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Bioengineering for low-resource settings

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Bioengineers need to adopt holistic and human-centred design principles in the development of technologies intended for applications in low-resource settings, to overcome infrastructural limitations and ensure functionality in all environments.

Bioengineered technologies, for example, for diagnostics or environmental monitoring, are often designed from the perspective of users from high-income regions, and thus restrictions in low- and middle-income regions, such as infrastructural barriers, lack of cold chains or limited equipment and repair options, are overlooked. For implementation of bioengineered tools and technologies in low-resource settings[1], where they are often most needed, such restrictions need to be considered early in the design process. Perhaps the most prominent example of this is lateral flow tests[2], integrated with CRISPR-based[3] or electrochemical[4] biosensors, which can be engineered to be assessed on paper strips or by smartphone cameras[5] to allow the detection of pathogens, as well as of food and environmental contamination, without the requirement for advanced diagnostic laboratories. These diagnostic tools have been engineered with the specific aim of enabling their application in low-resource settings and thereby greatly contribute to the prevention of the spread of infectious diseases across the globe.

However, engineering contributions for low-resource settings can go beyond diagnostic kits; an example of this is frugal bioengineering: reduction of the complexity and costs of a platform and its production through the use of only a few resources in a sustainable manner. This is a promising approach to engineering healthcare devices and tools for resource-constrained parts of the world. For example, in this issue, John Rogers and team discuss skin-interfaced, wireless biosensors that can replace bulky and expensive hard-wired data-acquisition and display systems for perinatal and paediatric applications. Such reusable sensors can account for the special considerations that apply to the monitoring of vulnerable patients in low-resource settings, such as the limited availability of specialized medical staff, challenging operating conditions, lack of support facilities and severe cost constraints.

> **"frugal bioengineering... is a promising approach to engineering healthcare devices and tools for resource-constrained parts of the world"**

Despite their being irreplaceable tools for medical diagnosis, there are about 40 times more computerized tomography scanners per million inhabitants in high-income regions than in low- and middle-income regions[6], and two thirds of the global population does not have access to magnetic resonance imaging (MRI)[7]. In this issue, Kevin Sheth, Taylor Kimberly and team discuss the technical aspects of low-field MRI, a more affordable, accessible and portable alternative than conventional MRI for neuroimaging, not only in low- and middle-income regions but also in high-income regions with geographically dispersed populations.

Such frugal bioengineering efforts require careful consideration of the local context and needs. In particular, products or processes should be safe and effective while being robust, reliable, simple to operate, self-powered and adaptable to harsh or variable conditions, such as high temperature, humidity, dust and power fluctuations. Therefore, it is important to test engineered platforms against such conditions and in the context of the setting that they are intended for.

Moreover, it is essential that data can be stored and shared through cloud infrastructures to enable patients to access online care and engage with physicians at distant locations, ideally through existing smartphones and available means of communication.

Another challenge to consider is the lack of reliable ultracold-chain networks for the transportation and preservation of biological materials, which could be mitigated by the development of cryopreservation media resistant to suboptimal environmental conditions. Moreover, the scale-up of products or processes from laboratory to field settings needs to consider the availability, maintenance, distribution and cost of raw materials and equipment, as well as trained personnel, ideally in the context of local settings. There are many endeavours that aim to address these issues; Engineering World Health is a great example of such efforts[8].

These challenges require bioengineers to adopt a holistic and interdisciplinary approach that integrates technical expertise with social science knowledge and human-centred design principles. Bioengineers should also engage with local stakeholders, such as end users, healthcare workers, policymakers and community leaders, to understand their needs, preferences, values and expectations, to ensure not only the applicability of their design but also its cultural and social acceptability.

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