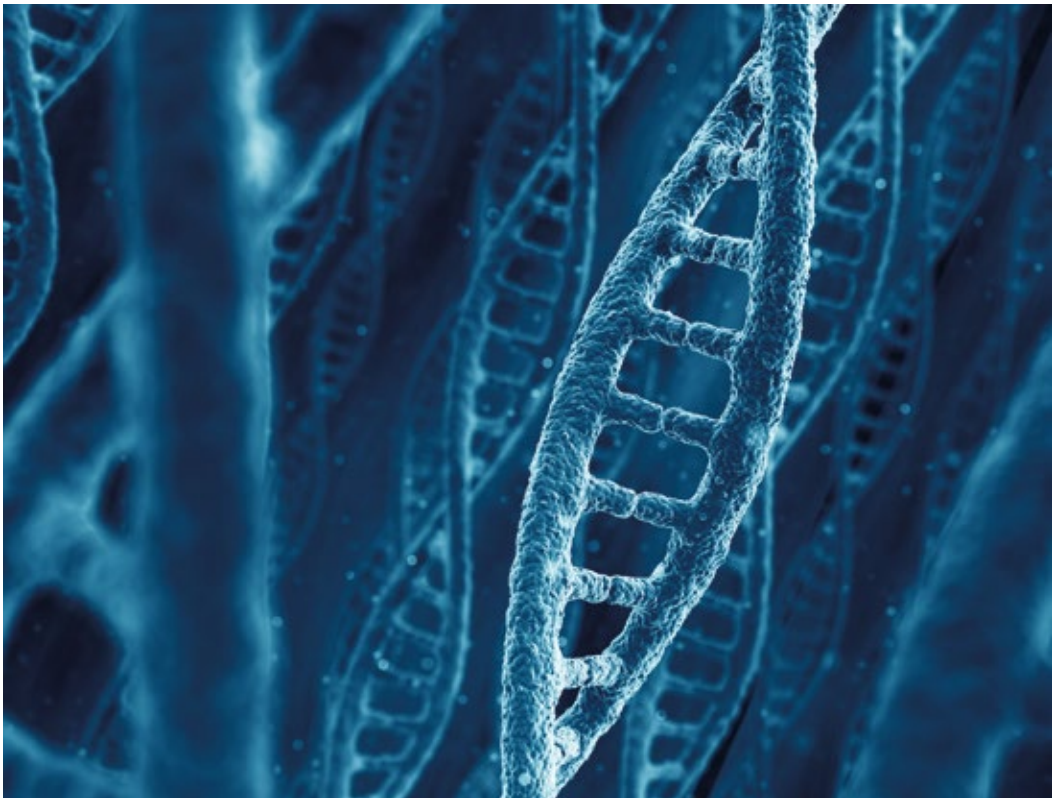

Research Councils UK

Synthetic biology

RESEARCH COUNCILS UK

Research funded by the Research Councils makes a vital contribution to the UK's economic growth, prosperity and well-being.

We take a variety of approaches to support innovation and deliver impact from research, including the development of collaborative research programmes, investment in major research capabilities, such as national research facilities, and the support of impact-related capabilities.

Often the impact of research is realised through the combination of several investments over time. The Research Councils seek to ensure that the outputs and outcomes of their funded research have significant long-term benefits for the economy and society. This timeline, one of a series, highlights how investments made in research over the long term combine to create a significant impact in particular areas. In addition, research in one area can combine with that from another to drive innovation and make a key contribution to UK growth. For example, Research Council investment in different disciplines and technologies has led to the development of next generation sequencing, bioinformatics approaches and DNA synthesis, all of which are central to the current field of synthetic biology and its future application.

A key part of the Government's Industrial Strategy is supporting technologies where the UK has the depth of research, expertise and the business capability to develop and exploit them commercially. Synthetic biology is one of 'Eight Great Technologies' identified by the Chancellor of the Exchequer in autumn 2012 when he announced an additional £600 million to help support their development. These eight are: Big data and energy-efficient computing; Satellites and commercial applications of space; Robotics and autonomous systems; Synthetic biology; Regenerative medicine; Agri-science; Advanced materials and nanotechnology; and Energy and its storage.

Synthetic biology

Synthetic biology is one of the most exciting areas of current global research – and the UK is a world leader. As a technology it seeks to design and engineer biologically based parts, novel devices and systems as well as redesign existing, natural biological systems. As an approach, it offers the potential to help society meet some of the major challenges we face in the 21st century, in healthcare, energy, agriculture and the environment.

The UK is home to some of the most innovative academic research groups and a community of emerging synthetic biology enterprises, making us well placed to harness this technology to drive economic growth and job creation and improve wellbeing.

The strength of UK synthetic biology, and the country's ability to benefit from its application, is based on more than a decade of investment by the Research Councils in the field, itself building on earlier investment and work in underpinning technology developments dating back to the 1950s. The Research Councils have supported the UK research community to build international links and collaborations and to forge partnerships with industry.

Early research laid the groundwork for today's synthetic biology field, including Research Council investments in pioneering computational biology, DNA sequencing and synthesis, and the development of humanised monoclonal antibodies. Since then, Research Council investments have helped UK scientists through capacity and community building initiatives such as Networks in Synthetic Biology.

Research Council funded scientists have led or been key partners in many of the high impact international achievements in this relatively young field. This has included the expansion of the genetic code of several model organisms and the production of stable and safe 'XNA' polymers.

Since the emergence of synthetic biology, Research Councils and the research community have been at the forefront of developing approaches and processes to consider public and stakeholder views around the new technology. The Research Councils have engaged the public and stakeholder groups in dialogue that has influenced long-term thinking, recognising the importance of responding to and reflecting public views in developing the field.

Building capability

2007: The Research Councils establish seven research networks in synthetic biology to bring together different disciplines, develop a common language and develop potential research projects.

2009: The Research Councils provide £2m of co-funding for the European Science Foundation's synthetic biology EUROCORES programme, EuroSYNBIO, including grants that aim to build an artificial genetic system and develop biomolecular building blocks that can be combined into a synthetic 'nanocell'.

2009: The Centre for Synthetic Biology and Innovation at Imperial College is launched with funding from the Research Councils.

2009: RCUK partners with the US National Science Foundation (NSF) to enable UK and US researchers to develop transformative synthetic biology projects.

2010: An MRes course in synthetic biology is established using Research Council funding.

2011: Joint funding from RCUK and the NSF supports synthetic biology research projects focussed on enhancing photosynthesis – the process by which plants harness sunlight to create food and fuel.

2011: Three international symposiums bring together the UK's Royal Society and Royal Academy of Engineering, the US National Academy of Sciences, US National Academy of Engineering and Chinese Academy of Sciences and Engineering to allow researchers, policy makers and companies to discuss synthetic biology.

2011: Working with the UK's Defence Science and Technology Laboratory, the Research Councils announce a £1.7m Joint Synthetic Biology initiative to fund 14 proof-of-concept research projects on the use of synthetic biology to meet national security and defence needs.

2012: Research Councils award a total of £20m for six large strategic synthetic biology projects in areas including biofuels and biotechnology; industry provides a £3m contribution.

2012: The Centre for Chemical and Synthetic Biology is established at the MRC Laboratory of Molecular Biology in Cambridge through a £2m enhancement to help provide resources to drive synthetic biology forward.

2013: To date, the Research Councils have invested more than £100m in synthetic biology research and training.

2013: A new Innovation and Knowledge Centre, SynbiCITE, is announced by Research Councils and the Technology Strategy Board (TSB). Based at Imperial College London, the centre aims to integrate university- and industry-based research in synthetic biology and translate that into industrial processes and products.

2013: Frontier engineering awards are announced for two synthetic biology projects at the Global Grand Challenges Summit. 'Scaling up synthetic biology' and 'Synthetic biology applications to water' are led by Imperial College London and the University of Glasgow respectively.

2013: The TSB and Research Councils award £5.3m to UK companies using synthetic biology to develop novel products and processes. The companies receiving the funding include several spinouts from Research Council-funded research.

2013: Twelve partner countries, including the UK and US, commit €15.5m to the European Synthetic Biology ERA-NET. The first call for research projects aims to build synthetic biology capacity through innovative transnational projects.

2013: As part of a larger 'Synthetic Biology for Growth' programme, the Research Councils invite applications for up to six multidisciplinary Synthetic Biology Research Centres.

Plants, biofuels and the environment

2002: Spinout company TMO Renewables Ltd is founded to develop and commercialise bacteria that can produce bioethanol from waste. Funding from the Research Councils enables the company to develop its idea.

2006: Scientists at the University of Glasgow receive Research Council funding to study the structure and composition of microbial communities used in waste management which can be used in engineering design.

2009: A University of Glasgow researcher is awarded a Research Council Fellowship to develop mathematical models of microbial communities as a precursor to engineering and optimising these communities for wastewater treatment or for use in microbial fuel cells.

2010: Research Council scientists use the Diamond Light Source to take the first steps towards engineering a bacterial cell that can sense and respond to novel environmental cues. The groups show that it should be possible to design synthetic signalling circuits inside a cell, ultimately enabling the development of new biosensors.

2010: TMO Renewables signs a $500m deal with US company Fiberight to build fifteen municipal waste-to-ethanol plants across the US over 20 years.

2010: Cardiff University and Rothamsted Research scientists receive RCUK funding to develop a synthetic biology approach to produce new and more useful versions of odour molecules called sesquiterpenes for use in pest control and, potentially, in medicine and perfumery.

2012: University of Bristol researchers, supported by the Research Councils, are using rational protein design to convert a water-soluble protein structure called CC-Hex into membrane-spanning proteins that could be used in desalination and water purification.

2012: Researchers at the University of Glasgow, with RCUK and NSF funding, are using synthetic biology to develop an artificial 'leaf' that uses energy from sunlight to produce liquid fuel, replicating the process of photosynthesis.

2012: RCUK-funded scientists synthesise a new molecule that captures the energy of light and uses it to drive useful chemistry. The activity of the new molecule is determined using the Central Laser Facility, providing information that will help develop artificial photosynthesis systems.

2013: A synthetic foot-and-mouth disease vaccine, made from engineered protein shells, is produced by RCUK-funded researchers.

2013: RCUK and the NSF fund a project which aims to build a synthetic nitrogen fixing unit, based on the cellular machinery that allows cyanobacteria to fix nitrogen, which can be transferred into a new bacterial host and ultimately into crops, reducing their dependence on nitrogen fertiliser.

2013: UK scientists receive £1m funding from the Research Councils to contribute to a global consortium building a synthetic version of the yeast genome. Once finished in 2017, the genome could help researchers create novel yeast strains to produce biofuels, vaccines and other valuable products.

Better health

2009: Bicycle Therapeutics Ltd is spun out of Research Council-funded research in Cambridge to develop and commercialise unique cyclic peptides that could deliver a new class of therapeutic drug.

2007: A global consortia begin to develop a semi-synthetic artemisinin-based combination therapy for malaria by identifying the genes required to generate the artemisinic acid pathway in the wormwood plant and inserting this pathway into microorganisms.

2011: For the first time, Research Council scientists expand the genetic code of an animal *(Caenorhabditis elegans)* by incorporating synthesised amino acids into its proteins. This will enable the study of development, disease and neurobiology in model organisms with molecular precision.

2011: A millisecond pulse of light is used by Research Council scientists to activate an enzyme in mammalian cells. This will allow the study of single steps in cell signalling cascades, changes to which often lead to diseases, such as cancer.

2010: RCUK scientists redesign a cell's machinery for producing proteins so that it reads the genetic code in quadruplets. This system, which does not interfere with normal cellular processes, potentially allows the cell to use synthetic amino acids to produce proteins with unique properties that could deliver novel protein-like medicines.

2012: Scientists supported by the Research Councils expand the genetic code of a second model organism, the fruit fly *Drosophila melanogaster*, by incorporating synthesised amino acids into its proteins.

2012: Research Council scientists engineer enzymes that can copy DNA templates into 'XNA' polymers, which could play an important role in the construction of cellular 'factories' for producing new medicines and other useful compounds.

2013: Scientists at the University of Bristol, supported by RCUK, design small protein molecules that, when combined, form a hollow sphere. The spheres could form the basis of new vaccines, or deliver drugs to cells and diseased tissues in the body.

2013: Using bacteria engineered with novel gene pathways, UK scientists discover the molecule that inhibits HIF-1, the protein that enables the survival of cancer cells at low oxygen levels. The identification of this molecule could lead to new cancer treatments.

2013: RCUK-sponsored chemists from the University of Bristol develop a method to create synthetic prostaglandins in only seven steps – compared to 20 using conventional technologies. Prostaglandins regulate a range of activities including blood circulation, digestion and reproduction in the human body.

Policy, ethics and regulation

2000: The Genetically Modified Organisms (Contained Use) Regulations (2000) come into force in the UK, regulating the use of GMOs in contained environments such as laboratories, industrial plants or greenhouses. Such regulations also apply to GMOs created via synthetic biology.

2002: The Research Council-funded Genomics Network is established to examine the social impact of the development and use of genomics and emerging developments in life sciences, including synthetic biology.

2002: The Genetically Modified Organisms (Deliberate Release) Regulations (2002) come into force, implementing a 2001 EU Directive for the release of GMOs into the environment for commercial or research purposes.

2004: Regulations on the use of GMOs in food and animal feed are implemented in England, following the publication of an EU Directive in 2003.

2008: The report 'Synthetic Biology: social and ethical implications' which was commissioned by the Research Councils, is published. It identifies ethical and social concerns, and recommends that researchers continue to engage with broader society and regulators to discuss the implications of synthetic biology.

2007: BBSRC's Bioscience for Society Strategy Panel forms a synthetic biology subpanel to provide strategic input on the social implications of the new technology.

2010: RCUK, together with Sciencewise Expert Resource, commission and run a public dialogue on synthetic biology to ensure that future policies reflect the views, concerns and aspirations of the public.

2012: An independent panel of experts, including those from academia, industry and the Research Councils, produce a Synthetic Biology Roadmap for the UK to provide the vision and direction for supporting a world-leading synthetic biology community in the UK.

2012: A review by the UK Health and Safety Executive concludes that synthetic biology is currently covered by regulations aimed at controlling GMOs, including the Environmental Protection Act (1990).

2012: The Synthetic Biology Leadership Council is established by the UK Government to provide strategic coordination between funding agencies (including RCUK and TSB), researchers, industry, government sponsors and others. It will shape priorities for synthetic biology research and oversee delivery of the recommendations from the UK roadmap.

Synthetic biology

RESEARCH COUNCILS UK

The seven Research Councils are:

- Arts & Humanities Research Council (AHRC)
- Biotechnology & Biological Sciences Research Council (BBSRC)
- Economic & Social Research Council (ESRC)
- Engineering & Physical Sciences Research Council (EPSRC)
- Medical Research Council (MRC)
- Natural Environment Research Council (NERC)
- Science & Technology Facilities Council (STFC)

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Research Councils UK is the strategic partnership of the UK's Research Councils.

We invest annually around £3 billion in research. Our focus is on excellence with impact. We nurture the highest quality research, as judged by international peer review providing the UK with a competitive advantage. Global research requires we sustain a diversity of funding approaches, fostering international collaborations, and providing access to the best facilities and infrastructure, and locating skilled researchers in stimulating environments.

Our research achieves impact – the demonstrable contribution to society and the economy made by knowledge and skilled people. To deliver impact, researchers and funders need to engage and collaborate with the public, business, government and charitable organisations.

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