouses of today. Black land-grant institutions were never funded at levels necessary to support their growth as major research universities. A low number of Blacks had access to higher education via a single option: from

~100 historically Black colleges and universities (HBCUs) that were both underresourced and overworked. In sum, higher education institutions in the North were largely segregated by tradition, while those in the South were segregated by law.

An orchestrated challenge to *Plessy* by the NAACP led to some inroads in desegregating graduate and professional education in the segregated South, but it was not until the 1954 Supreme Court decision in *Brown v. Board of Education* that the legal barriers to educational desegregation enshrined by *Plessy* were finally torn down. Still, Jim Crow laws that forbade "race mixing," along with segregated residential housing patterns created by "redlining," kept educational opportunity mostly as it had always been. Even after *Brown*, schools, colleges, and universities remained segregated for many years. "Quiet desegregation" of colleges and universities occurred in some states after *Brown*, while desegregation in other places was characterized by significant violence and near-constitutional crises, such as at the University of Georgia (1961), University of Mississippi (1962), and the University of Alabama (1963).

Despite these circumstances, some Black scientists and mathematicians were somehow able to ascend to the highest levels of scholarly achievement, yet were then thwarted in finding employment that would support their scholarly ambitions. For example, even with a Physics PhD awarded by Yale in 1876, Edward Bouchet could not find a job at a university. Some scientists were hired by HBCUs, but here they encountered heavy teaching responsibilities and unequal research opportunities. The developmental biologist E. E. Just and the topologist William Claytor were faculty at Howard University; both encountered difficulties being accepted in American research environments (28). Manning (29), in his biography of Just, speaks of the unwelcoming environment that Just's family encountered at Woods Hole when they accompanied him during a summer of research at the Marine Biological Laboratory. Claytor, who received his PhD from the University of Pennsylvania, was once referred to as one of the most promising mathematicians in his field. But, as recounted by the American Mathematical Society, "his passion for research in mathematics was squelched by racist attitudes that restricted opportunities and impeded the full participation of Black mathematicians in the math community. A striking example of this occurred at the AMS meeting in December 1936, co-hosted by Duke University and UNC-Chapel Hill. The research Claytor presented there was praised by Solomon Lefschetz as the 'best of the session' and was later published in the *Annals of Mathematics*, his second paper in that journal. Yet Claytor was not allowed to stay at the conference hotel because he was Black" (28).

Today, scientists, mathematicians, and biomedical professionals who are women or members of racially minoritized communities recount ongoing stories regarding lack of respect, harassment, and unwelcoming environments, regardless of what they achieve (30). For them, achieving STEM professional accomplishment involves monumental barriers, low expectations, lack of access to quality K–12 education including advanced placement courses and International Baccalaureate programs, inadequate and inappropriate career counseling that directs students away from STEM education and careers, higher education that does not support student success with the prevalence of "weed-out" courses that are neither culturally nor pedagogically relevant, lack of diverse faculty and role models, harassment and unwelcoming environments, inequities in access to research opportunities and graduate students, lack of access to graduate programs with supportive mentors driven in part by overreliance on standardized testing as an admissions screen, and more.

We should not, therefore, be surprised by the high numbers of persons from historically excluded groups who have been unable to overcome this system of hurdles and become "represented" in today's science system. Yet we know that this obstacle course does not have to be the norm in science. Today, for example, there are institutions making outsized commitments to the education and career development of historically excluded groups. HBCUs today enroll about 9% of Black students in colleges and universities yet award 17.2% of engineering bachelor's, 27.8% of physical sciences bachelor's, 25.5% of mathematics bachelor's, 24.7% of biological sciences bachelor's, and 29.9% of agriculture bachelor's degrees (31). HBCUs are disproportionately represented among baccalaureate institutions for Blacks who receive PhDs in the sciences, just as high-Hispanic-enrollment institutions (HHEIs) are for Latinx populations. We contend that any institution with a strong commitment and the correct supporting strategies can become "minority serving," as illustrated by a number of predominantly White institutions that have recently broken into the ranks of leading bachelor's degree-awarding and baccalaureate origins institutions. Prominent among these is the University of Maryland at Baltimore County, where its long-serving president and HBCU graduate Freeman Hrabowski III has created innovative programs and an unwaveringly welcoming environment for graduate students of color to become scholars and leaders in science, engineering, and biomedicine.

Scientific Workforce Culture. The culture of science (defined here as the values, norms, priorities, and practices of the science system) has evolved in ways that reinforce it as an unwelcoming career path to socially subordinated groups. Overrepresentation of a narrow demographic in STEM leadership positions, implicit and explicit biases based on socially constructed racial, gender, and identity stereotypes, hypercompetitive and metric-based criteria for success, outdated but entrenched transactional leadership models, uniquely imbalanced and potentially harmful power dynamics, and other obstacles to an inclusive culture persist. The consequences of this culture are becoming increasingly clear. A recent survey of UK scientists regarding their views on research culture reported that 78% of respondents experience high competition and aggressive research environments, 54% felt pressured to meet key performance indicators/metrics, and 61% experienced or witnessed bullying (32). Respondents overwhelmingly favored new policies and approaches that would reduce competition in favor of collaboration and that would provide true accountability for harmful behavior. Harmful workforce culture affects everyone, but underrepresented groups are affected the most—to the point where they often leave the field (33). Overall, we are beginning to recognize that increasing diversity, equity, and inclusion in STEM is not just about increasing numbers or patching the "leaky STEM pipeline"; it depends critically upon transforming research culture and climate. In other words, it is the system, not the participants. And the system is rooted in the values, norms, and practices that were established long ago by and for a narrow subset of society; therefore, uprooting and rebuilding is the great task we now face. Where and how to start are big questions.

At its core, we argue that our science culture is built upon values. Thus, an important question is "What do we value in science?" vs. "What do we measure and reward?" Do incentive systems in our science systems provide accountability for doing the wrong things and rewards for doing the right things? If the current and regularly occurring scandals occurring at our premier science institutions are considered, the answer is "not yet." Traditionally established measures of success (e.g., number of grant dollars and publications, impact factors, social media metrics) select for highly competitive rather than collaborative environments, a style of mentoring that elevates the success of mentors more than that of mentees, and potentially harmful environments for groups underrepresented in science. For example, minority scientists, who are too often underrepresented, tokenized, or "onlys" in scientific departments, are immersed in predominantly straight, male, White environments where they must navigate implicit and explicit bias in all aspects of the competitive science ecosystem. One need only follow any of the myriad grassroots groups, such as #blackinSTEM, #whitecoats/blackscientists, #queerinscience, #metooSTEM, and others, to grasp the unacceptable professional and personal costs of being "underrepresented" in our science workforce culture. Another example is provided by a recent report on sexual harassment in STEM issued by the NAS (34) documenting that academic science is second only to the military in rates of gender harassment, which takes an astonishing and corrosive toll on women who enter STEM fields. Accountability for such conduct is rare. The recent documentary *Picture a Scientist* presents a devastating and courageous look at bias against women scientists, gender harassment, and retaliation against victims in the scientific workforce (35). In the end, women in science realize that their options for redressing these harms are limited. Human resource departments ultimately protect institutions, their leaders, and reputations over employees. Legal remedies are also insufficient—the nearly 50 y that have elapsed since implementation of Title IX have seen little reduction of gender and sexual harassment in the science system. In some cases, victims report that it only compounds the harm and that the costs are not worth reporting the abuse. Yet still, and at significant personal and professional risk, courageous women continue to come forward regularly to expose perpetrators and enablers at our most prestigious and well-known scientific institutions.

One traditional value in science that reinforces our current workforce culture is "the meritocracy"—the tenet that advancement in science is based on an individual's capabilities and merits. This core value is what underlies many of our longstanding practices—entrance criteria, hiring procedures, peer review practices, promotion criteria, and others. However, our society is unequal, and our science system is as well; we have never been a meritocracy. Meritocracy myths deny all the ways that some members of our society have acquired privilege and advantage while others run the gauntlet of economic and racial inequality, social oppression, and intersectional and cumulative disadvantage. Moreover, upholding the erroneous idea that science is a "meritocracy" can cause serious psychological harm. When a STEM student or an early-career scientist from a disenfranchised group hears that education and career opportunities are fair and that individual merit is rewarded, self-blame and negative stereotypes about oneself and one's group can result. Research shows that such meritocracy myths cause declines in self-esteem, increases in dropout rates, and substantial psychological costs, such as self-blame and imposter syndrome. Thus, this cultural pillar of science is both false and damaging. We will need to reexamine this and other cultural pillars of science, even while building more opportunities, before achieving greater systemic equity.

Scientific Progress. By now, the research on the relationship between diversity and scientific progress is conclusive: Quality of science is greatly improved by a greater diversity of scientists (19, 36, 37). Racial, ethnic, gender, identity, ability, and other types of diversity lead to increased creativity and innovation. People with different backgrounds have different experiences and perspectives; they therefore approach problems differently, ask different questions, and develop a spectrum of more innovative solutions. Further, more and more scientific research is being accomplished in collaborative teams, and diverse teams are shown to be more innovative than homogenous teams: They outperform homogenous groups in problem-solving, innovation, accuracy, performance, and results. This essentially describes the business case for diversity in science: It leads to better science and a greater return on investment. But there are many more benefits. Increasing diversity in STEM will allow much broader utilization of the available talent and ingenuity that resides in the millions of individuals for whom a career in the scientific workforce has been previously unattainable. The US population is becoming more diverse every day, and our diversity is a unique tool for our global scientific leadership aspirations. Investing in the diversification of science will promote the economic growth and competitiveness of the nation by mobilizing all available societal potential (38). It will also elevate our ability to translate science to society and policy.

Translation and Application of Science. Who participates in science not only affects the design, practice, and knowledge outcomes of scientific research, it also deeply affects public trust in science and the effective translation of science to society and policy. The scientific enterprise has too often been aligned with injustices that reinforce the oppression of the racially disenfranchised, women, and LGBTQ+ communities, all of which has diminished public trust in science. This erosion of trust is painfully evident in the public's response to COVID-19, as members of racially minoritized communities are disproportionately impacted yet vaccine hesitant, in part because of scientific and medical distrust. This mistrust has deep racist roots from centuries of Blacks and indigenous peoples being exploited for research (the Tuskegee syphilis study is a well-cited example), ongoing disparities in treatment and access to clinical studies, and current discrimination that limits training and professional opportunities (39, 40).

Restoring trust is imperative because public trust in science is a critical bridge for the translation and application of scientific discoveries. Suggestions regarding how to increase trust in science include the need for strong science integrity and ethics, proper stewardship of research funds, open access, increased public engagement, and better communication. These are all necessary but, we contend, not sufficient. We cannot continue to accept a science system comprising a demographically narrow group of scientists and hope that those not a part of science will trust them as long as scientists behave correctly and communicate better. For example, the currently enormous industry of science communication seeks to increase public trust in science through enhanced public engagement and improvement of scientists' communication skills. Improved science communication is important, but we suggest that the real key to achieving public trust in science lies in representativeness: having a diverse group of scientists, including members of minoritized groups who have historically been excluded, in the scientific community (41, 42). Participation of these groups as researchers, educators, physicians, scientists, engineers, and policy makers will influence who becomes a scientist, public understanding and trust in science, who is represented in lifesaving clinical trials, who sets science policy, and who has opportunities for and access to discoveries. In short, we contend that there will never be science for the people until all the people are in science. When the scientific workforce looks like our society, greater public trust in science will ensue—which will then lead to greater societal support for science funding, broader acceptance of scientific conclusions, the prioritization of science in public policy, and evidence-based political and civic decision-making by the public.

Future Science

Let us make a world in which we believe.
—Celeste, "Hear My Voice"

Given the continued lack of equity and inclusion in today's scientific enterprise, the consequences of that for science and society, and the massive challenge to reform discussed above, we suggest that the scientific community bears a collective responsibility to frame a more just science agenda and to work together toward transformative systemic change. The systems that we have become comfortable with are sustaining an inequitable enterprise that favors narrow participation in science. These systems are highly linked, mutually reinforcing, and resistant to change. Science is obviously an extraordinary and beneficial human endeavor, and its imperfections are the imperfections common to all socially created systems. At its best, science contributes to the progress of knowledge and understanding, enhances public well-being, and harnesses human ingenuity for a better world. The right to the benefits of scientific progress is recognized (if not fully realized) in the United Nations Universal Declaration of Human Rights (43). This "right to science" is also connected to the appropriate application of science and technology in order to attain other basic rights—including the rights to health, food, security, and clean air and water. The right to science also underlies a burgeoning call for science to be more broadly beneficial to society, and for the increased social responsibility of scientists. Such a profound paradigm shift can only be achieved by mobilizing the entire community and implementing a combination of top-down and bottom-up policies for systemic change.

Mobilizing for a New Science Agenda. First and foremost, scientists must assess our roles holistically. Scientists are members of society as a whole, in addition to being members of the scientific community—meaning that being a scientist comes with social responsibilities, in the same sense that it does for a social worker, doctor, lawyer, teacher, or any professional. The social responsibilities of scientists also arise ethically because much of our research is funded by the public (17). Furthermore, scientific research is explicitly carried out in the name of societal progress (see virtually all mission statements of prominent science and academic organizations), even though certain societal groups have disproportionately benefitted throughout history. Finally, the expertise that derives from a scientist's work, education, and training makes them uniquely capable of understanding the limits of science and the circumstances under which its application will either further societal welfare or damage it. Researchers have a responsibility, for example, to oppose the misuse of science, to anticipate societal impacts, and to assess unintended consequences of scientific or technological applications. Indeed, a "societal equity impact assessment" prior to deployment of emerging technologies could prevent some of the negative consequences we routinely observe (e.g., wrongful arrests of Black individuals stemming from the use of biased AI facial recognition technology, digital divides, and environmental innovations that ignore environmental justice). A socially responsible science system fundamentally depends upon who is at the science and innovation tables to begin with.

A modern science agenda that is based on explicitly updated principles and values is urgently needed but not simple. A 2016 study surveyed ∼400 members of elite scientific societies concerning the core values they found most important in a scientist. The top five were honesty (64%), curiosity (60%), perseverance (34%), objectivity (21%), and "humility to evidence" (19%) or the willingness to reject hypotheses that do not fit the data (44)—all worthy values for scientists to hold. This project continued to conduct interviews with scientists to provide a broader representation of their ethical positions. Of particular interest here was a widely reported attitude summarized as "the majority of scientists don't have an agenda." However, as with all human pursuits, there is no agenda-free science (even if our agendas are obscure to us). In any case, we suggest that scientists should have a more explicit new agenda in these historic times. A foundational platform of that agenda could be based on creating an equitable and just scientific enterprise for all of society. It could be further based on the premise that the translation of scientific and technological research be equitably distributed across society and that it not entail costs borne by the already disadvantaged. Bozeman (45) touches on such a paradigm shift with the concept of "public value science," stressing economic inequality and the science–society bargain entailed via the public's funding of research. Bozeman's public value science' emphasizes socioeconomic factors, and we would add to that concept here to encompass social justice issues as well.

In highlighting the importance of a new agenda for science, we are not suggesting a shift from basic to applied research. Indeed, applied research, use-inspired research, and all future research depends upon knowledge advances from basic research, and the latter requires sustained and healthy funding. A timely example is the basic research advances that were capitalized upon to develop COVID-19 vaccines. The amazingly swift and effective development of those vaccines would not have been possible without the decades of basic research in immunology and other fields. However, we do suggest that, when use-inspired research is proposed and societal impact is claimed, 1) its uses and impacts be for the benefit of all humans, not the privileged few; 2) it not exacerbate the disproportionate gaps of cost/benefit/harm across societal groups; and 3) stated broader outcomes be robustly evaluated.

We recognize, too, that scientists already play a significantly progressive social role, whether or not they realize it, by fundamentally contributing to the advancement of knowledge and understanding. But, for those who wish to do more to create a better future, myriad opportunities are available. There are contributions we can make by simply adding a layer of "public value science" or "social justice science" to our existing research programs. We as scientists can invest time and effort in a multitude of activities.

General. We can

- become educated about the history of oppression in science by scientists and their benefactors, the current legacy of that oppression, and potential systemic solutions;
- promote equity, antiracism, and antisexism in all aspects of the science system; and
- become further engaged in socially responsible science.

Precollege and higher education in STEM. We can

- center and prioritize minority recruitment and success in our classrooms and research programs;
- expose meritocracy myths in the academy and beyond; and
- recognize the monumental and disproportionate system of hurdles that minoritized STEM applicants have faced and overcome, and set educational policies accordingly.

Scientific workforce culture. We can

- consistently diversify search committees, candidate pools, leadership positions;
- speak out about abuse of power and harassment by colleagues, departments, institutions, professional societies, and others;
- reject traditional career incentive systems that are unwelcoming and exclusionary to some groups;
- insist on transformational service models of leadership and resist transactional, stringently hierarchical models of leadership;
- abandon colonialist and exploitive approaches to field and laboratory research;
- build authentic research collaborations with scientists at minority-serving and underresourced institutions;
- stop collaborating with otherwise excellent scientists who are also perpetrators or enablers of harmful behaviors toward women or racial minorities; and
- leverage roles in professional science societies and institutions to effect positive discipline-wide cultural change.

Scientific progress and translation. We can

- call for technological innovations to include analyses of impact on all communities;
- insist that biomedical research include diverse communities in trials;
- build genuine trust in science by going beyond one-way science communication and outreach toward inclusive and representative science; and
- incorporate meaningful two-way scientific engagement with marginalized sectors of society.

The set of possibilities is truly endless and exciting paths forward for many of us. But systemic change cannot be achieved solely by working scientists. We must continue to call for transformative action and policy implementation from science leadership. With the increasing attention to racial and social justice of the last few years, many leaders have deployed their innovation skills toward new approaches for enhancing diversity, equity, and inclusion in STEM. There is clearly a groundswell of motivation for "innovating for equity" at the current time, demonstrated here by a small subset of examples (Table 1).

The Science Moonshot of Our Times

The scale and scope of necessary reforms are enormous, but the benefits of transforming our science system into a more representative enterprise are even bigger: better science, greater innovation, more diverse and broadly impactful research agendas, greater public trust in science, and more effective translation of science to society and policy (Fig. 1). How to inspire and enact such an ambitious transformation seems formidable, but we have met large challenges before by changing hearts and minds and by choosing courageous leadership. Moonshot thinking is a mindset that cultivates courageous effort and audacious belief in achieving ambitious goals previously thought to be unattainable. The original science moonshot, articulated by President Kennedy in 1961, inspired a generation to believe that some challenges are incredibly formidable yet attainable if we provide sustained resources and mobilize our creativity, collaborative spirit, and innovation toward a common goal.

The Moonshot Catalog (61) collates a host of potential "big-bet, big-payoff' science and technology projects. These ideas focus on the biggest challenges facing humanity and the planet and the enormous scientific and political will required to solve them, for example, curing cancer, fighting climate change, achieving pandemic preparedness, and moving toward a circular bioeconomy. These are inspirational goals and will make the world a much better place if successful. However, for science to tackle society's greatest, moonshot-caliber challenges and to successfully translate them to society and policy, the scientific workforce must first be significantly diversified and fully representative

Table 1. Innovating for STEM equity

Example	References
Ensuring equitable STEM educational opportunities	(46–48)
Drawing from best practices at HBCUs, MSIs, HHEIs, and TCUs	(25)
Challenging and eliminating admissions practices that exclude minority applicants	(49)
Supporting persistence through STEM transitions from undergraduate to graduate school to STEM careers	(50)
Changing mentoring norms and practices from a "weed-out culture" to a "support learning and success" culture	(51)
Reimagining hiring, promotion, advancement, and retention for equity	(52, 53)
Bringing leaders and stakeholders together to create and implement new models that reduce harmful power dynamics and harassment	(35, 54)
Rethinking incentive systems	(55)
Using self-assessment processes for systemic institutional change	(56, 57)
Creating new initiatives to address structural bias and create culture change	(58)
Fostering greater understanding of implicit and explicit bias and requiring associated training	(59)
Diversifying peer review	(20)
Mobilizing the unique role of scientific professional societies to create culture change	(21, 60)

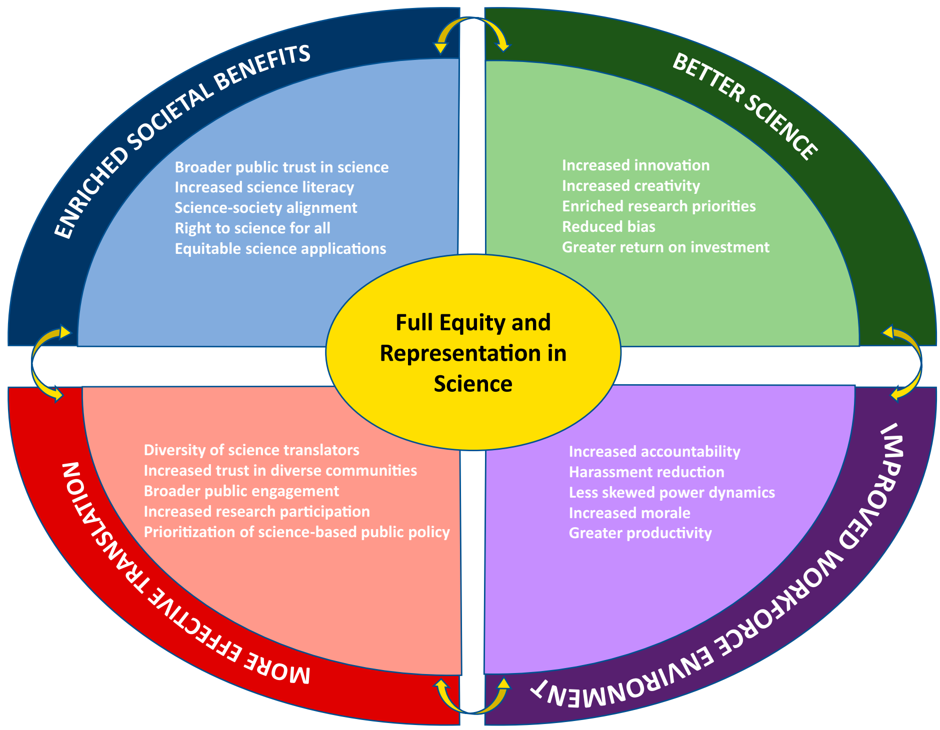

Fig. 1. **Increased representativeness within the overall science system is central to improving science and societal benefits.**

of our society. We argue that a STEM Equity Moonshot is the primary science moonshot of our times because a truly diverse and representative scientific enterprise is foundational to reaching solutions to our biggest science–society challenges (Fig. 1).

This goal will depend on ambitious investments, such as those that have previously been devoted to moonshot efforts in public health, space exploration, and others. It is encouraging to observe the growing momentum, enhanced leadership commitments, fuller understanding, and more-urgent calls for change (62, 63). For example, Tilghman et al. (64) recently called for a nationally coordinated diversity initiative for science and engineering. Within this compelling vision is what we consider an essential component of systemic change: coordination. A coordinated effort is crucial to connect and align the currently disconnected diversity, equity, and inclusion (DEI) efforts across all components of the scientific ecosystem such that they are synergistic and not counterproductive. Further, the numerous contributors to structural inequity within the science system are mutually reinforcing and compounding, and they can result in overwhelming emergent inequity. This cannot be truly solved without a systems approach. In addition to coordination, several other key aspects are likely required for transformative change: empowering new leadership, employing a rigorous data-driven approach to the study of successful and unsuccessful change models, increasing engagement with DEI professional experts and social scientists, and conducting a broad accountability assessment of current norms and processes to determine which reinforce the status quo and which disrupt it.

The leadership of such an initiative must include and empower persons who have experienced, firsthand, the injustices of racism, sexism, and other forms of discrimination in the scientific enterprise, and not in a tokenized manner. To address inequity and discrimination, power structures and power dynamics must be confronted because racism and sexism serve to maintain power structures and resist change.

The use of a rigorous scientific approach is also important. We should analyze data from successes and failures and move forward accordingly (25). Models of success should be fully explored for scalability, and new theories should be empirically tested—such as the intriguing finding that relatively lower-resourced institutions are also the most innovative and successful in making change in this space (65). It is conspicuous that HBCUs, HHEIs, minority-serving institutions (MSIs), and tribal colleges and universities (TCUs) have confronted some of the most difficult challenges in mentoring and educating underrepresented groups, while disproportionately educating minority scientists who are more likely to go on to receive PhDs and successful STEM careers. At the same time that these institutions have addressed serious challenges and exhibited models of transformational leadership and innovation, they remain historically underfunded and currently lack important infrastructure and faculty resources. Empowering those who have demonstrated success in achieving greater diversity makes scientific sense, and studying these can aid in identifying promising practices for other institutions (66).

A further important strategy is to fund more social science research aimed at a comprehensive understanding of the barriers to achieving equity at all levels of the science system. These barriers are nuanced and distinct at various points along the pathway to a successful STEM career. At some points, the primary barrier is lack of equal access or opportunity; at others, it is explicit and implicit bias; and, at still others, it is direct harm, abuse, harassment, and aggression. At some points, it is all of the above and intersectional. Sometimes, the obstacles are both obvious and frustratingly entrenched in wider social norms, as highlighted in a recent study demonstrating that academic productivity during the COVID-19 pandemic in 2020 affected males the least (67)—a result that would surprise no female in the world. Such studies are critical for connecting science inequities to the larger context of social inequities, which is important for understanding emergent inequity. Intersectionality is critical as well—Black women in academic positions were shown to be impacted most negatively of all in this study. These reinforcing science–society inequities require the scientific community to engage and collaborate with experts in the social sciences. Inequity in science is a multidimensional problem, and it requires greater understanding of effective interventions at contextually appropriate stages.

Finally, a serious obstacle to change is lack of authentic accountability systems. The science system moves along as it always has, business as usual, even as we try to operationalize many innovative DEI concepts. Few levers currently exist to significantly modify ongoing harmful behaviors or to reward and incentivize diversity-enabling behaviors. Those of us who have experienced harmful or discriminatory behavior in the science system know that no consequences for that behavior materialized. The few cases where accountability occurs garner news attention, but these are the exception, not the norm. More common are insidious forms of gatekeeping, misconduct hidden within settlement agreements, and social group codes of silence. Passive discrimination from quiet or fearful bystanders perpetuates the problem as well. There are currently few effective levers to ensure accountability or to require meaningful commitments to inclusive behavior. A broad accountability assessment of current structures and processes may aid in identifying those that reinforce the status quo and those where disruption may be most profitable. In any case, new overarching accountability framework is long overdue.

Concluding Remarks

Driving bold, breakthrough solutions for broadening participation in STEM would transform the STEM workforce, create higher-quality and more creative science, increase innovation, and enhance public trust in science directly via increased participation in the science system. Diverse participation in science is vital to fuel the high-quality research and innovation required to address today's greatest scientific and societal challenges and to generate the broadest buy-in for science by the public. A STEM Equity Moonshot is a moonshot that would be enabling to all other science and technology grand challenges. We envision a genuinely modern kind of scientific workforce that is representative of all our society, transforms knowledge outcomes, improves our research culture, and changes society and the world for the better.

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