# Rapid Technology Assessment: Synthetic Genomics

**Synthetic genomics is the large-scale modification of genomes or building of genomes from the ground up. This can be used to add a range of novel functionalities to cells, for example producing advanced materials or medicines. It is a key part of the wider area of engineering biology.**

## Introduction

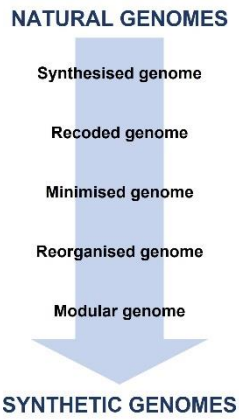
- **The use of living cells to produce goods is well established.** Yeast fermentation is used to produce beer, wine and biofuel, and genetically modified bacterial cells have been used to produce insulin and other drugs since 1982.
- **Redesigning the genome beyond inserting or modifying individual genes allows greater influence on the cell's functionality**. Cells focussed on producing a single product (with unnecessary functions removed) could increase yields and reduce downstream processing. Initial applications are expected to focus on high margin products such as **therapeutics**, including advanced treatments such as cell therapies.
- **Future products could include novel advanced materials, small molecule drugs, biofuels, and high value chemicals and compounds**. Synthetic genomic technology could eventually shift significant sections of these industries towards bio-based manufacturing, reducing carbon emissions and reliance on fossil fuels and help achieve Net Zero objectives.

## UK Position

- **The UK has a strong research base in synthetic genomics and related fields**. Several UK-based start-ups and academic groups are considered leaders in the field. The UK ranks 3rd worldwide for academic publications and investment activity, but 9th for patents filed by UK companies.

## Recent Developments

- **The costs of DNA sequencing (reading DNA) and DNA synthesis (writing DNA) fell by a factor of 1,000,000 and 1000 respectively from 2000 to 2017.** Advances in areas such as microfluidics, where fluids are manipulated at the sub-millimetre scale, has enabled more efficient DNA sequencing and synthesis.
- **Synthesised DNA is widely commercially available** and benchtop synthesisers have recently become available, lowering the barrier to entry.
- **Increasingly large DNA constructs and genomes can be assembled from synthetic DNA,** and computational advances are allowing better genome analysis and more complex design. A fully synthetic genome, designed from scratch with modular DNA parts is possible in the future with a greater understanding of gene regulation and the systems that control cell growth.
- **Global academic publications and patent applications are growing** on average 6% per year, with particularly strong growth in China. The US dominates the investment landscape, accounting for nearly all global investment activity.




***Steps from building a synthetic copy of an existing genome to a fully synthetic genome built from custom DNA parts.*** *Synthesised, recoded and minimised genomes have been created (Adapted from Tom Ellis, 2019)*

## Opportunities

- **Supporting UK research and development** in this area could provide economic benefits, allow a larger influence on responsible development, and maintain manufacturing capabilities and national expertise to address future biological threats.
- **Improvements to production methods.** Synthetic genomics could support enhanced yields, remove filtering and purification steps, reduce waste, and increase the lifetime of cells. This could reduce reliance on scarce resources or energy intensive manufacturing processes.
- **Environmental security.** Cells could be engineered to rely on specific nutrients to survive, which are not available outside of a laboratory setting.
- **Pathogen resistance** could be enhanced in engineered cells, improving reliability and robustness of manufacturing.
- Designing and synthesising genomes of greater scale and complexity will offer **insights into fundamental biological processes** with benefits for other areas.

## Challenges & Risks

- **Scale up and cost efficiency.** While synthetic cells promise cost savings, upfront development costs are high and increases in efficiency will be needed to compete with established processes.
- Experts highlighted **barriers for commercialisation of academic research,** with limited funding for joint projects with industry or for scaling up start-ups.
- **The main risk is the deliberate use of synthesised DNA to produce dangerous pathogens.** Most but not all commercial providers of synthesised DNA conduct checks on customers and compare sequences to known pathogens. Benchtop synthesisers could make DNA synthesis accessible to a wider range of users.
- **Regulatory systems** were designed prior to large-scale genetic modifications becoming a reality. Experts noted that proactively updating regulatory guidelines could limit emerging risks and support research and investment.

*This is a summary of a report completed in November 2021. There may have been developments and additional data since then that are not captured in this summary. Patent and research publication data was sourced from **Dimensions Analytics**. Search terms available on request. With thanks to the following for their contribution and expert review: BEIS, DSTL, Defra, HO, UKRI, and Prof. Erik Takano, Prof. Paul Freemont, Prof. Anne Osbourn, Prof. Tom Ellis, Prof. Jeremy Shears, Dr Hermann Hauser, Prof. Ian Shott, Steve Bates, Dr Carole Foy, Dr Michael Booth, Prof. Lionel Clarke and Gregory Lewis.*