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Emerging technology snapshot

Genetic design and modification of pathogenic microorganisms

Applications for engineered or synthetic microorganisms are rapidly expanding into new industries. Advances in genetics paired with artificial intelligence (AI) and other new technologies hold incredible promise for medicine and industry but may also simplify the intentional creation of harmful pathogens. As a result, there are increasing concerns about how such technologies will be used and by whom.

Enabling Science and Technology

Synthetic biology

Synthetic biology encompasses a set of concepts, tools and technologies that enable the creation or redesign of biological organisms using engineering principles. The field has benefited from improvements in DNA sequencing, genome editing tools, and artificial intelligence techniques that can model and predict the outcomes of altered gene sequences.

Microbial cell factories

Microbial cell factories are cells that act as miniature chemical plants capable of synthesizing a wide variety of compounds. They can be manipulated to produce advanced biofuels, food ingredients, commodity chemicals and therapeutics. They may also provide a cleaner way to produce chemicals, and are described as a promising approach to support the 'greening' of these industries.

Machine learning

Machine learning (ML) refers to algorithmic methods that identify patterns and relationships in complex datasets. ML is being used to automate the analysis, target selection, editing and synthesis of microbial species, strains and genetic components. This facilitates the modification of microbes for the production of therapeutic treatments and industrial chemicals, but can also be used to enhance pathogenicity.

Genome mining

Genomics research has created massive datasets of DNA sequences from a wide array of organisms and made them open source. Genome mining uses computational technologies and bioinformatics tools to mine these datasets in order to characterize physiological processes, identify new drug targets and discover new chemical entities that could be used for drug development or other industrial applications.

Gain of function research

Gain of function (GOF) research involves the genetic alteration of an organism to enhance genetic functions relating to pathogenesis, host selection, transmissibility or drug-resistance. While it can help enhance pandemic preparedness by predicting emerging diseases and facilitating vaccine development, there are obvious concerns regarding potential nefarious uses of GOF research to enhance pathogenicity.

"We are increasing the synthetic capacity of biological systems […] We need to push beyond what biology can naturally do and start getting it to make compounds that it doesn't normally make."

Kristala L. Jones Prather, Massachusetts Institute of Technology. Building a better chemical factory-out of microbes, MIT Technology Review, 24 August 2023.

Signals

Academic

Academic literature is dominated by the USA and China. AI and machine learning are some of the fastest growing research topics associated with genetic design and modification.

Government

In January 2023, the National Science Advisory Board for Biosecurity voted unanimously to recommend a major overhaul of how the US supervises dual-use research on dangerous pathogens.

Collaboration

Research collaborations involving engineered or synthetic microorganisms tend to be national in scope. This is increasingly true for some of the more dangerous microorganisms, like *Bacillus anthracis*, for which collaborations often involve government partners.

Defence

The USA's Intelligence Advanced Research Projects Activity (IARPA) has invested heavily in biosecurity tools and techniques to rapidly distinguish genetically modified organisms from those that are naturally occurring.

Corporate

Corporate players largely focus on industrial or therapeutic applications of model organisms. There are only two privately owned labs in the world authorized to work with the most dangerous pathogens.

"The challenge in biology is that it is not terribly difficult to engineer organisms, to engineer living systems, to do things that can potentially be very harmful. So how do we think about monitoring, regulation, safe oversight in the biology world."

Lloyd Minor, Stanford University. AI Accelerates Ability to Program Biology Like Software, Wall Street Journal, 19 September 2023.

Impact

Social

Engineered or synthetic microorganisms have the potential to broadly impact society, from healthcare and agriculture, to energy production and fighting climate change.

Policy

A 2023 bill introduced in the US House of Representatives seeks to ban the National Institutes of Health, the largest public funder of biomedical research worldwide, from financially supporting any gain of function research.

Economic

According to research firm MarketsandMarkets, the global market for synthetic biology is expected to reach $36 billion US by 2027.

Environmental

Microorganisms can be engineered to support climate goals and environmental remediation. Engineered microbes could reduce methane emissions from livestock, sustainably produce industrial chemicals and biofuels, remove toxins from wastewater and break down plastics, among other uses.

Defence

The increasing accessibility and ease of use of technologies for manipulating pathogenic microorganisms introduces a considerable safety and security threat that could lead to the deliberate or accidental spread of high consequence pathogens.

"[O]ne-size-fits all policies aimed at mitigating dangers from one approach could limit other, less-risky research, and overly broad regulations could ultimately limit the scientific community's ability to prepare for future disease outbreaks."

Center for Security and Emerging Technology. Understanding the Global Gain-of-Function Research Landscape, August 2023.

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