economics bias in the Third Assessment Report[5], and that highlight AR5's neglect of indigenous knowledge[6].

Our analysis of the Coordinating Lead Authors (CLAs) of the IPCC's AR5 exposes this continued bias towards natural scientists and economists, as well as the persistent absence of humanities research. As expected, CLAs for WGI consist almost entirely of natural scientists. Focused on human impacts, vulnerabilities, and adaptation, WGII is dominated by natural sciences, with 39 natural scientists (including 5 engineers working on physical environments), 25 social scientists, and zero humanities researchers as CLAs, according to our analysis. To put this in perspective for WGII on human systems, imagine if 61% of WGI CLAs on the scientific basis were from environmental social sciences and humanities disciplines. WGIII on climate change mitigation has stronger social sciences representation among CLAs, with 12 fitting broadly into natural sciences, 23 in social sciences, and zero in humanities. Yet, 18 of the 23 social scientists are economists, demonstrating the IPCC's narrow conception of social sciences. Overall, of the 99 CLAs in WGII and WGIII, there are none detected from the humanities. At a lower level of authorship, the WGIII AR5 methods chapter (Chapter 3) — which outlines the principles, theories, and values underlying WGIII — does have one humanist (philosopher) as a lead author. This philosopher is among 16 CLAs, lead authors, and review editors, 13 of whom are economists.

The IPCC might yield broader impacts if it included environmental social sciences and humanities researchers from a much wider diversity of fields and approaches, as Castree *et al.* explain. Philosophers such as Dale Jamieson[7], who analyses humans' cognitive capacity to grapple with global environmental change ethics and causation in climate change, and musicologists such as John Luther Adams[8], who introduces weather through an ecology of sounds and emotions, can effectively uncover humanity's experiences with climate change and thus help adaptation and mitigation. But the IPCC's current disciplinary bias and organizational disjuncture is unlikely to change because IPCC authorship is by invitation only, from a group of natural scientists and economists who may not embrace the work of most environmental social sciences and humanities fields and who lack an understanding of which disciplines and individuals' credentials are valuable to climate change research. Such a transformation in the IPCC leadership and structure — to include environmental social sciences and humanities researchers on equal footing with natural scientists and economists — would be a step towards implementing the goals of Castree *et al.* It would also provide a useful starting point for deciding how to communicate climate change research to a diversity of human populations living in profoundly different cultures, political–economic systems, and communities. ❐

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Acknowledgements

This article is based on work supported by the US National Science Foundation under grant 1253779. Thanks to M. Jackson for helpful feedback.

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COMMENTARY:

Facing the diversity crisis in climate science

Adam R. Pearson and Jonathon P. Schuldt

The climate movement is failing to engage a diverse set of stakeholders in efforts to address climate change, and a lack of diversity within the climate community itself may be, in part, to blame. Research-informed solutions are urgently needed to address the problem and help build a more inclusive and influential movement.

On 28 July 2014, a team of researchers led by Dorceta Taylor at the University of Michigan released a new report[1] on the state of diversity in the United States environmental sector. Their message is clear: despite rapidly growing racial and ethnic diversity within the United States and Europe on the whole, substantial racial and ethnic disparities persist in the climate sector, even relative to other science and engineering fields.

The problem is urgent. According to US census estimates, racial and ethnic minorities now account for a majority of US births and 93% of the nation's population growth. And the United States is not alone. Nations within Europe and Australasia have experienced similar demographic shifts[2] with the arrival of skilled migrants and humanitarian entrants. In the very near future, many developed nations will have a more diverse demographic makeup than ever before, at a moment when broad-scale cooperation to address climate threats is paramount — at both the national level, as countries consider major climate legislation, and at

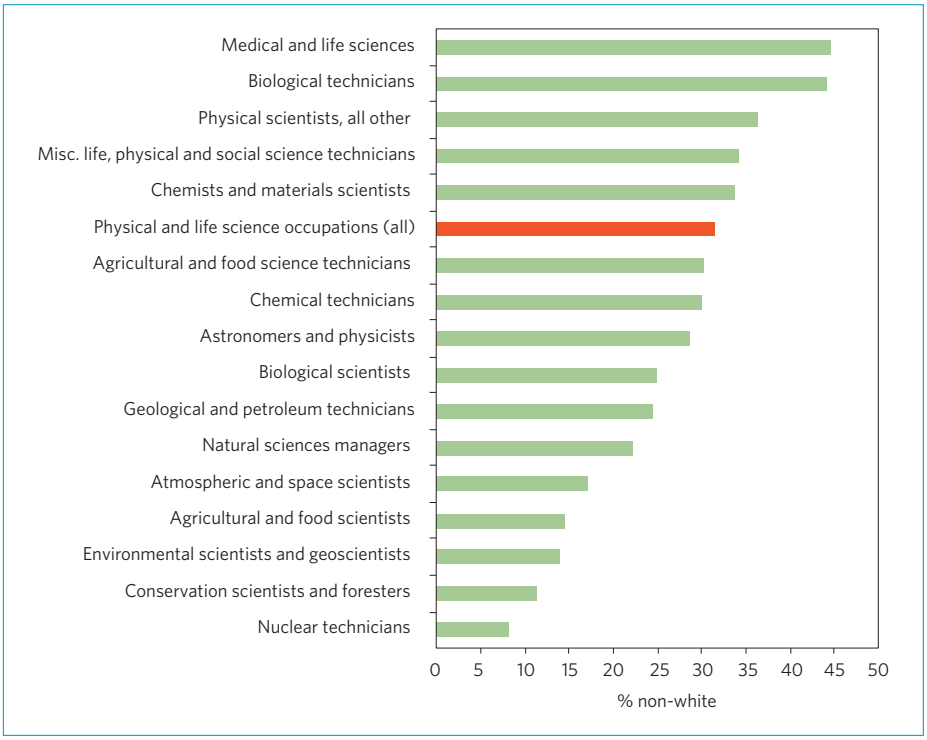

Figure 1 | Occupational disparities within the United States across 16 physical and life science classifications. Bars indicate the percentage of non-white representation within each classification. Red bar indicates average non-white representation across all classifications. Data from US Census Bureau, 2011 American Community Survey.

the international level, as the world's nations work together to face global threats.

Diversity has long been viewed by climate researchers as a problem of equity[3] (for example, environmental justice) and for good reason: people of colour are considerably more vulnerable to the negative impacts of climate change and lack essential access to green jobs and educational opportunities. Yet, the persistent gap between the social and the scientific consensus on climate change[4] and declining public interest in climate issues in the United States and globally over the past decade[5] underscore a broader significance of diversity efforts for engaging a larger segment of the public on climate matters. The Taylor report highlights important deficiencies in current organizational practices, as well as structural reforms needed for diversifying the climate movement, including combating insular hiring practices, establishing formal oversight of diversity efforts and publicizing institutional diversity goals. However, structural reforms alone are not enough. We need a comprehensive scientific approach to addressing the diversity crisis — one that incorporates the best evidence-based solutions that are 'wise' to the underlying psychological processes that drive climate engagement and may hold the key for building a broader and more inclusive climate movement.

A unique challenge for climate science

The lack of diversity in governmental and non-governmental environmental organizations has long been acknowledged. A 1992 study[6] found that nearly one-third of US environmental organizations had no racial or ethnic minorities on their staff. Although diversity has increased in mainstream environmental organizations over the past two decades, it remains far below national levels. The Taylor report, which surveyed 293 US environmental government agencies, non-profits and foundations, found that non-white minorities comprised no more than 16% of staff in all three types of institution, despite constituting 38% of the US population and 29% of the overall US science and engineering workforce.

Employment statistics[7] for science, technology, engineering and mathematics (STEM) occupations from the US Census Bureau further underscore a unique challenge confronting climate-related fields. Across 16 physical and life science classifications, the bottom five occupational groupings in terms of non-white minority representation include atmospheric and space sciences, environmental and geosciences, and conservation and forestry (Fig. 1). Within academia, the picture is similarly grim. A national survey[6] of US faculty across 17 environmental disciplines revealed only 11% minority representation, with a majority of faculty reporting having either one or zero faculty of colour in their department.

Early studies[3] looked to explain racial and ethnic disparities in terms of differing concerns about the environment. Yet, opinion polls[8] reveal consistently high (and in many cases higher) levels of support for national climate and energy policies among US blacks and Latinos relative to whites, including the regulation of carbon emissions, investment in renewable energies and placing a price on carbon. Moreover, national surveys[1,6] point to a robust pool of minorities who are interested and qualified to work in the environmental sector. The evidence therefore suggests that factors beyond environmental attitudes and qualifications are contributing to these disparities — factors that may be more subtle and, thus, easily overlooked.

These statistics, together with those detailed in the Taylor report[1], portray the diversity crisis as a persistent and complex problem — one in need of a comprehensive approach that goes beyond organizational reforms. What is missing is science-based solutions that focus on the fundamentally social nature of this problem. In particular, research from social psychology offers insights into factors that can powerfully influence participation in STEM fields. We briefly describe three such factors — namely, visual cues to belonging, stereotypes about the sciences and 'colour blind' organizational messages — that illustrate the value of a scientific approach to diversity.

Visual cues to belonging

A study[9] by researchers at Stanford University illustrates how low representation, particularly in leadership roles, can undermine a sense of belonging and perpetuate STEM disparities. In their experiment examining gender STEM disparities, university students were shown one of two versions of a seven-minute promotional video for an upcoming STEM leadership conference that depicted either a gender-balanced or a gender-unbalanced (3:1, male to female) ratio of attendees. Compared with those in the gender-balanced condition, women (but not men) in the gender-unbalanced

condition showed elevated stress levels and reported a lower sense of belonging and less interest in attending the conference.

Low diversity can also critically undermine trust in institutions. In another experiment[10], black professionals were shown corporate brochures that depicted either many or few minority staff members and were asked for their opinions about the organization. When minority representation was low, participants were less comfortable envisaging themselves as an employee, less trusting of the organization's management and more concerned about how others in the organization would treat them. Although the insidious effects of low numerical diversity can be difficult to combat in the short term, research[11,12] suggests that boosting diversity among institutional leadership may be an especially effective strategy for enhancing trust and a sense of belonging within organizations. With minorities accounting for less than 12% of all leadership positions and only 4% of board members of environmental non-governmental organizations[1], these findings point to a critical area for intervention for building a more inclusive climate movement.

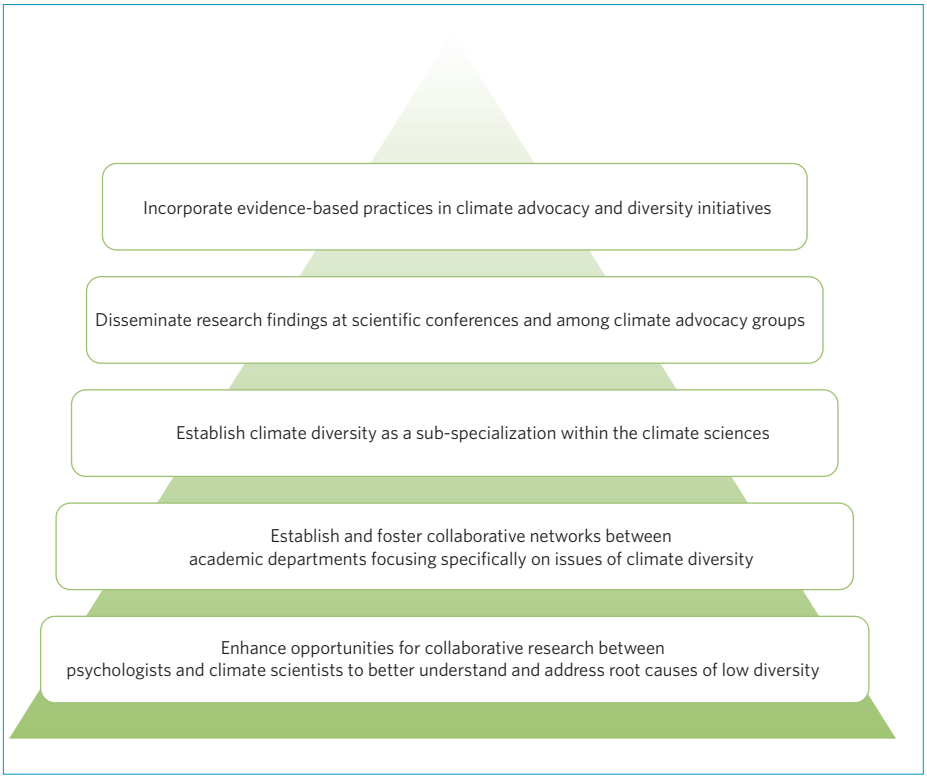

Figure 2 | Building an integrated science of climate diversity.

Stereotypes about the sciences

Nearly six decades after Margaret Mead's classic study on public perceptions of science revealed pervasive stereotypes among US school children, the image of scientists as white and male has remained largely unchanged[13]. However, new research suggests climate scientists may face a dual burden, contending with both STEM- and environment-specific stereotypes.

In our own laboratory and field studies[14], we have found that stereotypes about environmentalists may contribute to structural disparities. In these studies, both white and minority respondents were quicker to associate whites with the concepts of 'environmentalism' and 'conservation' than the black, Hispanic and Asian groups. In another study, non-whites who were reminded of these stereotypes before completing an online survey expressed less interest in joining group-based environmental advocacy efforts (for example, joining a mainstream environmental organization, donating to an environmental charity) compared with a control group. White participants showed no such effect.

Additionally, challenging existing stereotypes about minority engagement — for example, the belief that a lack of participation reflects a lack of concern for climate issues — may be critical for building support for diversity initiatives within organizations. Although racial and ethnic disparities have persisted in the climate sector, the gender gap has narrowed substantially in recent years[1]. One reason for this may be due to prevailing stereotypes that women are more concerned about the environment compared with other groups[15], which may contribute to the willingness of environmental organizations to prioritize efforts to reduce gender disparities over other diversity initiatives[1].

Media images that perpetuate cultural stereotypes can substantially hinder diversity efforts inside and outside of academia. Nevertheless, stereotypes are malleable. In one experiment[16], simply reading a short (200-word) news article that computer scientists no longer fit the male stereotype significantly increased women's (but not men's) career interests in STEM fields. This suggests that messages that challenge pre-existing beliefs about people involved in the climate movement may alter these stereotypes and help to boost climate engagement — a promising avenue for both research and outreach efforts.

Organizational messages

The framing inherent within mission statements and promotional materials may also help to bridge racial and ethnic divides. Research on political divisions underscores the importance of message framing in climate discourse. For instance, national survey experiments reveal that US conservatives and liberals widely disagree about the existence of 'global warming', a divide that is dramatically reduced merely by rewording survey questions in terms of 'climate change'[17]. Beyond political divides, 'colour blind' communications that focus on member similarities and avoid issues of race and ethnicity can paradoxically signal that these identities are not valued and can fuel distrust in organizations, particularly when coupled with low diversity[10,18].

Ironically, the scope of the climate crisis and the corresponding need for cooperation at the global level may lead advocacy groups to avoid issues of race in favour of ostensibly more unifying messages. Although well-intentioned, these messages can alienate the very groups that they seek to include. In contrast, 'multicultural' approaches to diversity in which group differences are openly discussed and even highlighted have been shown to be far more effective for engaging members of underrepresented groups[18,19]. Messages that emphasize the diversity of climate stakeholders, and present diversity as a source of growth and strength for the climate movement, can help to convey that all groups are welcome and valued in the climate community.

Towards a science of climate diversity

The examples above offer a glimpse of the complex and often hidden social forces that impact STEM participation. However, addressing the unique challenge of minority underrepresentation in climate STEM fields and the climate movement at large will require a more comprehensive and coordinated response between behavioural scientists and climate researchers. Psychologists need to engage climate scientists and advocacy groups to identify organizational norms and practices that may impede broader engagement with the movement. The climate community, in turn, needs to engage psychologists and other diversity researchers to develop research-informed solutions for addressing the problem. These collaborations should also consider how other forms of diversity beyond race, such as socioeconomic, geographic and religious diversity, impact public interest in climate initiatives and receptiveness to advocacy efforts.

We outline five steps that the climate community can take to foster these collaborations and develop new evidence-based remedies (Fig. 2). These include enhancing funding and support for basic research on climate STEM diversity; establishing the scientific study of climate diversity as a sub-specialization within the climate sciences; expanding opportunities for disseminating diversity research at scientific conferences, as well as between academics and non-academics; and using diversity research to guide climate advocacy and reform efforts. Current funding mechanisms, such as the US National Science Foundation's Sustainability Research Networks competition, and existing organizational partnerships[1] can help lay the groundwork for these collaborations, but addressing the diversity crisis will require new infrastructure and new commitments on the part of scientists and non-scientists alike.

Climate science is a fundamentally collaborative and interdisciplinary enterprise, tasked with understanding complex biophysical and social forces contributing to climate challenges. A science of climate diversity can help us better understand what brings diverse stakeholders to the table. Leveraging these insights will allow the climate community to more effectively engage policymakers and the public, and help build a more informed and influential movement for the twenty-first century. ❐

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COMMENTARY:

Going back to basics

Christian Jakob

Climate models have increased in complexity over time as more processes have been included. Now we need to return to the underpinning basics in the models and ensure they are the best they can be.

All predictions and projections of weather and climate from days to centuries ahead fundamentally rely on models of the atmosphere, ocean and land, increasingly including representations of biological and chemical processes. Much of our scientific enquiry in climate science makes use of the same set of tools, which are collectively referred to as climate models. Lives and property are saved every day by the application of weather models, and climate model results underpin major planning decisions for our future.

The use of models is very common well beyond the field of climate science. However, unbeknownst to many, climate models differ fundamentally from those used to predict the behaviour of many other systems, such as population or economic models. While the latter are often based on statistical relationships derived from the observed behaviour of the system, at the core of climate models are well-known fundamental laws that describe the circulation of the atmosphere and ocean complemented by complex sub-models of less well-understood and unresolved processes.

Building climate models involves four fundamental steps:

(1) Expressing the fundamental laws in mathematical terms[1].
(2) Applying numerical approximations to the resulting set of equations[2].
(3) Building and implementing sub-models — often referred to as parameterizations — for those processes that are excluded from the