Public perceptions of engineering biology

Part 1: Health applications

Contents

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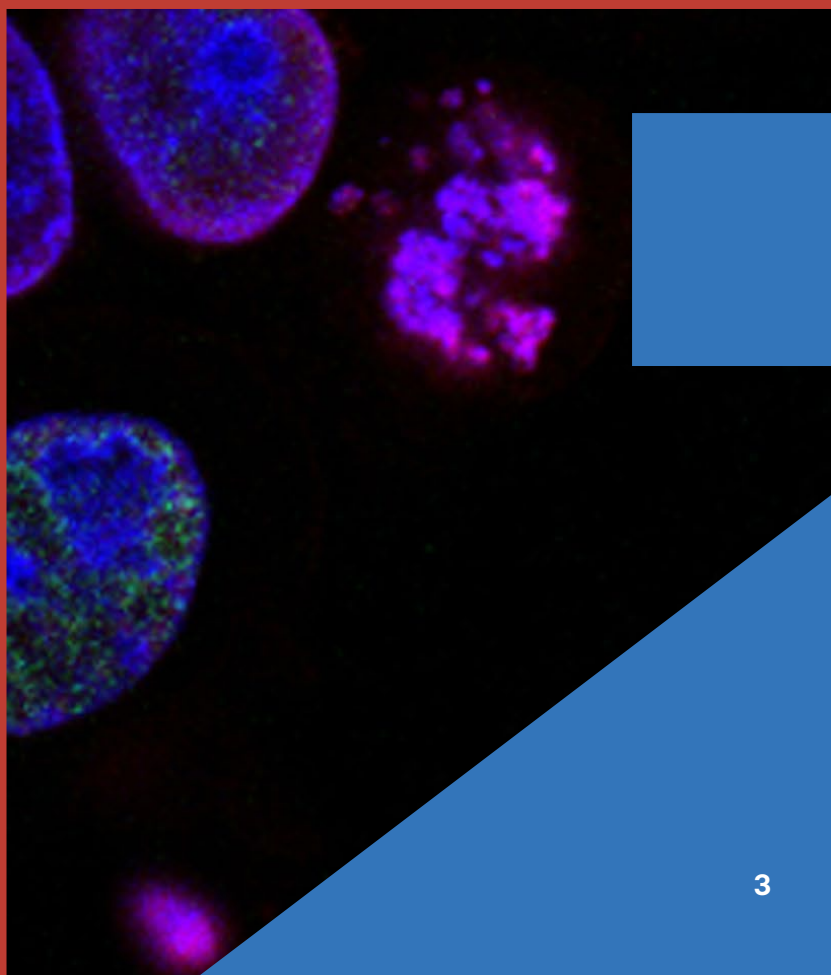
Sciencewise, a public dialogue progamme delivered by UKRI, has conducted this research with a view to identifying areas of research and innovation and technologies where early public engagement would be useful, and welcomes further discussion with research funders, government departments, government agencies and other public bodies working on these issues.

Excecutive summary

This report outlines what is known about public views and values on engineering biology and identifies key themes which could be further explored through public dialogue.

It explores the use of engineering biology in the health sector and its main applications which are likely to impact the public in the next 15 years, such as creating new medical treatments. A further report will be published separately and will consider the applications of engineering biology in food and agriculture.



Like many emerging technologies, applications of engineering biology could create public benefit alongside social, health and environmental risks, so there is a need to start a conversation with the public early on in their development.

Our five findings are:

- There is a lack of recent UK engagement on engineering biology. Many sources included in this report are from international studies, and cannot be assumed to be transferable to a UK context.
- Attitudes to engineering biology are likely to be dependent on the context and people's values, including their levels of trust in science.
- People are likely to be optimistic about using engineering biology to solve societal challenges, especially when they have a higher level of awareness about engineering biology.
- People are likely to be concerned about safety, inequitable access (particularly in health applications), misuse, and blurring the boundary between natural and artificial.
- Policy leaders may have a perception of negative public attitudes to engineering biology because of previous anti-GM (genetic modification) sentiment.

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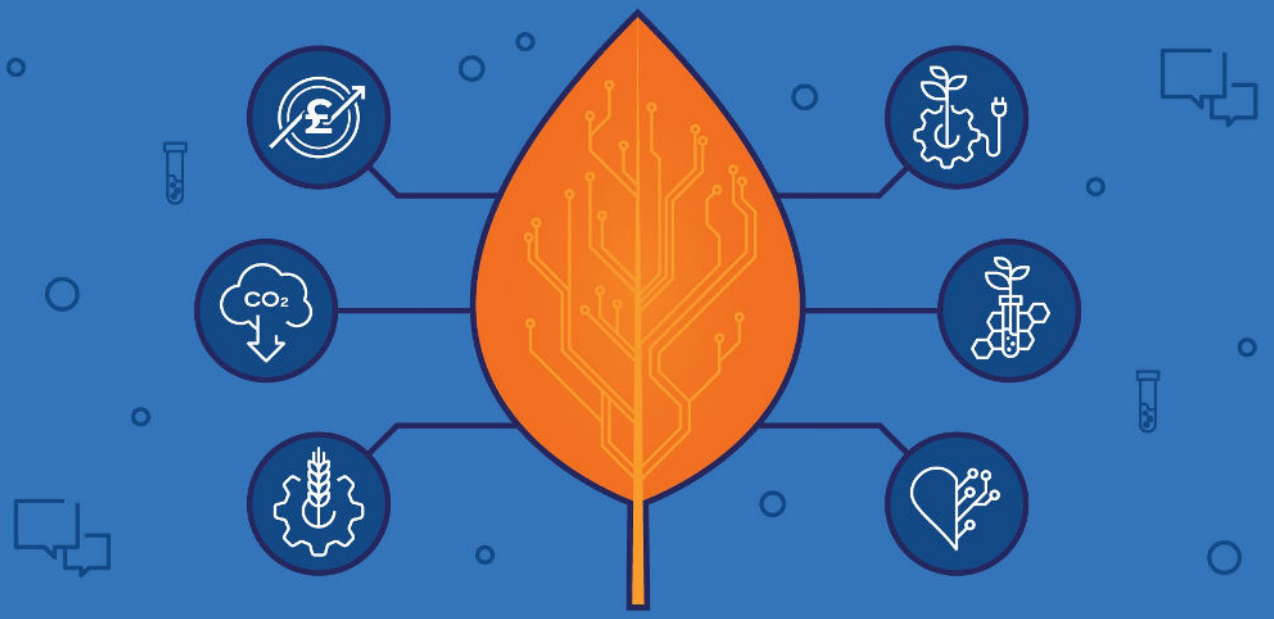


What is engineering biology?

Engineering biology is the application of engineering principles to biological systems.

As the natural successor to biotechnology, engineering biology enables the development of new or enhanced biological entities and products, like cells or proteins[1]. It offers innovative solutions across the economy, and by being a low carbon technology, it presents opportunities to solve societal challenges faced in food, health, energy, materials, and chemicals[2].

In early 2023, engineering biology was identified by the UK Government as one of five critical technologies[3]. Together with AI, semiconductors, telecommunications, and quantum technologies, engineering biology has been prioritised as one of the areas where the UK can develop a global competitive advantage and establish governance leadership in regulation, standards, and responsible innovation[4].

In December 2023, the Department for Science, Innovation, and Technology (DSIT) published a national vision for engineering biology which outlines the Government's plans to have a broad engineering biology ecosystem that can develop and commercialise the opportunities that come from the technology and the underlying science[5].

[1] Council for Science and Technology. (2023). Report on engineering biology: opportunities for the UK economy and national goals.

[2] Royal Academy of Engineering. (2019). Engineering biology: a priority for growth.

[3] Department for Science, Innovation and Technology. (2023). Science and Technology Framework: taking a systems approach to UK science and technology.

[4] Department for Science, Innovation, and Technology. (2023). Engineering biology call for evidence.

[5] Department for Science, Innovation, and Technology. (2023). National vision for engineering biology.

Building on more than 15 years of rapid progress, engineering biology could now offer more sustainable alternatives to existing products, as well as new products and processes which are likely to transform whole industry sectors[6]. In their 2020 report, the McKinsey Global Institute compiled a list of 400 potential end-use applications of engineering biology that could be commercially viable by 2050. It estimated that in the next 10 to 20 years, these applications could have direct economic impact (the value of investment and transactions) of between $2 trillion and $4 trillion globally per year[7]. The report classifies the applications into four main categories:

- **Human health and performance** – this includes cell, gene, and RNA therapies to treat and prevent disease, as well as innovations in drug development;
- **Agriculture, aquaculture, and food** – for example, new, quicker ways of breeding animals, more precise tools for the genetic engineering of plants, development of alternative proteins including lab-grown meat;
- **Consumer products and services** – personalised products and services based on consumers' biological makeup. For example, direct-to-consumer genetic testing, and beauty and personal care based on increased knowledge of the microbiome;
- **Materials, chemicals and energy** – new ways of making and processing materials, chemicals and energy. For example, improved fermentation processes and innovative forms of low carbon energy storage.

Synthetic biology and engineering biology

Synthetic biology and engineering biology are two terms which significantly overlap and are often used interchangeably by experts. While synthetic biology is the design and fabrication of biological components and materials from biological elements, engineering biology is the process of taking those synthetic biology concepts and translating them into solutions[8].

In other words, synthetic biology is a field of science focused on building new biological systems, while engineering biology captures the entire innovation ecosystem, including advances in synthetic biology research, as well as its translation, commercialisation and application.

In recent years, the UK government has shifted away from using "synthetic biology" to using "engineering biology" following a similar trend in the broader international community[9]. For example, the Synthetic Biology Leadership Council, which exists to provide a strategic coordination of the sector, became the Engineering Biology Leadership Council[10] in 2020[11].

In this report, we have looked at sources of public opinion on both synthetic biology and engineering biology.

[6] Council for Science and Technology. (2023). Report on engineering biology: opportunities for the UK economy and national goals.

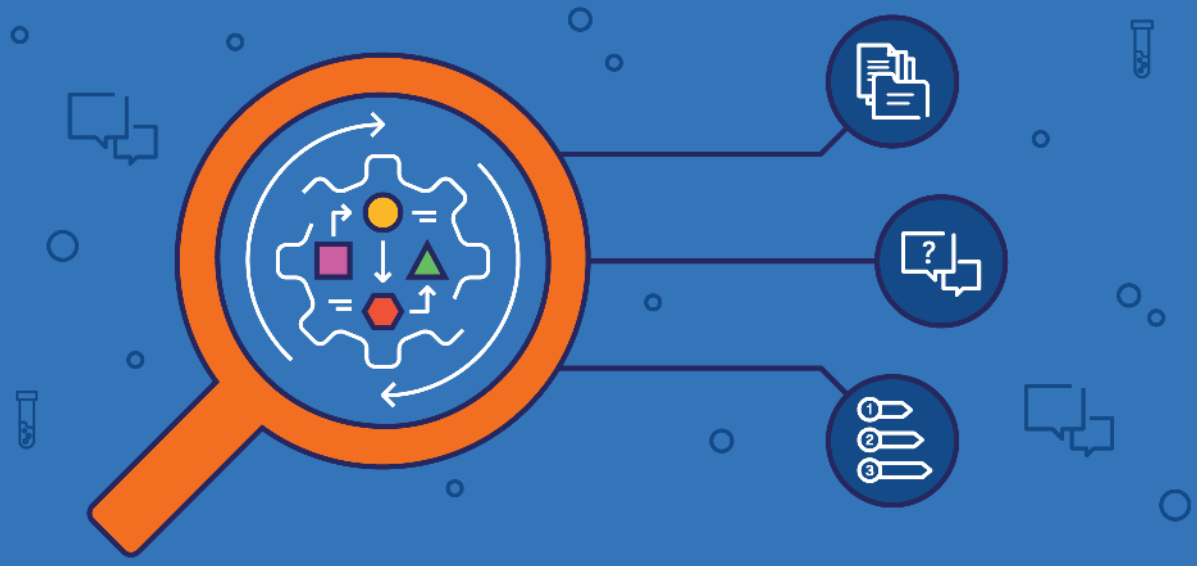
[7] McKinsey Global Institute. (2020). The Bio Revolution: Innovations transforming economies, societies, and our lives.

[8] UKRI. (2021). Engineering biology.

[9] Watcher, G., Gallup, O., Bayne, J., Horsfall, L. (2022) Synthetic biology landscape in the UK. Biotechnology Notes.

[10] Innovate UK KTN. (2023) Engineering Biology Leadership Council. Accessed December 2023.

[11] The Engineering Biology Leadership Council was disbanded in 2023, and will be replaced by the Biosecurity Leadership Council, and the Engineering Biology Steering Group.



Context and methodology

How were applications chosen for the report?

There are many potential applications of engineering biology that are scientifically viable today but their path to commercialisation is not always clear.

To identify applications to include in this report, we followed a three-step process of indexing, consultation and prioritisation. We first scanned lists of early-stage applications that have been compiled by relevant government bodies and research groups (for example, UKRI[12] and McKinsey Global Institute[13]) and identified applications that appeared across several lists.

We then consulted experts in engineering biology, and science and technology policy, and conducted initial research to find out which applications have been covered by recent opinion polls and surveys.

Among the applications considered for inclusion in the report were sustainable materials, environmental solutions, energy, and clean growth, but for this programme of work we chose applications in food and health as the two areas which are most scientifically advanced, have the clearest pipeline from research to commercialisation, and are covered by recent opinion polls.

[12] UKRI. (2023). Engineering biology missions hubs and mission awards. Accessed December 2023.

[13] McKinsey Global Institute. (2020). The Bio Revolution: Innovations transforming economies, societies, and our lives.

What public opinion sources were used in the report?

To find out about the public opinion on applications of engineering biology in health, we analysed recent surveys, reports, and social research. We did not commission any new research as part of this process.

In our research, we looked for public opinion sources that are publicly available, transparent about their sampling procedure and methods, and published since 2017. We were particularly interested in research and surveys that are UK-focused or demonstrably transferrable to UK, but also analysed international sources, especially when specific applications have not been covered by surveys in the UK.

It is important to note that the challenge of transferability between contexts and communities restricts the conclusions that we were able to draw from international sources. Another limitation we identified in our research was the sample sizes which are too small to provide useful information on groups which are traditionally marginalised, such as disabled people and minority groups.

Public opinion on engineering biology

Despite the Government, industry, and researchers' interest in the discipline, recent evidence on public attitudes to engineering biology in the UK is relatively scarce.

Many of the studies we found were from international sources, particularly Australia, China, and the US. These cannot be assumed to mirror UK views, because attitudes may depend on factors like past history with life science technologies like GM, religious beliefs, and trust in science. However, international evidence can provide a helpful starting point for identifying areas to explore with UK populations.

It is also worth noting that we found many UK studies and activities looking at public attitudes to synthetic biology which were published prior to 2017 and therefore out of scope.

Several experts we consulted pointed us towards resources dating back to 2009-2012, e.g. the Royal Academy of Engineering's report "Synthetic Biology: scope, applications, and implications,"[14] "Strategic Roadmap for Synthetic Biology in the UK,"[15] and the public dialogue on synthetic biology supported by Sciencewise[16]. These resources have been an important part of our background research, but it cannot be assumed that their findings related to public attitudes are still relevant today.

[14] Royal Academy of Engineering. (2009). Synthetic biology: scope, applications, and implications.

[15] UK Synthetic Biology Roadmap Coordination Group. (2012). A synthetic biology roadmap for the UK.

[16] Sciencewise. (2010). Synthetic biology dialogue.

In the UK, the former Department for Business, Energy, and Industrial Strategy reported on what the public think about synthetic biology in their "Public Attitudes to Science" survey published in 2020[17]. Their main findings were:

- Overall awareness of synthetic biology increased from 61% to 70% between 2014 to 2019.
- 27% of respondents said they never heard of synthetic biology.
- Men were more likely to say that they have heard of synthetic biology than women (76% vs 70%).
- People aged 65+ were less likely to have heard of synthetic biology than those aged under 65 (66% vs 75%).
- 83% of those educated to a degree level reported that they have heard of synthetic biology, compared with 46% of those with no qualifications.
- Of all who have heard of synthetic biology, 32% felt that its benefits outweigh the risks, while 14% felt that synthetic biology's risks are greater than its benefits.
- The support was higher among those who felt informed about the technology than those who have only heard about it (48% vs 32%).

Attitudes to synthetic biology dependent on the context and people's values

Researchers in the US studied how the public attitudes to synthetic biology compare with attitudes toward other issues[18]. The study found that the main values and predispositions which correlate with attitudes to synthetic biology are religiosity (note that the UK is more secular than the USA), deference to scientific authority, and trust in scientists. The study reports that religiosity is less of a factor for people with high confidence in science, who are generally more likely to support the use of synthetic biology. However, among those with lower levels of confidence in scientific authority, respondents who identified themselves as religious or very religious were more likely to oppose using synthetic biology.

A 2020 study which compared US scientists' and non-scientists' views on synthetic biology[20] found that levels of religious guidance and political ideology are related to different perceptions of synthetic biology, and that non-scientists' perceptions were influenced more strongly by religion and political ideology than the scientists' perceptions.

[17] Department for Business, Energy, and Industrial Strategy. (2019). Public attitudes to science 2019.

[18] Akin, H., Rose, K.M., et al. (2017). Mapping the Landscape of Public Attitudes on Synthetic Biology. BioScience.

[19] Howell, E.L., Scheufele, D.A. et al. (2020). Scientists' and the Publics' Views of Synthetic Biology. Synthetic Biology 2020: Frontiers in Risk Analysis in Governance.

[20] CSIRO. (2021). Public attitudes towards synthetic biology. Accessed December 2023.

New technology optimism despite low levels of awareness

In Australia, a recent survey of more than 8,000 people found that the public were 'curious', 'hopeful', and 'excited' about synthetic biology and its potential to solve some of the environmental, agricultural and health problems. Despite low levels of awareness (85% had little or no knowledge of synthetic biology), the overall support for the technology and its different applications was moderate to high. According to the authors of the study at the Commonwealth Scientific and Industrial Research Organisation (CSIRO) and their analysis, these positive attitudes were likely to be driven by emotion, perceived benefits, efficacy of the technology, and trust in science.

The Australian Office of the Gene Technology Regulator conducted a study on community attitudes to gene technology[21]. The survey asked the public about their awareness of different technologies, such as biotechnology, genetic modification or GMO, gene editing, and cloning of animals, and found that synthetic biology was the term that the public were the least familiar with.

The authors of the study report that:

- 8% of respondents knew enough about synthetic biology to explain it to a friend
- 34% have heard of it but knew very little or nothing about it
- 50% have not heard about it
- 9% were unsure of whether they heard about the technology or not.

Wider literature review confirms that the general awareness of synthetic biology among non-specialists is low.

Based on nationally representative survey data, a study in the US[22] found that:

- 15% felt informed
- 10% felt neither informed nor uninformed
- 75% felt uninformed about synthetic biology.

When asked about how important synthetic biology issues were to them personally:

- 22% said that it was important for them.
- 18% said that synthetic biology was neither important nor unimportant for them
- 60% of respondents indicated that it did not have much personal relevance.

Researchers at the University of Klagenfurt in Austria analysed public outreach events organised across Europe in the frame of an EU-funded project on Responsible Research and Innovation in synthetic biology[23]. Their analysis shows that the public are largely unfamiliar with the topic, and only comfortable with discussing ethics, risks, and governance of synthetic biology on an abstract level and express their opinions in generic statements which could be made for any new technology. Despite the low level of awareness, the researchers also noted that the participants felt optimistic about synthetic biology and its potential to solve major societal challenges, such as clean energy, health, and environmental protection.

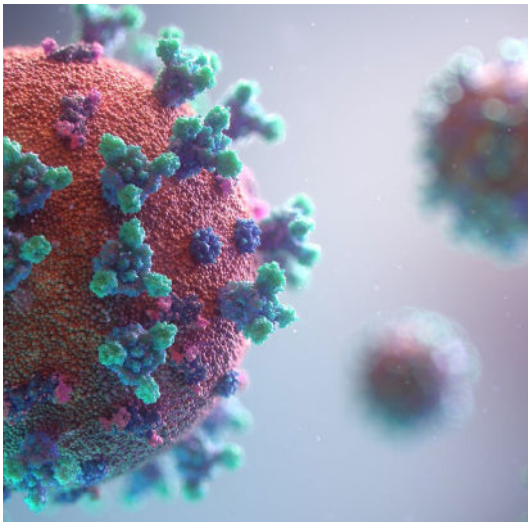
[21] Office of the Gene Technology Regulator. (2021). Community attitudes towards gene technology.

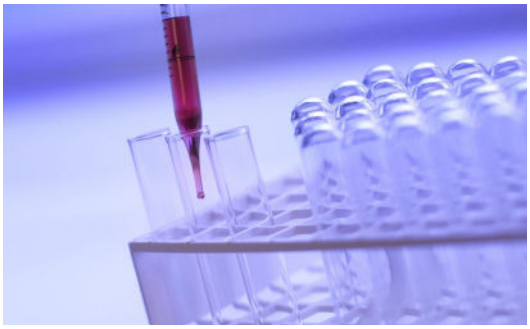
[22] Akin, H., Rose, K.M., et al. (2017). Mapping the Landscape of Public Attitudes on Synthetic Biology. BioScience.

[23] Bauer, A., Bogner, A. (2020) Let's (not) talk about synthetic biology: Framing an emerging technology in public and stakeholder dialogues. Public Understanding of Science.

Concerns over misuse and overstepping boundaries

Existing research suggests that there are several concerns that the public have about potential misuse of engineering biology, most often linked to biosafety, biosecurity, and ethical concerns. Manipulating biological matter could, for example, lead to the loss of biodiversity, human health problems, and opportunities for bioterrorism[24]. A survey of US adults found that most respondents supported regulating synthetic biology and other ways of protecting the public from unknown risks of the technology, with 59% agreeing that academic synthetic biology research should be regulated[25].





Rapid advancements in engineering biology in recent years have also led to concerns over increasingly blurry lines between natural and artificial[26]. Several studies mention the perception that some members of the public have about scientists who are creating organisms and DNA from scratch and therefore overstepping humans' authority to alter the natural world, or "playing God"[27]. Previous surveys of public opinion on synthetic biology technologies confirm that the highest level of public scepticism and social resistance arise when the entity being engineered is perceived to be more 'alive'[28]. For example, 'synthetic cells' closely resemble biological cells, but are often made from scratch using DNA, RNA, proteins, small molecules and lipids. As construction of synthetics cells advances, "aliveness" is increasingly often discussed in the context of ethical and societal implications of synthetic biology.

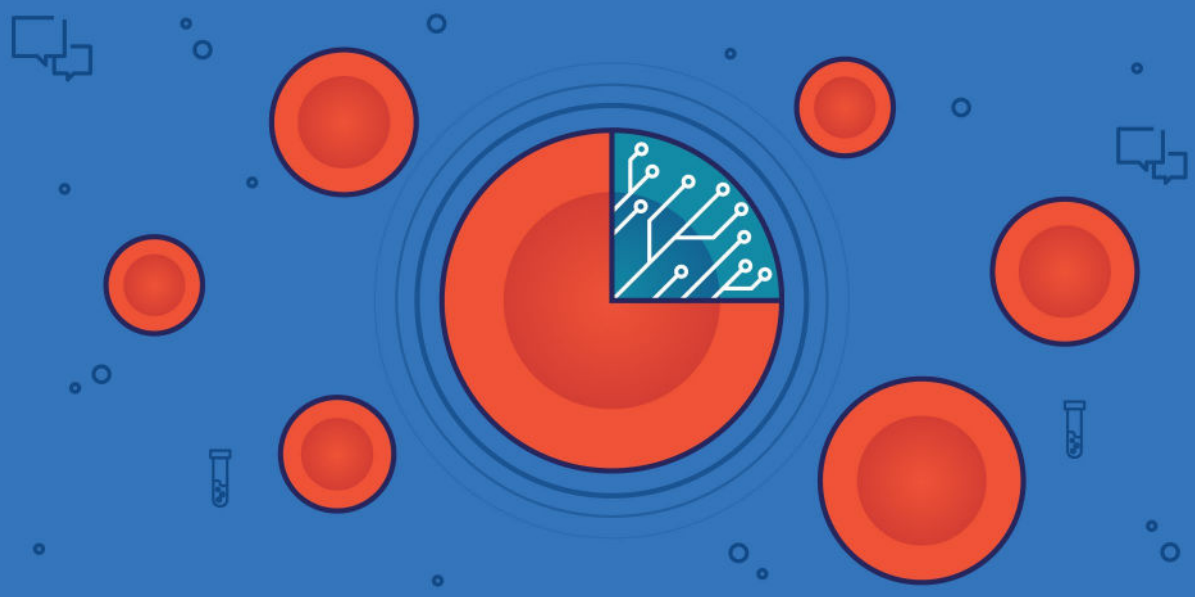
[24] Akin, H., Rose, K.M., et al. (2017). Mapping the Landscape of Public Attitudes on Synthetic Biology. BioScience.

[25] Akin, H., Rose, K.M., et al. (2017). Mapping the Landscape of Public Attitudes on Synthetic Biology. BioScience.

[26] Howell, E.L., Scheufele, D.A. et al. (2020). Scientists' and the Publics' Views of Synthetic Biology. Synthetic Biology 2020: Frontiers in Risk Analysis in Governance.

[27] Akin, H., Rose, K.M., et al. (2017). Mapping the Landscape of Public Attitudes on Synthetic Biology. BioScience.

[28] Elani, Y., Seddon, J.M. (2023) What it means to be alive: a synthetic cell perspective. Interface Focus.



Applications of engineering biology in health

Using engineering principles to redesign biology has already contributed to significant medical breakthroughs, and is expected to transform and enhance how we diagnose, prevent, and fight disease in the future[29]. With the rise of technology, and medicine, researchers can now design healthcare tools, devices, and software and respond to a range of healthcare challenges.

In the UK, the potential of health-centred applications of engineering biology has been well recognised. Over a decade of investment has resulted in research clusters spread across the country, supported by catapults and infrastructures, such as the Medicines Manufacturing Innovation Centre in Renfrewshire, which exists to help businesses as they develop and scale up[30].

[29] UKRI. (2023). Engineering biology missions hubs and mission awards. Accessed December 2023.

[30] Council for Science and Technology. (2023). Report on engineering biology: opportunities for the UK economy and national goals.

Examples of engineering biology applied in health

Engineering biology techniques contributed to the rapid development of COVID-19 messenger RNA (mRNA) and viral vector vaccines[31]. Before the outbreak of the virus, major research institutions and companies around the world had already established various types of mRNA technology research and development platforms with the aim of improving prevention of infectious diseases and cancer treatments[32]. These prior advancements allowed rapid development and roll-out of COVID-19 vaccines in 2020, which highlights the potential of new vaccine technologies based on engineering biology for versatile development against emerging diseases.

Other examples of engineering biology applied in health include:

- Researchers at the University of Bristol developed new techniques for making red blood cells in the lab[33]. These cells could be used to help patients with rare blood types who cannot be matched with donor blood. By using gene editing, the team at Bristol were able to produce a blood cell which has had five problematic blood groups removed. They are now exploring how the methods could be developed to engineer lab-made blood cells with a range of therapeutic benefits.

- Simple cells, or SimCells, are new kinds of reprogrammable cell developed at the University of Oxford. They have their native chromosome taken out and replaced with an artificial gene-circuit designed to make them perform specific functions[34]. Researchers at Oxford demonstrated that SimCells work well in diagnostics and could be used to detect viruses quicker and cheaper than the purified enzymes that are currently used for this purpose.

- Ziylo, a University of Bristol spinout company, developed an innovative technology platform which could be a key component to enable the next generation of 'smart' insulin[35]. The team at Bristol found a way to design synthetic molecules that bind to glucose in blood[36]. By attaching these glucose-grabbing molecules, it should be possible to create a new form of insulin that is active when glucose levels are high, but not when they are low. This would eliminate the risk of hypoglycaemia – dangerously low blood sugar levels – and transform treatment of diabetes.

[31] Council for Science and Technology. (2023). Report on engineering biology: opportunities for the UK economy and national goals.

[32] Liang, Y., Huang, L., Liu, T. (2021) Development and Delivery Systems of mRNA Vaccines. Frontiers in Bioengineering and Biotechnology.

[33] UKRI. (2021). Engineering biology. Accessed December 2023.

[34] UKRI. (2021). Engineering biology. Accessed December 2023.

[35] University of Bristol. (2018). University spin-out Ziylo acquired by global healthcare company.... Accessed December 2023.

[36] UKRI. (2021). Engineering biology. Accessed December 2023.

Public opinion on applications of engineering biology in health

Despite the growing investment and interest in the potential of engineering biology in the health sector, we found no major UK-based public engagement initiatives such as surveys, dialogues, focus groups, or workshops that have been published over the past five years.

Most analyses of engineering biology applications in health focus on potential pathways to accelerate the commercialisation of research within the field and growing the sector. Many resources mention or even highlight the importance of public acceptability in developing engineering biology applications that are fit-for-purpose, but refer to sources of public opinion from 2015 or earlier.

Support highest when there is a public health need

Several of the international studies we found suggest that the public's support for engineering biology is the highest when it is used to improve human health. CSIRO, Australia's national science agency, conducted surveys across seven synthetic biology applications, including managing invasive pests, reducing pollution in waterways, and reducing mosquito-borne diseases[37]. They found that support for synthetic biology was the highest when there was a public health need or an environmental benefit.

Synthetic biology technologies, such as gene editing, have the potential to offer innovative solutions to mosquito-borne disease (e.g. malaria, yellow fever) by targeting genes related to disease susceptibility in mosquitoes[38]. In the future, scientists might be able to remove or change genes so that mosquitoes can no longer carry viruses. If these mosquitoes are then released to the wild to mate with wild mosquitoes, the disease resistance genes would be passed onto wild mosquito offspring, which would eventually reduce the number of disease-carrying mosquitoes.

In their study of public opinion, CSIRO reports that:

- 95% of Australians rated synthetic biology technologies as moderately to very helpful in managing the problem of mosquito-borne diseases
- 65% agreed that this technology would be better than current methods of reducing mosquito-borne diseases[39].
- When asked to consider the use of this technology in their local area, 53% of respondents indicated that they would not be bothered if this synthetic biology technology was implemented in their own community.

In a study of senior citizens' attitudes towards synthetic biology, researchers at the University of Zurich found that their respondents valued the utility of biotechnologies and were particularly fascinated by the prospects of medical biotechnological applications[40]. When presented with several innovations that can be made possible with the use of emerging biotechnologies, the group associated synthetic biology-fabricated antibiotics as an innovation with particularly high benefits. However, it is important to note that participants of this study were recruited through an education programme for seniors at the University of Zurich, which means that the sample is not representative of wider society.

[37] CSIRO. (2021). Public attitudes towards synthetic biology. Accessed December 2023.

[38] CSIRO. (2020). Public perceptions of using synthetic biology to reduce mosquito-borne diseases.

[39] CSIRO. (2020). Public perceptions of using synthetic biology to reduce mosquito-borne diseases.

[40] Ineichen, C., Biller-Andorno, N., Deplazes-Zemp, A. (2021) Between fascination and concern: an exploratory study of senior citizens' attitudes towards synthetic biology and agricultural biotechnology. Universal Access in the Information Society.

Impact of COVID-19 on public attitudes to biotechnologies

Researchers at the University of Science and Technology of China conducted an international literature review to profile ethical and societal insights into synthetic biology in the post-COVID-19 era[41]. Their research suggests that various conspiracies and rumours about bioweapon and biohazard leakage, which emerged during the pandemic, have had a negative impact on people's confidence over biotechnologies and science institutions. However, at the same time, synthetic biology has allowed rapid development of COVID-19 vaccines and helped to save lives all over the world.

As the influence of synthetic biology expands and surpasses the fields of fundamental scientific research, the authors of the study call for greater cooperation between researchers in natural sciences and social sciences, as well as government officials and the public to address the complex questions of governance, ethics and public perceptions of synthetic biology[42].

[41] Wang, G., Kong, Q., Wang, D., Asmi, F. (2023). Ethical and social insights into synthetic biology: predicting research fronts in the post-COVID-19 era. Frontiers in Bioengineering and Biotechnology.

[42] Wang, G., Kong, Q., Wang, D., Asmi, F. (2023). Ethical and social insights into synthetic biology: predicting research fronts in the post-COVID-19 era. Frontiers in Bioengineering and Biotechnology.

Perception of negative public attitudes as a result of anti-GM sentiment

Another study in Australia explored three synthetic biology applications and their potential to address significant global health and environmental challenges[43]. Researchers at CSIRO analysed:

1) gene editing cane toads to reduce their environmental impact;

2) engineering bacteriophages to combat antimicrobial resistance in humans; and

3) engineering microbes to improve biomining efficiency in the mining industry.

They also analysed their research implementation environment to uncover the potential challenges and opportunities in the impact pathways of these three applications.

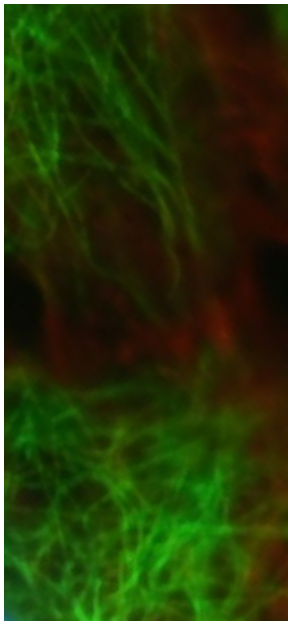
The strongest theme emerging from the researchers' interviews with stakeholders from government, research, and civil society is the perception these stakeholders hold of negative public attitudes towards the use of genetic technologies. The participants of the study often expressed concerns over the lack of public trust in biotechnologies. This is likely to be driven by the perceived anti-GM sentiment in Australia and elsewhere.

In the early 2000s, the industries failed to engage the public in the conversation about genetically modified foods, which resulted in the public opposition to genetic interference in food production. These failures continue to affect the attitudes of government and science communities who are anxious about the public acceptability of genetic technologies, even though there is evidence that public mood in many countries has shifted[44].

Concerns over access to benefits of new treatments

Another theme which emerges from our analysis is the public's concern over the access to new therapies developed with the help of engineering biology. As synthetic biology research advances towards clinical application, the question of how the new technologies are made available and desirable to the public becomes increasingly relevant. Research by the University of Edinburgh suggests that the interplay of commercial, individual, public and scientific interests creates complex ethical tensions that will need to be carefully considered if the new synthetic biology treatments are to serve the public interest[45].

It is also important to consider synthetic biology technologies from a global health equity perspective. Healthcare, provision of treatment and new therapies, and clinical research are much more regulated in some countries than others, which might result in a health and research tourism[46]. Evidence suggests that the public are in favour of new technologies being adequately regulated. However, if the regulations are too tight it might mean that some scientists and biotech companies relocate to other countries, which could have economic and political consequences, or that people would travel overseas to access new treatments, which might have implications for the local health care systems. To address this, a global cooperation between both policymakers and scientific community will be needed.

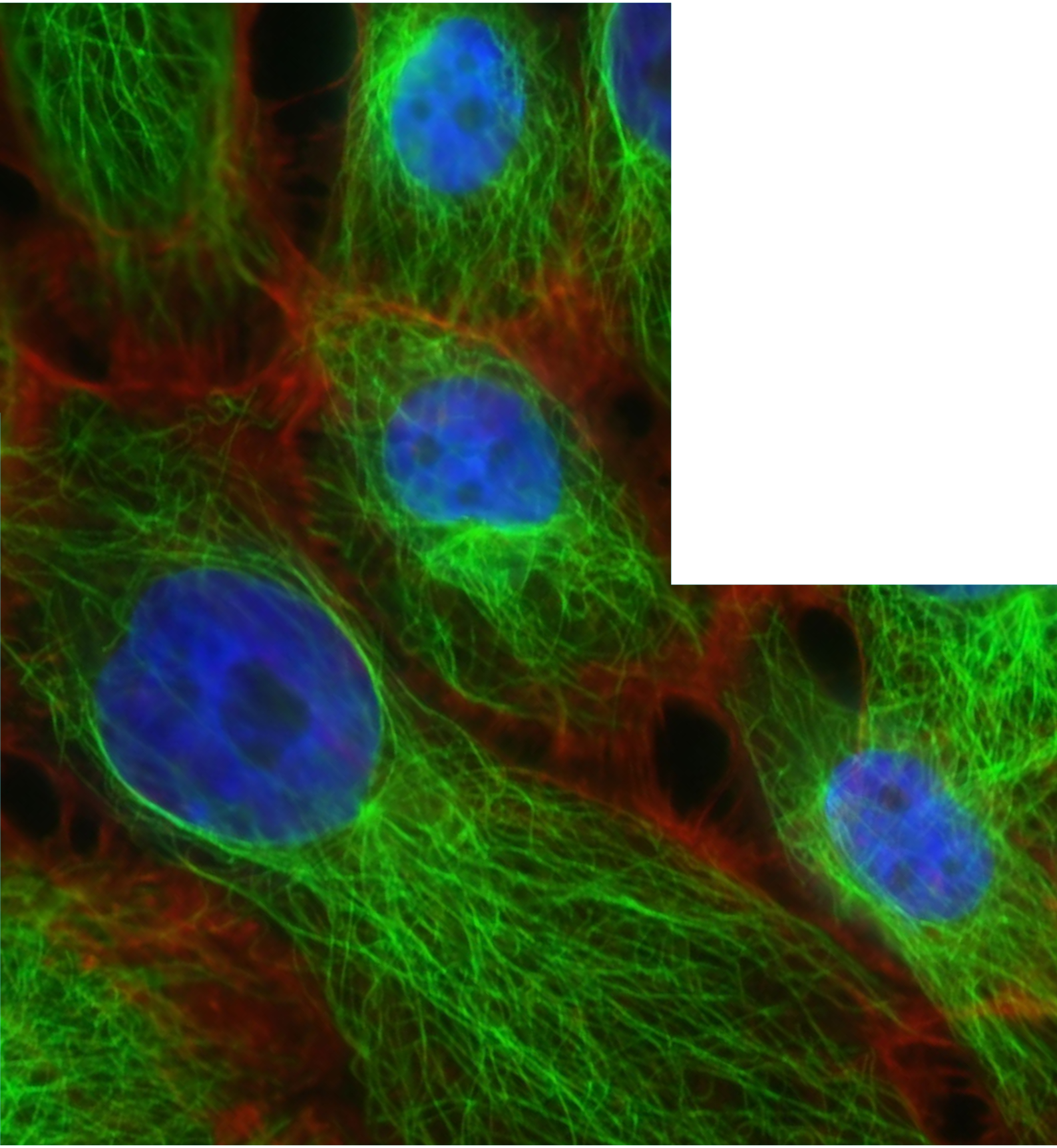


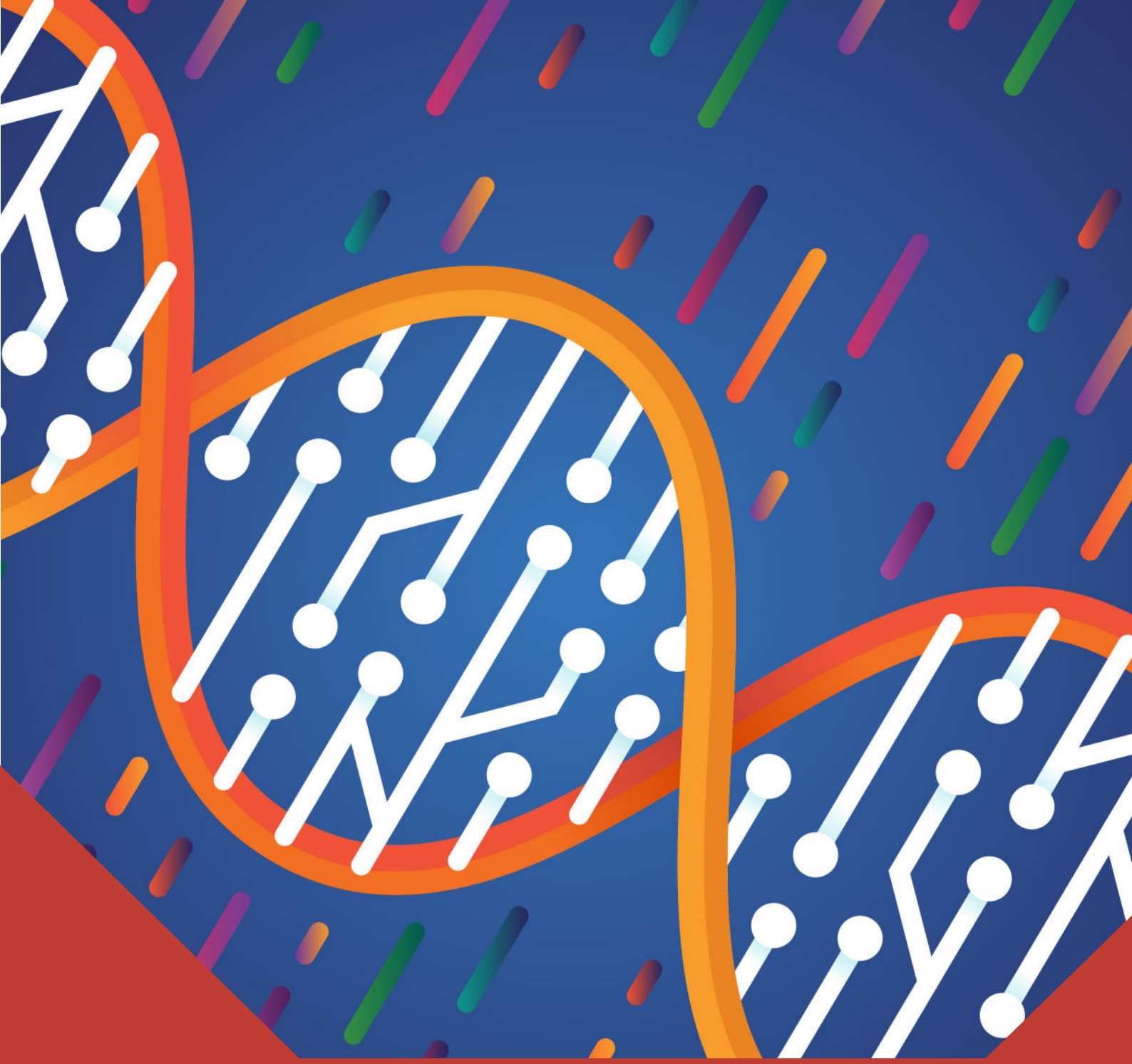
[43] Carter, L., Mankad, Ad. et al. (2022). Three synthetic biology applications and their paths to impact in Australia: Cane toads, bacteriophages, and biomining microbes. *Biotechnology Journal.*

[44] Carter, L., Mankad, Ad. et al. (2022). Three synthetic biology applications and their paths to impact in Australia: Cane toads, bacteriophages, and biomining microbes. *Biotechnology Journal.*

[45] Chan, S. (2018). Research translation and emerging health technologies: Synthetic biology and beyond. Health care analysis.

[46] Chan, S. (2018). Research translation and emerging health technologies: Synthetic biology and beyond. Health care analysis.





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