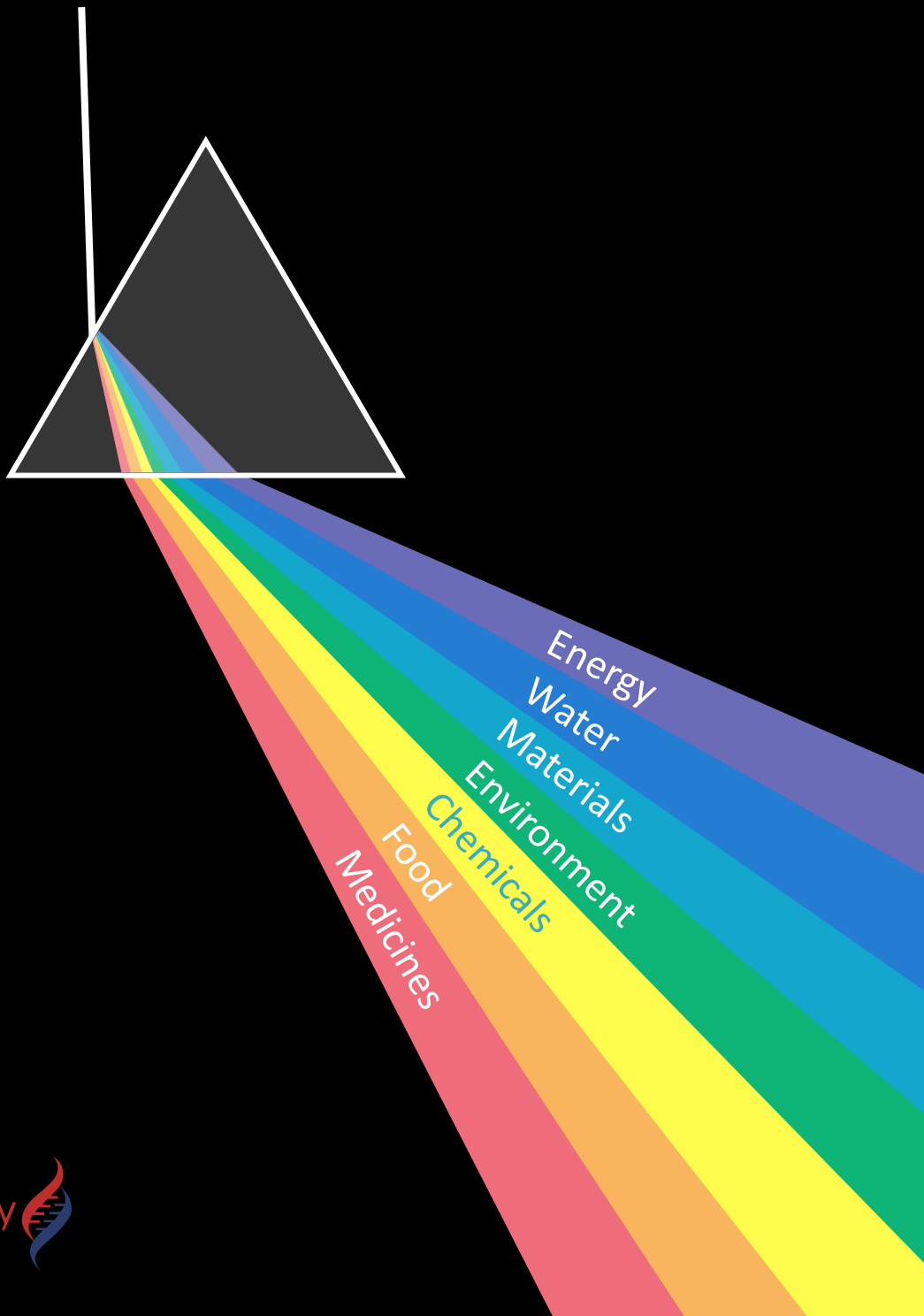
Synthetic Biology UK

A Decade of Rapid Progress

2009-2019



Synthetic Biology
Leadership Council

Foreword

The application of engineering design principles to the intersection of leading-edge developments in biology and information technology – synthetic biology – is helping to build the foundations for a 21st century industrial revolution.

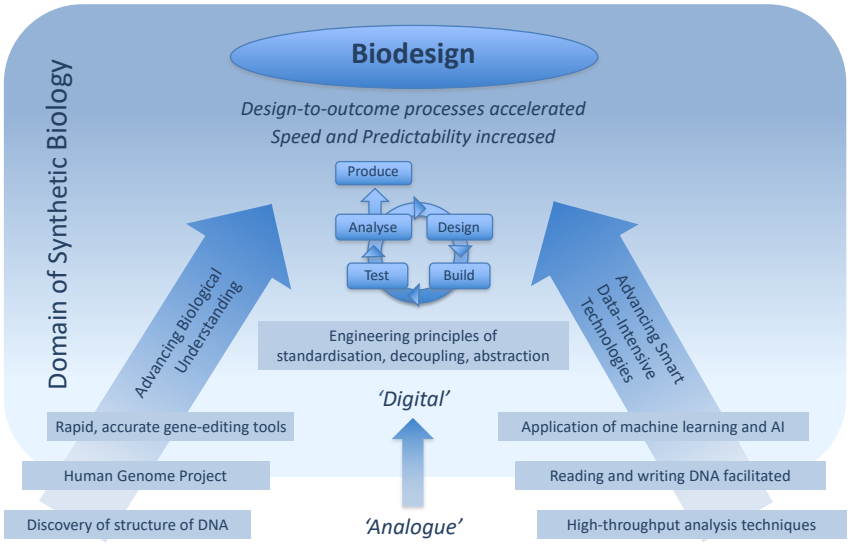
Within the past decade, the UK has embraced a clear vision, leading technological advances and societal engagement through government policy and strategic investment to stimulate an innovation pipeline and accelerate progress, overseen by the UK Synthetic Biology Leadership Council.

Propelled at pace by multiple innovations ranging from the discovery of CRISPR-based gene editing tools to the assimilation of AI techniques within increasingly automated operating environments, this has indeed been a decade of rapid progress. Practical applications are now emerging as engineering biology technologies continue to be developed to address tough healthcare and sustainability challenges.

The selection of examples included in this brochure - limited only by space – aims to convey a sense of the breadth of activities inspired and facilitated by such multidisciplinary developments to date. The potentially considerable economic and societal benefits arising from this ongoing UK commitment to synthetic biology and associated technologies are becoming increasingly clear.

Lionel Clarke OBE, co-chairman

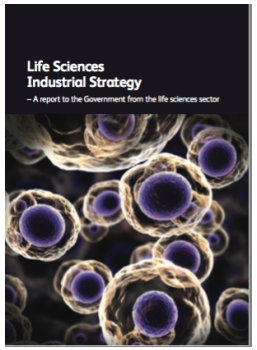
Synthetic Biology Leadership Council



Synthetic Biology applies engineering principles to facilitate the design and construction of new biological systems

Coordinating Routes to Industrialisation

The UK Synthetic Biology Leadership Council assists the coordination of activities in line with the Roadmap Vision and Strategy



Delivering Healthcare

A significant proportion of synthetic biology start-ups and SMEs, alongside established companies, are directly contributing healthcare solutions – providing more bespoke and cost-effective therapies and tackling previously intractable problems

Development and delivery of novel therapeutics

A number of companies are using engineered strains to develop novel treatments and preventative medicine for unmet medical needs, including the generation of more effective delivery systems.

Prokarium has already taken a treatment for Enteric Fever to early stage clinical trials.

CHAIN Biotech is developing transformative gut microbiome therapeutics based on engineered bacteria. These oral drugs target a broad range of disease including inflammatory bowel disease and cancer.

Quethera, acquired by Astellas Pharma for £85m in 2018, developed a therapy for Glaucoma by engineering viral vectors to support the simultaneous delivery of multiple gene therapies.

Cagen develops self-assembling protein nanocages which could be used to carry drugs to specific targets within the body.

Developing innovative therapies and production systems

Autolus has developed T cell therapies that have been shown to be effective as a cancer treatment in some haematological malignancies with the potential for cure in some patients. It raised $160m through an IPO in 2018.

LabGenius is using AI-driven protein engineering to discover new therapeutics

Touchlight has developed a scalable enzymatic DNA amplification platform enabling the next generation of DNA-based therapeutics.

Leaf Expression Systems has developed a proprietary plant-based transient expression system for the production of vaccines, antibodies and complex biomolecules

OpenPlant scientists have developed powerful new technology to turn plants into green factories, producing new vaccines and other bioactives (e.g. adjuvants and anti-cancer drugs) for disease control. This technology has recently been used to make the first polio vaccine that does not require live polio virus for its generation, so opening up the possibility of attaining the World Health Organisation (WHO) ambition of eradicating polio permanently.

Making human blood cells

Scientists at **BrisSynBio** and NHS Blood and Transplant (NHSBT) have produced the first immortalised cell lines capable of manufacturing human red blood cells, hugely increasing the scale and affordability of these *ex vivo* produced cells, opening up the possibility to reduce reliance on donated blood and potentially to use blood as a therapy by adding new functionality to red blood cells.

Improving Precision, Potency and Affordability

Rapid advances in synthetic biology tools and techniques – in turn benefiting from advances in IT, automation and machine learning - are transforming the precision of methods, the speed, potency and affordability of solutions

Facilitating and enhancing operational capabilities

Developments, such as the miniaturization of DNA sequencing technology by **Oxford Nanopore**, and high throughput micro-fluidics by **Sphere Fluidics**, are helping drive down costs and increase ease and speed and of data generation. **Synthace'**s software platform gives biologists sophisticated, flexible and integrated control over lab hardware.

Building better toolkits

Scientists at the **UK Centre for Mammalian Synthetic Biology** in Edinburgh have built a 'tool box' for cell biologists that enables new levels of sophistication in cell engineering for a wide range of biomedical and industrial applications, ranging from the creation of libraries of synthetic transcription factors, the 'master regulators' of cell behaviour, to turning cells into biosensors for drug discovery, helping to reduce the need for animal experimentation.

A network of biofoundries

Biofoundries are seen as part of a natural progression in wet lab activities in relation to synthetic biology. Over the last few years there has been a significant increase in the use of liquid handling robots and automation more generally. Biofoundries are a direct extension of this approach. Foundries are an effective means of increasing reliability and reproducibility in synthetic biology. In 2013 the BBSRC (acting as the coordinating partner for other research councils) funded a number of foundries around the UK - in Earlham, Edinburgh, Liverpool, London (Imperial College). SYNBIOCHEM in Manchester has also developed a biofoundry. This has recently led to the formation of a Global Biofoundries Alliance, of which SynbiCITE has been one of the prime movers.

"It is essential that we develop the full spectrum of expertise required to take advantage of the emerging field of synthetic biology, which has the potential to solve some of the world's most intractable problems. ***Evonetix*** *is developing a radically different approach to gene synthesis, a fundamental technology that underpins this exciting area. Our approach uses silicon chips with independently addressable pixels for the highly parallel synthesis and assembly of high-fidelity DNA at scale"*

Tim Brears*, CEO, Evonetix*
Chairman, BIA Engineering Biology Advisory Committee

Growing the UK Bioeconomy

The UK Bioeconomy Strategy, launched in 2018, sets out to double the size of the Bioeconomy from £220bn to £440bnGVA by 2030. Synthetic Biology has a potentially significant role to play in helping achieve this. In 2016, the SBLC set out a strategy '**Biodesign for the Bioeconomy'** for the development and commercialisation of synthetic biology applications in the UK. Routes to market will be achieved directly via the growth of start-ups and also through their partnership with existing industrial biotechnology companies.

"Both synthetic biology and industrial biotechnology are at the heart of the transformational potential of the bioeconomy. For the past eight years the Industrial Biotechnology Leadership Forum and the Synthetic Biology Leadership Council have been working closely together to ensure a joined up approach with government, funding councils, academia and industry. I was delighted when the UK's National BioEconomy Strategy was launched with us both as co-signatories"

Steve Bagshaw
CEO FujiFilm Diosynth Biotechnologies, Chairman IBLF

Optimising bioprocesses

Ingenza is an Industrial Biotechnology company that provides proprietary, scalable bioprocesses to manufacture products that include chemicals, bio-pharmaceuticals, agri-tech and consumer goods. The company works with global partners, combining synthetic biology with natural selection to create bespoke biomanufacturing systems using bacteria, yeast and mammalian cells.

Renewable chemicals from biofeedstocks

Green Biologics uses evolved and engineered strains of *Clostridia* to ferment biofeedstocks, converting them at commercial scale to sustainable alternatives to petro-chemicals, such as 100% renewable n-butanol and acetone.

As technologies continue to be scaled and refined, the role of engineering biology solutions within the bioeconomy is set to grow substantially

Developing advanced biomaterials and bio-chemicals

In 2018, **SYNBIOCHEM** in Manchester published a roadmap for the development of advanced materials via synthetic biology. The centre's integrated technology platforms provide a unique automated *Design-Build-Test-Learn* pipeline capability for the predictable engineering of microbial bio-factories for chemicals production and material monomers. Working with industry the Centre has developed new routes to antimicrobial compounds, drug precursor chemicals, flavours and fragrances (e.g. pravastatin, menthol and monoterpenes), and new component enzymes for fuels production.

Designer enzymes for chemical transformations

Oxford Biotrans use patented (P450) enzymes to produce high-value chemicals. An example is the bio-conversion of valencene, extracted from oranges, to nootkatone, the flavour and scent of grapefruit.

Cutting-edge foundational DNA tools and technologies for research and industry

OpenPlant is pioneering the development of open tools and innovation in agri-tech research, industrial biotechnology and bioengineering services. These efforts are catalysing domain-specific advances in DNA reprogramming of plants, computational modelling, and artificial intelligence (AI) deep learning approaches that will open revolutionary opportunities for agriculture and bioproduction and deliver step-changing advances in the field.

Addressing Global Challenges

There is mounting awareness of global challenges that must be overcome to maintain a healthy planet and to protect it from increasingly damaging human impacts, such as ocean pollution and climate change. This in turn demands new approaches and technologies.

Synthetic biology is facilitating the development of innovative and potentially disruptive alternatives to conventional approaches

Global freshwater reserves are becoming increasingly polluted due to the accumulation of persistent hazardous chemicals that remain in wastewater after current treatment methods. This leads to increasing water stress, predicted to affect 47% of the world's population by 2030.

Removing persistent micropollutants

CustoMem has applied synthetic biology to develop absorbent that can remove persistent hazardous micropollutants from treated water

The $3 trillion textile/clothing industry is world's 2nd largest polluter of water, the dyeing process itself it harmful to the health of workers.

Low environmental impact dying of textiles

Microorganisms have been engineered by ***Colorifix*** to fix dyes to textiles, reduces water use by 90%, energy by at least 20% and dyes released by 99%, via a process that is itself significantly less toxic to the workers.

Generating alternative market options

Societal awareness and concerns regarding environmental sustainability and associated issues are generating increasing demand for alternatives to conventional food, such as for plant-based 'meat' products or animal-free 'leather' and 'silk'.

Until very recently, such market trends have been most apparent in the US, but are now increasing in the UK, as highlighted in the 2018 'Fashioned by Nature' exhibition at London's V&A museum and featuring **Colorifix**'s synthetic dye approach. Synthetic biology startups are already responding with increasingly innovative commercial solutions.

Effective responses to the effects of climate change include reducing dependence on fossil feedstocks (such as using bio feedstocks for chemicals and materials) and sequestering or using, instead of emitting, CO_2 to the atmosphere. Policy drivers, such as the commitment to establish a Circular Economy are shifting the economic balance of commercial options in favour of those that can convert and add value to waste streams.

Generating advanced and low carbon options

Synthetic biology expertise in the UK's synthetic biology research centres, such as being developed for chemicals and materials at **SYNBIOCHEM** and for gaseous fermentation at **SynBio Nottingham**, are generating a stream of enhanced and alternative technological options in response to these emergent needs and opportunities.

Bio-propane

SYNBIOCHEM, via its spin-out company **C3 Biotechnologies,** is commercialising the world's first fermentation route to bio-propane using biomass propagated from bioengineered bacteria.

Low carbon jetfuel

In October 2018, the world's first commercial flight landed in the UK using low carbon jetfuel derived via a fermentation process from industrial gases from a steel mill. Developed via a partnership between **Lanzatech and Virgin Atlantic,** they are now proposing to develop a commercial biojet fuel facility in the UK.

Ever-increasing global trade and the effects of climate change are increasing the opportunities for diseases to spread rapidly.

Arresting the spread of tropical diseases

Oxitec engineered non-breeding mosquitos to arrest the spread of tropical diseases including Zika, Dengue Fever, Chikugunya and Yellow Fever. Bought by Intrexon for $127m in 2015, it is now operating at commercial scale in Brazil.

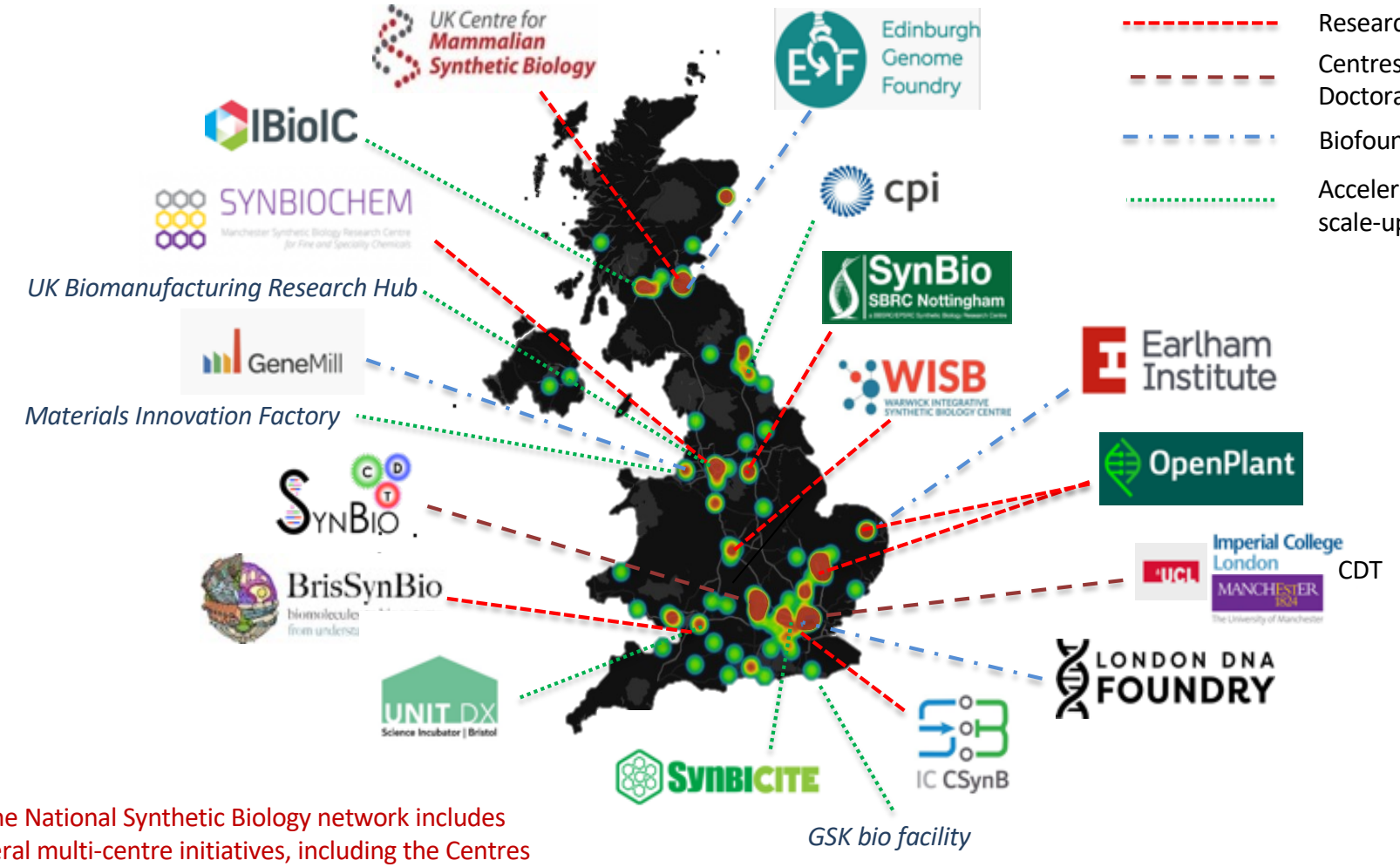
Up to 12 million tonnes of of plastic ends up in the sea each year, including microplastics from cosmetics, bathroom products and tyres, threatening natural systems and increasing market demand for access to less damaging options.

Biodegradable natural polymers

Biome Technologies has developed and supplies innovative biodegradable natural polymers that replace and enhance products previously made from oil based materials

UK-wide start-up company activity: a heat-map

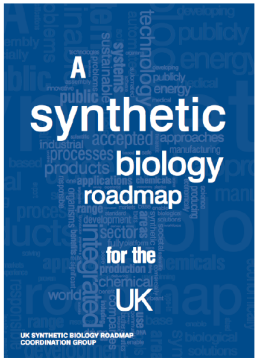
Clusters of companies link to the UK-wide network of
Research, Training and Translation Hubs and Scale-up Facilities



The National Synthetic Biology network includes several multi-centre initiatives, including the Centres for Doctoral Training, SynbiCITE, and the UK Biomanufacturing Research Hub

Building Foundations, Generating Options

Following the publication of the UK Synthetic Biology Roadmap in 2012, the UK government supported Research Council investments into six new synthetic biology research centres ('hubs') and a Centre of Doctoral Training (CDT) to complement to original CSynBi synbio research facility at Imperial College.



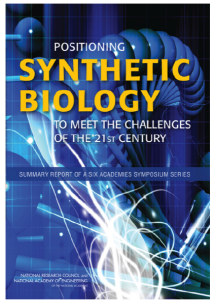
This has generated significant benefits: generating a hub and spoke network connecting more than 30 academic communities the length and breadth of the UK, and forming clusters of expertise able to support the development of local and national business communities.

Synthetic Biology Research Centres (SBRCs)

BrisSynBio (Bristol): biomolecular design and engineering
Centre for Mammalian Synthetic Biology (Edinburgh)**:** cell engineering tools, modelling, and DNA design, construction and phenotyping, for mammalian system applications
OpenPlant (Cambridge and John Innes Centre, Norwich)**:** tools and methods for plant synthetic biology and mechanisms to assist their sharing and deployment
SYNBIOCHEM (Manchester): fine and speciality chemicals (including for drug development, agrochemicals and sustainable materials) production
SynBio Nottingham: industrially-useful products from C1-feedstocks including carbon monoxide and the greenhouse gases carbon dioxide and methane
WISB (Warwick**):** next-generation tools and systems, biosynthetic pathways, synthetic communities of microbes, and plant-microbe interactions
CSynB (Imperial College London): platform technology for synthetic biology that can be applied across a wide range of applications

Building on a foundation of research excellence and expertise: the UK & US have generated more global publications in synthetic biology than the rest of the world combined

Active Participation of Learned Societies and Private Consultancies



The **Royal Society** and **Royal Academy of Engineering** (RAE) have been proactively contributing to the evaluation and dissemination of synthetic and engineering biology by learned societies, through to the present day. Contributions include the initial RAE report in 2009, Engineering Biology 2019, and co-hosting the 'Six Academies' workshops alongside counterpart societies from the US and China in 2010-2011. In 2017, the Royal Society hosted a conference, 'Synthetic Biology – Does Industry Get it?'.
In 2018 **Cambridge Consultants** published its workshop outcomes: 'Building the Business of Biodesign'

Innovation Centres, Clusters and Networks

Innovation clusters: Imperial White City

A major new synthetic biology innovation cluster in London has been established in and around the iHUB building on the new Imperial College White City Campus. SynbiCITE, the National Translation Centre for Synbio in the UK, has taken over the first floor of the building. The new SynbiCITE configuration includes the SynbiCITE Headquarters, the London Biofoundry, the Imperial/NPL Centre of Excellence for Engineering Biology, Metrology and Standards,

and a number of Synbio Start-ups/SMEs (including CustoMem, CyBio and Arborea), Synthace and Agilent are in close proximity. SynbiCITE is also partnering with RebelBio, a pre-seed accelerator that works across a range of disciplines, which is also located on the White City Campus.

Innovation clusters: Bristol and Glasgow

To address the urgent need for start-up lab space in Bristol, founders of the biodesign start-up **Ziylo** created **Unit DX**, a dedicated spinout incubator in the heart of the city which now hosts over 20 science-driven companies including four new biodesign companies stemming from BrisSynBio research (**Zentraxa**, **CytoSeek**, **Imophoron** and **Rosa Biotech**). **IBioIC** operates as an innovation centre In Glasgow for industrial biotechnology and synthetic biology, with a particular role to stimulate growth of the sector in Scotland

Manufacturing Process Development

A seven-year investment has been made into establishing the **UK Future Biomanufacturing Research Hub,** comprising several major centres across the UK, led from the University of Manchester, which will develop new underpinning technologies based on industrial biotechnology to enable efficient, sustainable and innovative bio-based manufacturing in three key sectors – Pharmaceuticals; Value-added Chemicals; Engineering Materials.

Imperial/NPL Joint Centre of Excellence in Engineering Biology, Metrology and Standards

The increasing importance of the Bioeconomy and the need to undertake the effective industrial translation of synthetic biology, requires the establishment of appropriate metrology and technical standards. Establishing industry-led measurements and standards will safe-guard the quality and safety of products, and allow companies to maintain competitiveness and enhance innovation. This innovation hub will further engage with industry to help transform high-value manufacturing into high-value products that will deliver economic and societal benefits.

Engineering biology at commercial scale

Facilities and expertise to support process development scale-up have been made available not only at institutional centres such as the national Centre for Process Innovation (**CPI**), but also through established companies including Unilever's **Materials Innovation Factory** in Liverpool, opened in October 2018, and at GSK's manufacturing facility in Worthing.

The UK Innovation Pipeline and Eco-system

Throughout the past decade, the UK has developed a uniquely supportive eco-system to support the translation and commercialisation of synthetic biology, leveraging public and private funds and establishing standards and guidelines to help accelerate ideas responsibly through the pipeline to market.

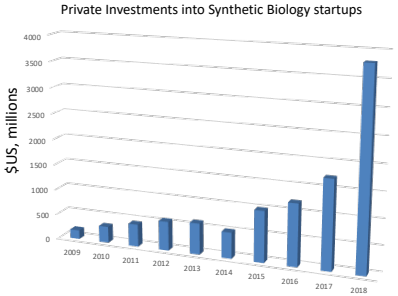
Stimulating opportunities for private investment

The UK Science and Innovation Seed Fund, managed by Midven, together with numerous private investment funds, support the commercialisation of synthetic biology technologies. Already by 2016, the ratio of private to public funding was exceeding 10:1.

There are now more than 150 UK-based synthetic biology start-ups, attracting increasing quantities of private funding relative to the initial public investment as new start-ups appear and as existing ones mature.
An increasing number of successful 'exits' – IPOs and acquisitions – such as **Oxitec, Quethera** and **Autolus** - demonstrate the establishment of the complete innovation pipeline from initial ideas through to commercial realization.

Private investments into US & UK synbio start-ups have been growing at over 35% pa over past decade, and reached $3.8bn in 2018.

Source: SynBioBeta



Since the start of **BrisSynBio** in 2014 there has been a surge of new biodesign innovation. Instrumental to this change was ***Ziylo***, a biodesign company established to commercialise the glucose binding technology developed in Bristol University by Prof. Tony Davis. In 2018, Ziylo was sold to the Novo Nordisk for a deal that could exceed £620 million.

The top 70 UK synthetic biology start-ups have attracted over £1.8bn private investment in the past 5 years

Whilst lower in total, on a per capita basis, UK synbio start-up companies attract even more private investment than their US counterparts.
As many more applications are developed and start-ups enter and grow through the pipeline, it is anticipated that UK start-ups could attract at least £1bn a year private investment within the next few years.

Responding to societal expectations

Synthetic Biology Dialogue

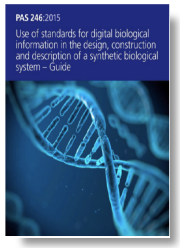
Recognising the close relationship between technological applications and market interests, as highlighted in the Public Dialogue 2011 and reflected in the UK Roadmap 2012, Responsible Research and Innovation (RRI) practices have been embedded in all the synthetic biology research centre programmes.
RRI approaches for synthetic biology are being pursued nationally, not only in the hubs but also, for example, in the Universities of Exeter, Sheffield and Newcastle.
A Biological Reporting hotline has been set-up to ensure effective response mechanisms are in place to address specific concerns.

Governing the innovation ecosystem

A thriving synthetic biology sector in the UK will require an innovation ecosystem that supports the translation to market of products based on the research done in the UK. The Innogen Institute in Edinburgh University, working with the SBLC and its Governance Subgroup (GSG), has developed a framework for Proportionate and Adaptive Governance of Innovative Technologies (PAGIT). This has contributed significantly to the UK Government programme on *Reforming the Governance of Technological Innovation* which will support a smarter approach to regulating the products of gene editing and synthetic biology. Based on PAGIT, BSI is now developing a *Standard for Responsible Innovation*.

Standards and metrology driving precision and predictability

Key to commercial industrialisation is precision and predictability.
Guidelines for the use of standards relating to synthetic biological systems (PAS 246) were published in 2015 by the British Standards Institution (BSI). Significant progress has been achieved in establishing internationally agreed technical standards, including SBOL (synthetic biology open language), adopted by ACS Synthetic Biology as a basis in 2016. Ongoing developments include the CAD standard DICOM-SB. The standard facilitates the characterisation of biological components (eg Bioparts) by the comprehensive capture of the data, metadata and notes associated with a characterisation experiment. DICOM-SB automatically converts these into comprehensive electronic datasheets for use by Bio-designers



"The early development and adoption of standards is one of the keys to accelerate the commercial success of the many start-up companies working in Synthetic Biology. As a leading global standards organisation, BSI sees itself as an integral part of the ecosystem supporting the SynBio community in the UK and internationally. As the journey towards digital technology continues, we welcome the achievements in the sector in recent years to develop and adopt consensus standards that will strengthen industry competitiveness and boost performance"

Scott Steedman *CBE*
Director of Standards, BSI

Building an Expert Workforce

Multidisciplinary skills via iGEM

iGEM inspires undergraduates, postgraduates and even school students to participate in multidisciplinary teams to discover and explore the technical, societal and entrepreneurial issues arising from the application of synbio techniques through participation in this annual Global Jamboree.

To date, the UK has fielded 146 teams, comprising over 2000 students from 29 different institutions. It has achieved numerous competition awards, including the Grand Prize (top out of 158 undergraduate teams) in 2016.

iGEM Grand Prize Winning team 2016

Many of the UK's start-up companies are founded, or staffed by, students who have participated in iGEM

"Participating in the iGEM competition created the breeding ground for CustoMem to form. It also shaped our diversity and Policy & Practices focus, which enabled us to hire exceptional scientists & engineers from 5 continents, including 6 females out of 12 FTEs. The profile of the competition provided a platform to engage governments from the US EPA to Singapore, crucial for highly regulated sectors like water treatment with engineered biomaterials"

Henrik Hagemann
Chief Executive Officer & Cofounder, CustoMem Limited

Higher degree training and skills development

Doctoral Training, Masters courses and undergraduate lectures in synthetic biology are now being given in numerous universities, including via dedicated centres for doctoral training (Bristol-Oxford-Warwick and, from 2019, in Imperial-University College-Manchester).

Over 1000 postgraduates have been trained in synthetic biology in the UK since 2014.

Inspiring and training entrepreneurs

SynbiCITE, the National Translation Centre for Synbio in the UK provides a range of training opportunities including the 4 day MBA for synthetic biology entrepreneurs, assisting the personal transition from academia, and the translation of application ideas into commercially viable start-ups Extending skills out into the national workforce not only at its White City campus but also in other regional centres.

Extending skills out into the national workforce

Start-ups themselves are also playing a significant skills development role by training employees on the job. It is estimated that the 150 UK start-ups to date now employ over 2000 staff. As synthetic biology contributes to and transforms manufacturing and services throughout the BioEconomy, so the benefits to an ever-wider range of jobs are being generated.

International Partnerships and Global Outreach

UK research centres and funders have fostered a wide range of international partnerships, that ensure that the UK SynBio ecosystem remains a valued partner with leading initiatives worldwide, and remains a significant influencer not only of technical developments but also of standards and societal engagement.

The UK has continued to work closely with US counterparts on many aspects of the development and commercialisation of synthetic biology, including joint workshops and roadmapping, research and training programmes (such as LEAP and Lean Launchpad), biosecurity, standards and metrology.

On the programmatic side, Dstl and UKRI have built strong international links, with a particularly strong interaction with the US, as indicated by US funding of projects in the UK.

International partnership and outreach programmes now extend globally.

Collaborating with Singapore's National University

SynbiCITE helped in the formation of SynCTI at Singapore's National University (NUS). Like SynbiCITE, SynCTI works with a range of companies, particularly start-ups and SMEs. Over the last few years there has been increasing collaboration between the two centres, to the point where now the centres collaborate on the support of a number of companies, as well as basic research projects and the development and implementation of strategy for industrial translation. In addition, the two centres have complimentary Biofoundries.

UK Max Planck-Bristol Centre for Minimal Biology

In April 2019, based on the world-leading fundamental synthetic-biology research at **BrisSynBio**, the University of Bristol and Max Planck Society created the Max Planck-Bristol Centre for Minimal Biology. It aims to understand the foundations of life and how it arose from non-living matter.

Mammalian Synthetic Biology and cell engineering

The **UK Centre for Mammalian Synthetic Biology** in Edinburgh the leading location in Europe for research and innovation in mammalian cell engineering. In 2020, it will host the Mammalian Synthetic Biology Workshop – the first time outside of the USA.

Global outreach and capacity building

OpenPlant has surveyed the potential benefits and bottlenecks for application of new technologies in the development of bioeconomies across Africa. It has developed the ***Biomaker*** programme to harness frugal and open technologies for interdisciplinary project-based learning and capacity building, and supported almost 200 projects across the UK and Africa. This is now being extended to the US, Canada and Australia.

References and Acknowledgments

All these achievements would not have taken place without the efforts of many organisations and individuals, including major research funding initiatives by the UK Government and UKRI.

Data sources used here include documents noted below, materials and analysis from SynbiCITE, SynBioBeta (www.synbiobeta.com), the SBLC and directly from the many institutions and companies referred to throughout.

There are many other significant and illustrative examples that regrettably could not be included here due to limitations of space, whilst for those that are included the very brief descriptions possible inevitably fail to fully represent the breadth and richness of current activities and future potential. Further clarification should be sought from the relevant websites and via individual contact mechanisms. The Knowledge Transfer Network (KTN) can assist in tracking down other companies and in identifying potential partnership opportunities. KTN's Synthetic Biology Landscape map (https://synbio.ktnlandscapes.com) also provides an overview of companies and research capabilities operating in the UK.

Further details about the UK Synthetic Biology Leadership Council (SBLC), including its current membership can be found on its website: *https://www.ktn-uk.co.uk/programmes/synthetic-biology-leadership-council*

Synthetic Biology (RAE)	https://www.raeng.org.uk/publications/reports/synthetic-biology-report
Public Dialogue	https://bbsrc.ukri.org/documents/1006-synthetic-biology-dialogue-pdf/
UK Synthetic Biology Roadmap	https://www.ktn-uk.co.uk/perspectives/a-strategic-roadmap-for-synthetic-biology-in-the-uk-2012
Eight Great Technologies	https://policyexchange.org.uk/wp-content/uploads/2016/09/eight-great-technologies.pdf
Biodesign for the Bioeconomy	https://ktn-uk.co.uk/perspectives/biodesign-for-the-bioeconomy-uk-strategic-plan-for-synthetic-biology
BSI PAS 246:2015	https://shop.bsigroup.com/forms/PASs/PAS-2462015/
LifeSciences Industrial Strategy	https://www.gov.uk/government/publications/life-sciences-industrial-strategy
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