



Five Burning Questions

Five questions on improving diversity, equity and inclusion in UK bioscience research or “How can UK bioscience be changed so that those from marginalised groups can thrive?”

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ABSTRACT

Diversity, equity, and inclusion play pivotal roles in advancing science and innovation by fostering a rich and supportive environment that benefits both individuals and society. UK bioscience research units are still on a journey towards being inclusive, and existing research on effecting changes in diversity, equity, and inclusion has yet to make an impact at the scale needed to transform the sector, leaving many to wonder *How can UK bioscience be changed so that those from marginalised groups can thrive?* This paper considers some of the questions that arise in addressing this, discusses what we already know and what we do not, and in doing so outlines a research agenda that aims to find out what works to effect diversity, equity and inclusion in UK bioscience.

Introduction

Diversity, equity, and inclusion (DEI) play pivotal roles in advancing science and innovation by fostering a rich and supportive environment that benefits both individuals and society. First, diversity brings together individuals from various cultural, ethnic, cognitive, and socioeconomic backgrounds, each with their unique life experiences and knowledge. This diversity of thought and perspective allows for a more comprehensive understanding of complex scientific challenges, leading to more robust and accurate research outcomes [1,2]. Second, promoting equity ensures fair opportunities for all individuals, regardless of their backgrounds, to participate in scientific endeavours. By removing systemic barriers and biases, people from marginalized and underrepresented groups gain equal access to resources, education, and opportunities, and have the opportunity to see role models with which they can identify, unlocking a wealth of fresh talent and widening perspectives. Third, inclusion complements diversity by creating an environment where all voices are heard, respected, and valued, which enhances collaboration, creativity, and collective intelligence within the scientific community. Ultimately, advancing science and innovation requires harnessing the power of diverse minds, promoting equity, and fostering an inclusive culture that celebrates and embraces differences, to enhance the experiences of the individuals working in research and innovation (R&I), thereby increasing the productivity of the R&I organisations and the

impact of the research produced on society. This inclusivity leads to diverse ideas, approaches, and problem-solving techniques, which fuel innovation and drive scientific progress forward.

It is almost 20 years since the Athena Scientific Women’s Academic Network (SWAN) scheme was established in the UK (United Kingdom of Great Britain and Northern Ireland) to encourage and recognise commitment to advancing the careers of women in science, technology, engineering, mathematics and medicine by universities, and later research institutes, from both an institutional and departmental level. 70% of higher education institutions (HEIs) have engaged with the charter [3]. This has evolved, and in its most recent transformation as Athena Swan, now includes all academic disciplines, intersectional inequalities with other protected characteristics (race, disability, religion and belief, etc.), and allows all parts of an organisation including technical and operational centres, to charter for an award that recognises their ambitions, progress, and impact in gender equity for all. Further, spurred on by the Equality Act of 2010, many HEIs have created both central and local faculty/departmental teams focused on advancing DEI. These teams have expanded their focus from equity for women (including also pregnancy, maternity leave and menopause) to also cover other marginalised groups, such as ethnicity, LGBTQ⁺, neurodiversity and disability. Despite all this effort, academia still struggles to be inclusive and existing research on effecting changes in DEI has yet to make an impact at the scale needed to transform the sector [4,5]. We

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maintain that one of the barriers to advancement is that, whilst often data-driven, DEI work tends to focus on making incremental tweaks to existing systems rather than considering how the various aspects and features of the R&I system conspire together to prevent significant leaps forward. Like others [6] we argue that, instead, we need to take a systems perspective, considering the various components within the larger system of higher education and the funding landscape that underpins academia in the UK, and the interactions and interdependencies between them, amidst the wider society in general. Adopting a systems perspective encourages us to think about how the policies, processes and culture within an organisation interact to create an environment that encourages some types of behaviours and discourages others. Inequitable outcomes are therefore not the responsibility of lone individuals to address, but the (often unintended) consequences of organisational practices which are the responsibility of the whole organisational community to change. Focusing on all aspects of the system, and understanding how they influence outcomes, can help us to realise that DEI can be designed into organisations, enabling the academic community to create a fairer and more equitable system.

There are many interesting open questions in DEI and its application to the biosciences. The five questions presented in this paper span several scales and topics within the area and reflect the well-known distinction in approaches that aim to “fix the numbers”, “fix the organisations” and “fix the knowledge content” as proposed by Londa Schiebinger’s Gendered Innovations framework [7]. In doing so, they demonstrate the interconnectedness of the factors that lead to a lack of diversity in both the people doing the science and the science that is conducted and promote a focus on system-wide improvements rather than isolated interventions. The authors hope that these questions prove not only relevant to university, department and DEI leaders within the biosciences, but also stimulating to bioscience researchers when reflecting on their own research practices. In considering what it will take to change the diversity and experiences of equality and inclusivity of UK bioscience, we identified 5 relevant and topical questions that we, the authors, consider to be the most pressing and which, if tackled together, would lead to meaningful change across the levels of Schiebinger’s framework:

1. How can we investigate gaps in the diversity of the students, researchers, and innovators within the biosciences?
2. How can we ensure that those from marginalised groups are recruited into bioscience units?
3. How can we ensure that all bioscience staff and students experience equal opportunities to succeed?
4. How can we increase the inclusivity of funded research on bioscience topics to maximise impact on society?
5. How can we encourage impactful change in DEI in the biosciences?

In the rest of this paper we consider each of these questions in turn, summarising where we are, identifying what is not yet well understood, suggesting what is required to address the question, and in doing so outline a research agenda that aims to find out what works to effect diversity, equity and inclusion in UK bioscience. We have focused on the challenges for academia in the bioscience disciplines most relevant to this journal, and from the perspective of UK bioscience departments, universities and research institutes (which we collectively term “units”). We recognise that the need for increased equity in other disciplines may be more urgent or challenging; the questions and answers here remain valid even if the actions required elsewhere need to be even more bold. In writing this paper we hope to inspire academics within the biosciences to further engage with the future research agenda on this important and timely topic.

Author positionality statement

The authors acknowledge that their relative privilege within society

provides them with certain advantages that other academics do not hold. Thus, we took great care in the writing of this paper to reflect on the following important questions during the process:

1. What is our primary motivation for writing this paper? Is it to raise awareness of DEI issues? Is it to serve and support the academic community?
2. Who will benefit most if our suggestions are followed?
3. What biases are we bringing to this work?

We have tried to use those words and phrases that are currently preferred by people that are marginalised by existing attitudes, structures, and practices. We recognise that this may change over time.

As members of the academic community, we believe that we all can help shape the organisations in which we work, and that those with the greatest power and privilege have the greater responsibility and capability to contribute. Therefore, apart from this section, which is about the two authors, the use of the term ‘we’ in this paper refers to the academic community.

Question 1: How can we investigate gaps in the diversity of the students, researchers and innovators within the biosciences?

To know where the opportunities to target interventions exist, we need to know where the diversity gaps are. The collection and interrogation of quantitative data is therefore a key enabler for DEI work. In the UK, comprehensive data is collected and curated by the Higher Education Statistics Agency (HESA) and made available for analysis, for example to the Office for Students (OfS) and the government public body UK Research and Innovation (UKRI). The current data shows that people from marginalised groups are underrepresented in universities [8] and reveals some of the factors that contribute to this.

To improve the equity of processes that determine advancement and speed change we need to prioritise knowledge and expertise in the use of high-quality quantitative data to enable the evaluation of intervention strategies. The comprehensiveness of the data collected by and from HEI in the UK provides an advantage in that it allows more sophisticated interrogation and therefore the design and testing of more targeted interventions to support the most marginalised. These learnings can be adopted by others.

To supplement national statistics and provide further insights, academic organisations need urgently to replace their legacy systems to make collection of data on staff and students easier to obtain. Further, currently many universities find incomplete disclosure of all protected characteristics: the reasons for this differ for characteristics. Care must be taken to understand how best to motivate staff and students to declare all personal data that would enable organisations to undertake intersectional analyses of their data, thus revealing how the ways a person’s combinations of social identities interact or intersect (like gender, ethnicity, class, first language, sexuality, ability, religion, and more) - called an intersectional approach. Such complete data would allow the synthesis and assessment of existing research evidence and policies and practices to advance DEI.

We recognise that there are challenges to implementing this kind of approach across the all bioscience units, particularly those outside of the UK where there are limits on the extent to which data on protected characteristics can be collected. We acknowledge the previous and ongoing efforts, for example in the European Union (eg <https://h2020.genderaction.eu/>, <https://www.genderportal.eu/>), including extensive training. How can such barriers be overcome whilst respecting the sensitivities about collecting this data in other contexts? In the UK, which strategies are most effective to reach fuller disclosure of personal data, enabling the collection, presentation, and interpretation of this data by HE as a whole, as well as by individual HE and funding institutions?

Question 2: How can we ensure that those from marginalised groups are recruited into bioscience units?

Inclusivity starts with recruitment processes, which can be deeply entrenched in the culture of an institution. Most UK HEI are long-standing: there was a doubling in the number of universities in the 1960s, other recognised institutes were granted power to award their own degrees in the 1990s, and still other established institutes gained their own university status more recently. It requires effort to overhaul well-established recruitment practices to remove bias, and these processes are very different for students and staff.

Student recruitment Student recruitment relies heavily on the outcomes of formal school examinations. Diversity gaps that impact the chances of students gaining access to university appear to start even before students reach the usual age of going to university (age 18). Whilst school leaders primarily focus on identifying and addressing gaps between students of different socioeconomic groups [9], gaps in attainment also exist across different parts of the UK. For example, examination of 2023 data on GCSE level results (age 16) shows the largest gap on record between those taking GCSEs in the north-east of England and London [10]. Such data suggest that one route to increasing diversity at university might be to target interventions at secondary schools to ensure that the brightest in all parts of the UK not only obtain the qualifications necessary to access higher (tertiary) level education but also see university as a career opportunity for someone like them.

Looking at university student recruitment data provides another opportunity to see diversity gaps and is commonly explored by universities themselves. As a consequence, increasing the diversity of the undergraduate student body by broadening the age range, ethnic diversity, socio-demographic group, gender and disability of those starting university has been the focus for many “widening participation” [11] initiatives. These have considered both how to support those entering university straight from school and those who enter later, who are more likely to study part-time (64% of university enrolments are >21 years, 23% are >30 years [12]). Consequently, much is known about how to increase the diversity of the undergraduate student population at the point of entry. Reviews of the efficacy of university interventions suggest that integrated programmes that aim to enhance access to universities via contextual offers and alternative programmes of study, as well as support students’ adjustment to university life through opportunities for mentoring, gaining research experience, and academic and personal tutoring by academic staff can be effective [13]. However, this must be complemented by efforts to ensure success during education (*see question 3*) to allow equitable progression. Recent data from the UK Office for Students [14] provides further support for the idea that there is increasing diversity in those entering both undergraduate and postgraduate education suggesting that at least some of these measures are effective.

Diversity gaps also exist at postgraduate level. Most, if not all, future academics will also undertake postgraduate education. Whilst postgraduate students are most likely to be in their early twenties there are a significant number of students choosing to enter postgraduate education later (37% postgraduate entrants are >30 years). Similarly, the numbers of postgraduate students with a disability (11%) and from a minority ethnic group (24%) have also been steadily increasing [12]. Similar changes are visible in the increasing diversity in demography of staff in the academy [15]. Whilst these changes in both student and staff populations are positive, they are slow. In addition, widespread disciplinary differences exist. For example, engineering, technology and computing are dominated by male students whilst education and psychology are dominated by female students. However, the gender diversity of subjects can change over time, as for biosciences and medicine, which now have more female students though senior levels remain male-dominated. Leaky pipelines are also common: the numbers of students and staff from marginalised groups decreases at more senior/advanced levels [16].

Staff recruitment The UK government Department for Business, Energy and Industrial Strategy [17] highlights the difficulties in finding people with the right skills to keep the UK at the forefront of research and innovation due to unstable career paths, barriers to mobility [18–21] and research cultures that are neither open nor inclusive, impacting recruitment and retention. The barriers, challenges, opportunities, and support needed for marginalised people to participate in the research and innovation system are not well understood or synthesised and an intersectional approach is rarely applied [22].

In addition to the challenges related to the pipeline of qualified candidates that occur as a result of diversity gaps in the student population, scholars have identified other factors that negatively impact academic recruitment [23]. These include outdated recruitment and retention practices, myths surrounding academic diversity, the decentralized nature of academic administration, and misconceptions about the compatibility of diversity with academic excellence. To effectively diversify the research pipeline, institutions must adopt proactive and creative recruitment strategies. These strategies should focus on not just attracting a diverse pool of candidates but also on retaining them (a topic we address in *question 3*).

To address the challenges in recruitment we need to know: What strategies can be implemented to address the diversity gaps in student recruitment, especially considering the disparities in educational attainment across different socioeconomic and geographic groups in the UK? How can universities effectively overcome the barriers and challenges in recruiting staff from marginalized groups, given the existing issues in academic recruitment such as unstable career paths, barriers to mobility, and non-inclusive research cultures?

Question 3: How can we ensure that all bioscience students and staff experience equal opportunities to succeed?

Within a university, the pursuit of success encompasses more than just measurable outcomes. While academic achievements and research accomplishments are undoubtedly important, they are intrinsically linked to a deeper and equally vital aspect: the sense of belonging. Success in the academic realm not only hinges on the quantifiable results students and staff achieve but also on the intangible feeling of being valued, included, and part of a supportive community. This holistic perspective recognizes that true success emerges when individuals thrive academically and personally, contributing to a vibrant and inclusive university environment that nurtures both their growth and their sense of belonging.

Measures of achievement

Students: The inequity in outcomes for students from marginalised groups has been well documented. Recent research has highlighted that awarding gaps (initially referred to as attainment gaps which implies that fault lies with an individual when it really lies with an inequitable system) exist between students of different identities [24]. Large differences have been found in the proportions of white students and those from ethnic minorities awarded a ‘good’ (i.e. first-class or 2:1) degree that have persisted for over 15 years. Even where gaps in ‘good’ degrees appear small, they often hide sizeable gaps in the number of first-class degrees awarded. These gaps suggest that whilst widening participation programmes are effective in increasing diversity of incoming students, there are still failings in the extent to which universities can ensure that the subsequent education experience is equitable.

Universities have been exploring ways in which the gap can be reduced. One common approach that is assumed to eliminate the impact of biases on behalf of the marker is the introduction of anonymous marking. This approach is now considered standard practice in many HEI but, interestingly, evaluation of its efficacy in eliminating awarding gaps suggests it has minimal impact [25]. Instead, the largest reduction in the awarding gap to date (between 2018/19 and 2019/20) can be

attributed to changes in assessment implemented as a result of COVID mitigation strategies [24]. However, preliminary evidence [26] suggests that these changes have not been sustained. Future research should explore whether these reported changes are reliable and exist across universities. Efforts to address the ethnic minorities awarding gap have also looked beyond differences in assessment methods to also focus on ensuring students have a positive experience and a sense of belonging, to tackling staff attitudes and decolonizing the curriculum [26]. Eliminating these awarding gaps is important because they have a long-term impact in reducing access to postgraduate qualifications and to reducing diverse talent along the R&I pipeline. Recognising, challenging and addressing these may be helped by participating in the Teaching Excellence Framework (TEF), a national scheme that began in 2017 and is now run by the UK Office for Students, that aims to encourage higher education providers to focus on improving and delivering excellence in teaching, learning and achieving positive outcomes for students by assessing excellence above minimum requirements expected when studying at university (<https://www.officeforstudents.org.uk/advice-and-guidance/the-tef/about-the-tef/>).

Staff: Academic staff also experience inequity when their outputs are assessed. Researchers spend a lot of their time writing papers and grant applications. Peer review determines paper acceptance, proposal approval, grant allocation, job promotion, and numerous other decision-making processes in many aspects of research and innovation. Gender gaps exist in highly prestigious international research awards [27] and the extent to which they are cited [28]. Recent analysis of UKRI funding data [29] shows that minoritised groups are underrepresented as applicants, reviewers, panellists and awardees in funding schemes. The persistent lack of diversity in reviewers can be a factor in perpetuating existing biases. Despite the hope that it is a rational, fair, and objective decision-making process [30], evidence shows this "gold standard" is a "flawed process at the heart of science" [31] with four different categories of bias shown to influence the peer review process [32–39].

Data has also revealed that those who speak English as a second language are under-represented in academia. With English being a universal language in science, and the most-spoken language in the world if non-native speakers are included, there is little thought given to the missed contributions of those who are not adept in this. In the UK all teaching and research is in English which requires students and staff to have achieved proficiency before receiving an offer to study or for employment. Grant writing and papers often need to be written in English for international bodies, yet funders and publishers provide little support for this. The burden of using another language and detrimental effect on R&I is rarely considered [40], and the barrier of language that inhibits opportunities for collaborative research with substantial people groups with consequential absence of some R&I receives little attention. Further research is needed to improve artificial intelligence (AI) tools that could help to reduce the effort of proof-reading and translation going forward.

A number of methods have been trialled by funders that show promise for reducing the opportunities for bias to influence funding decisions and for increasing funding of novel ideas and improving diversity, including anonymous reviewing [41–45] and random allocation of funds (e.g. internationally the Swiss National Science Fund, Austrian Science Fund, the New Zealand Health Research Council, and, in the UK, Innovate UK [46], Nesta [47], the British Academy [48] and NERC [49]). Such approaches appear to be more accepted by academics when combined, but it is not yet known which combinations impact who, when and how. This illustrates the urgent need to understand how constraints experienced by funders impact the design of funding calls and the subsequent impacts on prospective applicants, reviewers, and panellists, to provide all funders with guidance on how to design inclusive commissioning and funding systems.

Publishers too are beginning to address the bias within the scientific publishing system, with the UK Royal Society of Chemistry launching the 'Joint commitment for action on inclusion and diversity in publishing' in

2020 [50]. By 2023 this initiative has 56 publishing organisations working together with a total journal portfolio of >15,000. They are collecting data on diversity at each stage of the process (editorial decisions, authors, reviewers) and beginning to diversify, for example editorial boards, starting with gender [50,51].

Feelings of belonging

People are more likely to thrive in inclusive organisations where they feel recognised and valued, i.e. a sense of belonging. This is because less emotional effort needs to be spent on surviving and more is available for contributing. Understanding how inclusive a university feels to students and staff requires that we go beyond looking at quantitative data. Whilst quantitative data is effective in helping us understand the 'what' i.e. the extent to which the university experience is equitable, it is qualitative data that provides most insight into 'how' and 'why' and 'for whom' [52]. Such data, combined with behaviour change frameworks such as the Behaviour Change Wheel [53], can enable us to design interventions that address the capability, opportunity and motivational barriers to changing organisational practices.

Such approaches have been used to improve the inclusivity of university cultures for both staff and students. Exclusionary and discriminatory practices may arise from imbalances in power. These need to be identified and addressed.

Students: The student experience in UK universities is seen to be of paramount importance, as it profoundly influences student satisfaction, well-being, and personal development, contributing to higher retention rates and fostering a strong sense of belonging. Moreover, a positive student experience enhances the university's reputation, attracting top talent and bolstering academic standing. Universities that prioritize this experience provide diverse extracurricular activities and support services that shape students' skills and values, preparing them for both academic success and future careers, ultimately benefiting both individuals and institutions in the long run.

One effective approach is to focus on creating a sense of belonging amongst students, particularly those from underrepresented groups. This can be achieved by implementing inclusive curricula, staff training, and workshops that promote diversity and reduce prejudice [54] and through the personalisation of feedback. However, providing personalised feedback is not always possible when the identity of a student is not known to the marker. Anonymous marking has been widely adopted as a method to reduce the potential for bias in assessment processes [55]. However, such practices do little to foster increased feelings of fairness in the process from the students' perspectives [25] and make the creation of personalised, inclusive and interculturally sensitive feedback difficult. Creating the feedback after assessment has been conducted is not time efficient and the existing high workloads of academic staff are well documented. In the UK higher education sector, concerns about excessive workload and workplace stress are widespread. In 2004, most UK university professors (62%) were working in excess of 48 h per week [56]. This trend continued: a 2016 survey [57] of 12,000+ academic staff in Higher Education found that staff across all disciplines worked 50.9 h per week on average. This is equivalent to an average of 3 h beyond the maximum as stated by The Working Time Regulations [58]. We therefore need to explore new practices for assessment and feedback that can be both time efficient for academic staff and create personalised experiences for students, as well as normalising realistic workload expectations.

Staff: HEIs have also been giving increasing consideration to culture within their organisation motivated by a number of factors including the Research Excellence Framework 2029 which will place enhanced importance on this area. However, making changes to organisational culture, practice and procedure is difficult. Indeed, the recent acknowledgement from the Wellcome Trust that, since launching their Anti-Racism Programme and set of Anti-Racism commitments two years prior, they have taken "insufficient action" resulting in "limited

progress" [55] provides a clear example of this. Fostering trust and establishing clear accountabilities are critical to achieving systemic change [59].

Existing research about how to create and maintain an inclusive culture shows the importance of creating a sustained sense of being valued and of belonging [60] and legitimisation [61] that is supported by the culture and structure of the organisation. Research is often carried out on what helped those who remain in the system (for example, [62]) but there is a dearth of intersectional research, and activities that shape the collaborative, equitable relationships of network members have received still less attention [61]. Much application is siloed and cross-sectional which means changes can be minimal and at times superficial [63,64]. There is little work that has considered how to include the most marginalised within minoritised groups, rather than those with the strongest representation or voice [65]. It is important to ensure that marginalised voices are heard without making them responsible for this process, thereby adding both a burden of work and additional emotional labour.

To foster an inclusive culture, it is essential that those in power not only shoulder the responsibility of initiating change but also address the underlying power imbalances and the exclusionary or discriminatory practices in our communities. The burden for these changes must not be placed on marginalised groups but taken on by those who hold the power. Emphasizing inclusivity means prioritizing the input and needs of marginalized community members. This approach, centred on amplifying diverse voices, ultimately yields benefits for the entire community.

Existing literature demonstrates the importance of intersectional theory and practice in creating greater understanding, awareness of, and sensitivity to, each individual's multiple positionalities across various axes of disadvantage and advantage. However, more transformative applications have been limited by a lack of unified methodological practice, and limited consideration of non-binary categories. Applying intersectional theory [66] will create new insights and tools to help identify what works, when, how and for whom, when creating inclusive work cultures, enabling the need for support to be incorporated to mitigate identified burdens.

Research has shown that individuals who feel valued and supported, i.e. that they belong in their organisation, are able to contribute more. Many institutions have therefore supported the development of structured mentoring schemes for minoritised groups [67] in a bid to create an inclusive culture for staff. These acknowledge the challenges encountered by marginalised members of the academy, demonstrate a commitment to nurturing success, and serve as a dynamic platform for sharing experiences, guidance and knowledge, thereby enabling individuals to navigate the complexities of academia more effectively. Whilst there is little evidence of the impact of these schemes on accelerating career progression [68], these can foster a sense of belonging and community, and so enhance retention rates and overall satisfaction amongst marginalized individuals in academia [69].

We need to design new ways of working that reduce opportunities for biases to influence decision-making and current processes in all parts of the academia. Which methods are more effective at eliminating biases than the oft used, but ineffective, anonymous marking and reviewing processes? What are the best ways to design more inclusive commissioning and funding systems, and to improve dissemination practices so that we can ensure that students and staff succeed equitably in education and research? How can we include and apply intersectional theory to create new insights and tools to help identify what works, when, how, and for whom, when creating inclusive work cultures to retain more diverse individuals?

Question 4: How can we increase the inclusivity of funded research on bioscience topics to maximise impact on society?

Who decides what research takes place? Funded research often

reflects the interests of researchers and so tends to fail to explore the questions that are important to minoritised groups who are not in a position to submit grant applications [70] nor to participate in peer review and influence funding decisions, or design funding calls. The biases in review processes discussed above not only perpetuate the exclusion of marginalised groups from receiving funding but can also impact what research is funded and by whom – and thus can limit benefits for marginalised groups. For example, studies show that women inventors are more likely to develop products relevant to women [71]. Further, development of basic and routine health tests has been shown to often fail to take into account diversity; e.g. the accuracy of pulse oximeters varies with skin pigmentation [72], and underrepresentation of women in trials or research design has led to lack of understanding of health differences and even lack of research on health issues affecting women [73]. In contrast, meeting the needs of marginalised groups can inspire new inventions that go on to impact many more people, such as electric toothbrushes originally invented for those with limited motor skills [74] but now shown to improve oral health for everyone [75]. In attempting to widen the relevance and applicability of R&I by incorporating new approaches such as AI and machine learning, it will be important to ensure that these do not perpetuate existing or introduce new biases, and do not assume either universal applicability nor unnecessarily restrictive categories, as considered for human-computer interaction in reimagining women's health [76]. Providing equal opportunities to under-represented scholars to increase representation across disciplines is therefore beneficial to the research community as well as to the wider public. Funders can play a key role by using funding calls to address issues important to marginalised groups to increase R&I in neglected areas; this requires them to centre the voices of marginalised groups to find out what these areas are. However, there may be times when different combinations of diversity produce better outcomes for certain agendas.

In terms of diversity in those who conduct R&I we know most about gender, with current research dominated by men. There are an estimated 28 % of women research scientists worldwide; these face a substantial gender pay gap even as new HEI lecturers and principal investigators [77]. In one study in the UK, differences in working experience explain up to two-thirds of the gender pay gap of graduates even 20 years after their first childbirth, and that the gap is largely driven by differences in part and full-time working patterns [78]. Further, women are the most common victims of gender-based violence, harassment and bullying [79]: 58 % of women in USA academia experience sexual harassment in the work-place [80] and 10 % of UK HEI Staff have experienced sexual violence in the last 5 years [81]. Whilst work has already been done in an attempt to end gender-based violence in research and academia [82], more must be done to include and value the contribution of women scientists to laboratory research to retain and benefit from their talent.

Disability is still a neglected and under resourced area in HEI DEI strategies. Disabled students and staff are underrepresented in HEI, though in the UK there has been a steady rise in students declaring disabilities in the last decade, and for mental health particularly following COVID-19; more support, including financial, is being offered [83]. The importance of an active disability-informed perspective in R&I is now seen more positively. Indeed, engagement of marginalised communities in the design of research that is relevant to them is increasingly required by funders and publishers [84,85].

How can underrepresentation be improved? In terms of the sex/gender of research participants it is recognised that there was a major knowledge gap. Through intervention, females as well as males have had to be included in clinical research studies since 1993 [86] and research funded by USA National Institutes of Health (NIH) [87] is now approaching gender parity. Funding bodies have also encouraged the use of female animal models in basic science or preclinical research [88–90], following evidence that male organisms were used in preference, or the sex of the models was not defined, and few considered sex as

a biological variable (SABV) [91]. NIH and other funding bodies and publishers now implement a SABV policy for all funded research [92], [93]. This encourages researchers to factor sex into the design, analysis and reporting of all vertebrate animal and human studies to uncover important sex differences [94] to strengthen research [95], with evidence of improvements. Funders are also beginning to mainstream gender equality into all aspects of the application and award process, from research design to participation [96,97], e.g. the European Commission 'Horizon Europe' and national bodies such as UK Research and Innovation. Similar approaches to encourage the inclusion of other characteristics are less established; although there are international, national and even institutional funding calls that require multidisciplinary approaches and encourage wider collaborations to increase ambition and impact including DEI in R&I. This approach could be harnessed to address current lack of knowledge or more holistic understanding of topics of interest to DEI. In the future, the impact of more deliberate intersectional approaches and interventions on R&I should be analysed and monitored.

There is an increasing amount of interest and research into how expectations (which therefore includes limitations) are placed on scientists of different genders, and this is generally considered from a biological and societal perspective. Some of this work is led by research organisations such as the European Molecular Biology Organisation (eg [98]), the European Molecular Biology Laboratory and the Howard Hughes Medical Institute and should naturally lead into proposing the solutions that may be required and collecting the data required to follow how effective they are.

Research has shown that areas of most significance to marginalised groups are under-funded leading to knowledge gaps, however targeted interventions can address this successfully. How can funders know what processes to change to ensure funding of neglected areas by marginalised academics and universities can better support the careers of researchers from diverse backgrounds?

Question 5: How can we encourage impactful change in DEI in the biosciences?

Leading change in organisations is challenging and takes time. Drawing on the work of experts in organisational change might therefore be helpful for DEI leaders. For example, [99] describes an 8-step process on leading organisational change. These steps include:

- 1) Establishing a sense of urgency,
- 2) Forming a powerful guiding coalition,
- 3) Creating a vision,
- 4) Communicating the vision,
- 5) Empowering others to act on the vision,
- 6) Planning for and creating short-term wins,
- 7) Consolidating improvements and producing still more change,
- 8) Institutionalising new approaches.

Kotter argues that each of these steps is critical and also iterative, and their implementation requires commitment from those with good leadership skills. Creating a more inclusive working environment is an organisational change project and it therefore follows that DEI leaders must be effective managers of change. Adopting this model of organisational change has been shown to be effective in driving the DEI agenda [100].

Alternative mechanisms for driving organisational change can also be effective. Teams that operate as Communities of Practice – communities of engaged people with a shared interest, meeting regularly and developing shared resources and practice - could play a key role in inclusivity. This bottom-up approach has been shown to be a useful instrument in improving gender equality as well as DEI-focused professional development [101] due to their enabling of collaborative spaces for marginalised voices which enable all to contribute equally, to

share knowledge, identify common agendas, and support co-creation of new approaches towards transformative DEI activities.

Engaging with existing DEI charter marks designed for and responsive to the needs of HEIs, such as the Athena Swan charter mark mentioned above (designed and run by Advance HE with sector input), can also be an effective tool for creating a strategic plan for an equality area because of their focus on using data as evidence to motivate actions and monitor impact and in providing an effective process for the work. Such approaches are well aligned to the scientific ways of thinking of those in the biosciences. Further, the common framework makes it easier for cross-institutional learning.

However, one of the significant barriers to making progress in DEI at present is the lack of knowledge about which actions really work to effect change. HEI can encourage engagement of academics with DEI professionals to develop stronger links between research and practice. This can be through design of research projects suitable for undergraduate and postgraduate research projects (6–12 weeks) as part of the normal education provision as well as supporting longer and more in-depth research questions appropriate for a PhD thesis. Therefore, there is a need for those in the R&I sector who are leading on DEI to both share their research findings and also to engage with researchers from other disciplines that have investigated the effectiveness of interventions. In this way, the DEI efforts become truly inclusive, not just of people from marginalised groups but also of people from multiple disciplines.

Research has shown that with commitment and time it is possible to bring about organisational change [100]. Funding and support for further research is needed to identify what interventions and systems changes will have most impact? Scientists and HEI leaders all need to take responsibility for and be proactive and bold in changing the systems and thereby the culture of all the organisations that we engage with.

Discussion and conclusions

In conclusion, this paper recognizes the pivotal role of diversity, equity and inclusion in advancing science and innovation, and acknowledges the ongoing efforts made by higher education institutions to address these issues. However, despite progress, UK bioscience units still face significant challenges in achieving their DEI goals. A starting point could be adapting interventions that have proved effective in other disciplinary areas, which can be identified by researchers conducting a systematised review of existing literature. However, we argue that it is time to move far beyond the successful but piecemeal interventions, in which one aspect of practice within one part of an institute is redesigned, in order to change one aspect of DEI. Rather than addressing the 5 questions in this paper independently, or in turn, we argue that these questions need to be addressed using a systems perspective to improve DEI within the biosciences. That is, the most effective route to enhancing DEI is taking a multidisciplinary approach to discover what works and why, engaging a wide range of stakeholders in understanding and addressing the issues, and looking across the areas outlined in these questions. A diverse team will be able to combine the qualitative and quantitative data necessary to understand the interconnectedness of the different elements in the university system that impact DEI. These complex connections mean that changes or interventions in one part of the system (e.g. recruitment of students to bioscience degrees) can lead to wide-ranging effects elsewhere (e.g. the diversity of research topics). Understanding the complex network of relationships and influences within the university is therefore crucial. Our aim is therefore to inspire a continuing research agenda within the biosciences, to explore key questions regarding recruitment, inclusivity, equitable funding, impactful research topics, and effective strategies for driving change in DEI and in doing so, we hope to unravel the most effective interventions and design approaches needed to transform the systems supporting the sector and create a more equitable and inclusive environment. It is through such coordinated efforts, utilising research-driven insights, and

a commitment to holistic change, that we can foster a diverse and inclusive R&I landscape that maximizes the potential of all researchers and innovators, ultimately leading to greater scientific progress and societal impact.

Description of expertise of the authors on the topic

Anna Cox is Professor of Human-Computer Interaction whose research interests focus on understanding and designing novel technologies to support work and wellbeing. AC is also Vice Dean (Equality, Diversity and Equity) in the Faculty of Brain Sciences at University College London and previously led the Athena SWAN self-assessment team for the Division of Psychology and Language Sciences, achieving two silver renewals. AC was the recipient of the UCL Provost's Award for Embedding Equality, Diversity and Inclusion in 2021 in recognition of her impact in increasing DEI.

Sara Mole is Professor in Molecular Cell Biology, with experience in research and teaching within university and research institute settings, and working with many and varied collaborators and colleagues, that spans 40 years. SM is the UCL Envoy for Gender Equality which provides an overview of DEI work across UCL and of intersectional work through the gender lens. SM previously led the Athena SWAN self-assessment team for the UCL MRC Laboratory for Molecular Cell Biology to the first silver and gold awards at UCL. SM is recognised for activity in impacting and increasing equity in this area in UCL and beyond for 15 years.

CRedit authorship contribution statement

Anna L Cox: Writing – review & editing, Writing – original draft, Conceptualization. **Sara E Mole:** Writing – review & editing, Writing – original draft, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

No data was used for the research described in the article.

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