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Bioengineering needs diversity

Policies that limit diversity and inclusion undermine evidence-based science by creating gaps in the data, potentially distorting findings and skewing results. When diversity and inclusion are sidelined, scientific progress is hindered.

Evidence-based science requires inclusive data to improve human health, enhance quality of life and address global inequities. Polices to promote diversity in funding, project leadership, research databases and participants are necessary to ensure data is representative. By addressing factors, such as age, race, ethnicity and gender, in applied science, fundamental research and clinical studies, researchers can identify gaps in scientific knowledge to develop equitable solutions. In our new collection on inclusive bioengineering, we collate articles showcasing how accounting for inclusion and diversity can fuel advances in bioengineering that are central to biomedical research and to closing gaps in scientific knowledge.

Social science and humanities studies can assist researchers in addressing the influence of systemic discrimination and under-representation on biomedical research, such as the lack in diversity of scientific resources. This is an important factor to consider in bioengineering. For example, human cell lines are a valuable tool for disease modelling and tissue engineering, but in repositories for inducible pluripotent cell lines, donors of European ancestry are over-represented and male cell lines outnumber female cell lines[1]. Such imbalances limit the applicability of disease models that use cell lines, such as organoids, to the population as a whole. To develop bioengineered models that reflect human diversity, Amy Hinterberger emphasizes in this issue the need for deliberate actions from researchers to diversify the cells used in bioengineered models as well as doner engagement with biomedical research.

Inclusivity also involves recognizing and addressing biological variables, such as sex, that are frequently overlooked in the experimental design of animal and in vitro research. Sex differences in disease prevalence and mechanisms are documented; for example, compared with men, women exhibit different symptoms of cardiovascular disease[2] and have a higher prevalence of autoimmune diseases[3]. Additionally, women and men exhibit differences in adaptive immune responses, which could contribute to sex-specific immune responses to biomaterials[4]. Comprehensive models for disease and immunity should not ignore cell sex. To develop sex-accurate cell culture environments, extracellular matrix environments should correspond to the cell sex and include sex-matched serum and hormones[5]. Sex-conscious experimental design can advance disease research, and the development of therapeutics tailored for women. By focusing on challenges specific to female physiology, biomaterial and drug delivery systems can be engineered for women's health applications[6]. Of note, we refer to 'woman' and 'female' to reflect language used in our field, although we recognize that not everyone affected is a woman and that sex and gender both exist on a spectrum and are not necessarily aligned.

> "When bioengineers prioritize diverse inputs and inclusive methodologies, they improve the applicability and impact of their research"

Equitable research must also extend beyond biology and include diverse participant representation at the clinical level, where exclusionary policies persist. For example, in the neuroimaging field, participants with darker skin tones or coarser hair are often excluded from electroencephalogram studies[7]. Furthermore, decades of unethical and abusive experimentation on Black, Indigenous and marginalized populations have contributed to justified medical and scientific mistrust, which must be acknowledged and overcome to diversify recruitment in medical research studies[8].

Inclusive, human-centred design processes are necessary to ensure equitable access to bioengineered technologies and to develop solutions that serve all communities. Representation of bioengineers from low- and middle-income countries in research and development processes can drive local manufacturing and inclusive design, ensuring that bioengineering solutions are more relevant and accessible to their communities[9]. Additionally, by understanding and prioritizing community needs, global equity gaps in diagnostics can be addressed. For example, advances in optical imaging, such as light-emitting diodes and digital cameras, offer affordable, simple-to-operate diagnostic tools for point-of-care cancer screening in low-resource settings[10].

When bioengineers prioritize diverse inputs and inclusive methodologies, they improve the applicability and impact of their research. Policies that promote diversity and inclusion at every stage of research are essential to balance representation and close gaps in scientific knowledge.

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