Biotech frontiers

Biotechnology – the application of science and technology to living organisms – is used in a diverse range of sectors, including pharmaceuticals, aquaculture, agriculture and industrial biotechnology. In recent years, rapid advances in frontiers such as genetic technology, synthetic biology, microbiomes and bioenergy have changed the speed, cost and scope of its development, enabling new processes and unlocking new information.

Biotechnology is already part of our everyday lives. It is used for a wide variety of purposes, including DNA profile matching, tissue engineering and crop protection. It also features in the production of fresher and more nutritional food, cotton materials and environmentally friendly bio-plastics. Stone washing denim involves biotechnology too, as does washing clothes at lower temperatures using protease enzyme-containing biological washing powders. Rare disease therapies, vaccines and life-saving insulin treatments for diabetics also make use of biotechnology.

But each application of biotechnology creates ethical dilemmas as well as opportunities. For instance, agricultural biotechnology could increase food security and improve nutritional outcomes; but it could also negatively affect smallholder farmers with limited access to hybrid seeds, and reduce crop genetic diversity. Nevertheless, a confluence of trends, including high and volatile commodity prices, resource scarcity, climate change, competition for land and water for the production of food and energy, and pressure from NGOs and other groups to source sustainably, is increasing the impetus for exploring new and more sustainable forms of biotechnology.

There is uncertainty about the long-term implications of developments in biotechnology – particularly whether its risks can be effectively addressed so that sustainability benefits, such as delivering nutrition and medicines, can be maximised. The risks and benefits also vary across different types of biotechnology, and touch upon issues such as intellectual property rights for living organisms, what it means for smallholder farmers' livelihoods, and degrees of acceptable risk in terms of the containment and release of modified organisms.

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Implications

- Biotech solutions for satisfying world food demand – such as micronutrient fertilisers, biofortification of staples and genetically-modified drought and pest-resistant crops – may become more prominent in the long term, especially through increased investment. However, the effectiveness of these techniques will remain strongly dependent on healthy soils and ecosystems.
- As the space for experimentation in biotechnology opens up with the DIYbio movement, scientific methods and innovations might increasingly be developed by new actors, such as citizen scientists who do not hold the same protocols and legal standards as formal scientific institutions do. Due to these developments, policy regulation of new technologies and actors will be increasingly difficult and yet more important to promote innovation while tackling concerns of bio-terrorism, safety and ethics.
- So-called 'technofixes' that appear to offer a simple solution to a problem often have unintended consequences that make the problem worse in the long term. There are concerns that synthetic biology and other forms of advanced biotechnology could fall into this trap. For example, the recent development of engineered yeast to brew the anti-malarial artemisinin unintentionally displaced several hundred thousand smallholder famers from the world market for artemisia, who now face impoverishment. Plans to produce vanilla extract using a similar process may have the same effect on smallholder growers of vanilla. [1] Both the direct and indirect impacts of synthetic replacements must therefore be carefully considered before they are introduced into existing markets.

Footnotes:

1. The Guardian (2013). Synthetic anti-malarial compound is bad news for artemisia farmers

Current trajectory

- **Genetic engineering** research is creating new possibilities, aided by the recent development of the powerful gene-editing tool CRISPR-Cas9 in 2012, which has opened up levels of accuracy in DNA work never before seen in any previous generations of gene editing methods. This allows for a ground-breaking level of precision in the alteration of DNA, down to the level of a single letter in some cases. In 2015, scientists used Cas9 to modify the genome of human embryos for the first time. [1] CRISPR is already being hailed as a potential means to perform gene therapy on people with devastating genetic illnesses such as sickle-cell anaemia. [2] At the same time CRISPR/CAS is turning out to be so easy and inexpensive to use that a whole new world of DNA manipulation has opened up to amateurs who can now begin to play with them successfully too. [3] The debate on genetically modified organisms is also shifting away from groups being fundamentally opposed to GM in all situations toward a precautionary approach where actors such as scientists and NGOs are debating the benefits and risks of biotechnology and the emphasising the need for rigorous and consistent regulation. [4]

- **Bioenergy** - Biotechnology has significant commercial potential in producing sources for biofuels and other bioenergy applications. According to the IEA, bioenergy is the single largest renewable energy source today, providing 10% of world's primary energy supply, with demand projected to grow at 3.5% annually by 2018. [5] First-generation biofuels, generated from farmed crops, raise issues around competition for land, food security and ecosystem health when monocultures are prevalent. Second-generation biofuels, such as cellulosic ethanol, may avoid some of these issues by using, for example, non-food crops or inedible waste products as feedstock. But these approaches come with their own set of challenges, such as increased competition for waste as a resource. Third-generation biofuels – a term that has only recently entered the mainstream [6] – tend to be derived from algae, and usually feature some level of genetic engineering or synthetic biology to accelerate oil production rates. They are still in development, however, and not yet ready to be rolled-out at commercial scale.
- **Synthetic biology** involves the redesign of existing natural biological organisms, components and systems or making new ones from scratch. Champions of synthetic biology expect the field to radically restructure many existing industries and create significant new ones. The potential applications of synthetic biology span many sectors: from engineered plants in agriculture and synthetic biofuels in energy to synthetically designed natural fragrances in fine chemicals and rapid synthesis to speed up vaccine development in healthcare. [7] The synthetic biology market has registered a massive growth in current times, owing to the rise in demand for bio-based chemicals, renewable fuels, and inexpensive drugs and vaccines, which use synthetic biology techniques and products.
- **Microbiome** - The microbiome is a significant 'new' frontier for the drug and food (i.e. probiotics and hygiene) industries. Scientists are just beginning to understand how the living colony of trillions of bacteria in and on our bodies affects our health. The makeup of our microbiomes has shifted over the years, as changes in diet and the use of antibiotics affect the mix of bugs living on us. Startups are eager to figure out how to manipulate the microbiome for beneficial treatments. One such startup, Seres, has generated great investor interest with shares nearly tripling in their first day of trading. The company is developing a pill called Ecobiotics that combines 5 to 15 purified bacterial strains into a two- to three-pill, once-a-day dose that appears to restore the equilibrium of the

microbiome and the health of the gut. [8]

Footnotes:

1. Nature (2015, April). Chinese scientists genetically modify human embryos.
2. The Futures Centre (2015). Genetic engineering of human embryos raises sharp ethical concerns
3. Yahoo News (2015, Sept). DIY biology: How amateur scientists are playing with genetic code
4. Jonathon Porritt (2013). The continuing benefits of the precautionary principle.
5. International Energy Agency (2014). Renewables – Bioenergy.
6. Biofuel (date accessed 2015, Oct). Third generation biofuels.
7. The Guardian (2015, Jan). UK Synthetic Biology Centres tasked with addressing public concerns
8. Bloomberg (2015, June). Investors think this company's gut bacteria are worth $1.9 billion