CSER Policy Brief: Emerging opportunities and risks associated with biological engineering

Human genome editing, 3D-printed replacement organs and artificial photosynthesis – the field of bioengineering offers great promise for tackling global environmental and societal challenges. But these and other developments provide both opportunities and risks in the short and long term. The sector needs to proceed with caution to ensure we can reap the benefits safely and securely.

Rapid developments in the field of synthetic biology and its associated tools and methods, including more widely available gene editing techniques, have substantially increased our capabilities for bioengineering – the application of principles and techniques from engineering to biological systems, often with the goal of addressing 'real-world' problems.

In a feature article published in the open access journal *eLife*, an international team of experts led by the Centre for the Study of Existential Risk at the University of Cambridge, capture perspectives of industry, innovators, scholars, and the security community in the UK and US on what they view as the major emerging issues in the field.

Why Undertake A Horizon Scan of Emerging Issues In Bioengineering?

Many governments and organisations are faced with decisions that are directly impacted by developments in science and technology and require up-to-date information to stay relevant and effective. Processes for incorporating scientific and other relevant expertise are typically unstructured and at risk of bias. Our horizon scan uses a structured, more objective technique to elicit and cross-examine the perspectives of a large group of experts with wide ranging backgrounds. This approach, which is described in the paper, promotes a more complete picture of the current state and future direction of biological engineering, and the specific issues that are set to shape global society in the next 20 years or so. The paper raises awareness of new advances, engages the scientific and security community, and provides a summary and launching point for policy makers across a range of sectors to further explore those issues that may be relevant to them.

What Are The Main Findings of The Horizon Scan?

Among the issues highlighted as being most relevant over the next five years are:

Artificial photosynthesis and carbon capture for producing biofuels – If technical hurdles can be overcome, such developments might contribute to the future adoption of carbon capture systems, and provide sustainable sources of commodity chemicals and fuel.

Enhanced photosynthesis for agricultural productivity – Synthetic biology may hold the key to increasing yields on currently farmed land – addressing food security – by enhancing photosynthesis and reducing pre-harvest losses, as well as reducing post-harvest and post-consumer waste.

Synthetic gene drives – Gene drives promote the inheritance of preferred genetic traits throughout a species, for example to prevent malaria-transmitting mosquitoes from breeding. However, this technology raises questions about whether it may alter ecosystems, potentially even creating niches where a new disease-carrying species or new disease organism may take hold.

Human genome editing - Genome engineering technologies such as CRISPR/Cas9 offer the possibility to improve human lifespans and health. However, their implementation poses major ethical dilemmas. It is feasible that individuals or states with the financial and technological means may elect to provide strategic advantages to future generations.

Defence agency research in biological engineering – The areas of synthetic biology in which the some defence agencies invest raise the risk of 'dual-use' research: that is, research that can be used to both benefit and harm humanity.

In the next five to ten years, we identified the following areas of interest:

Regenerative medicine: 3D printing body parts and tissue engineering – While this technology will ease suffering caused by injuries and illnesses, reversing the decay associated with age is still fraught with ethical, social and economic concerns. Healthcare systems may rapidly become overburdened by the cost of replenishing body parts of citizens as they age and could lead new socioeconomic classes, as only those who can pay for such care themselves can extend their healthy years.

Microbiome-based therapies – The human microbiome is implicated in a large number of human disorders, from Parkinson's to colon cancer, as well as metabolic conditions such as obesity and type 2 diabetes. Synthetic biology approaches could greatly accelerate the development of more effective microbiota-based therapeutics. However, there is a risk that DNA from genetically engineered microbes may spread to other microbiota in the human microbiome or into the wider environment.

Intersection of information security and bio-automation – Advances in automation technology combined with faster, more reliable engineering techniques have seen robotic 'cloud labs' emerge, where digital information is transformed into DNA then expressed in some target organisms. This opens the possibility of new kinds of information security threats, including tampering with digital DNA sequences to produce harmful organisms, and sabotaging vaccine and drug production through attacks on critical DNA sequence databases or equipment.

Over the longer term, issues identified include:

New makers disrupt pharmaceutical markets – Community bio-labs and entrepreneurial start-ups are customizing and sharing methods and tools for biological experiments and engineering. Combined with open business models and open source technologies, this could herald opportunities for manufacturing therapies tailored to regional diseases that multinational pharmaceutical companies might not find profitable. But this raises concerns around the potential disruption of existing manufacturing markets and raw material supply chains, and inadequate regulation.

Platform technologies to address emerging disease pandemics – Emerging infectious diseases—such as recent Ebola and Zika virus disease outbreaks—and potential biological weapons attacks require scalable, flexible diagnosis and treatment. New technologies could enable the rapid identification and development of vaccine candidates, and plant-based antibody production systems.

Shifting ownership models in biotechnology – The rise of off-patent, generic tools and the lowering of technical barriers for engineering biology has the potential to help those in low-resource settings benefit from developing a sustainable bioeconomy based on local needs and priorities, particularly where new advances are made open for others to build on. The shift in ownership away from big business and towards more open science also promotes public trust and acceptance of the industry.

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