# SynBio SRI

## December 2017 Report

**The Synthetic Biology Strategic Research Initiative provides a hub for anyone interested in Synthetic Biology at the University of Cambridge, including researchers, commercial partners and external collaborators.**

Synthetic Biology is an emerging field which applies engineering principles to the design and modification of living systems. The University of Cambridge has been an important and early contributor in this area. The Synthetic Biology Strategic Research Initiative was established in 2013 with the support of the Schools of Biological Sciences, Physical Sciences and Technology to bring together related activities by researchers across the University.

Academic leadership of the SRI is provided by the Steering Committee, supported by the SRI Coordinator who works with researchers and external partners to implement SRI activities. The major aims of the SRI are to:

1. Provide a hub of interdisciplinary exchange for all those interested in Synthetic Biology at the University of Cambridge, from researchers and students to industrial partners and policy makers.
2. Promote interdisciplinary collaborations across the University through regular events and twice-yearly seed funding competitions.
3. Facilitate funding applications in the field of Synthetic Biology
4. Initiate academic-industrial partnerships across the SRI Research Themes.
5. Explore open technologies for innovation, widening participation in novel IP practices and business models for tools related to Synthetic Biology.
6. Explore the wider social context of GM technologies at the local and global level, particularly responsible innovation for sustainability and conservation.

## 1. Our Achievements 2016-17

The SRI has the objective of building a vibrant, self-sustaining and interdisciplinary community around the new discipline of Synthetic Biology in Cambridge and in the last year we have focused on consolidating this effort to establish strong foundations for an IRC. Our three main areas of development are (i) interdisciplinary exchange, including fostering scientific collaboration, shared curriculum development, participation in large scale funding initiatives, and international leadership in the development of new approaches to synthetic biology (ii) open technologies as catalysts for innovation and industry and (iii) responsible innovation.

**Interdisciplinary exchange**: The SRI provides a hub for exchange and collaboration between the physical sciences, life sciences and engineering to underpin advances in Synthetic Biology. Significant achievements since December 2016 include:

(i) BBSRC GCRF funding to explore practical and impactful applications of synthetic biology in Africa and other poorly resourced environments. A meeting was held a in South Africa in Feb 2017 with a wide range of participants from Cambridge, Africa and beyond. The meeting led to publication of a report: Capacity building for the bioeconomy in Africa (https://www.openplant.org/global-challenges/).

(ii) A consortium of UK and South African scientists led by Dr. Jim Ajioka has been awarded £1.8M EPSRC GCRF funding for the Low Cost Viral Diagnostics with our SA partners. This was a direct outcome of the Bakubung GCRF meeting earlier in the year. The grant will be focused on the implementation of open source, cell-free *in vitro* diagnostics to produce better systems for viral diagnosis under African conditions.

(iii) A Lecturer in Synthetic Biology is being recruited in the Department of Engineering, with the support of the School of Biological Sciences. This is the first senior position dedicated to synthetic biology to be created in Cambridge and represents an excellent opportunity to develop interdisciplinary links and synthetic biology research and teaching at the University. The Lecturer is likely to be based in the Nanoscience Centre, offering additional links to departments in West Cambridge.

(iv) An extensive programme on cell-free synthetic biology is underway. This is an emerging area of interest using cell-free extracts from bacteria or other organisms to transcribe and translate engineered DNA over a short time course, without GMOs and in resource-poor environments. Recent technical advances have enabled many applications from production of biologics to paper-based diagnostic tests and biosensors. Since Dec 2016 our activities have included i) a formal SynBio Forum on 'Programmable cell extracts –a new biomanufacturing paradigm'; ii) a hands-on practical workshop on cell-free synthetic biology for physicists and engineers, held on the West Cambridge Site; iii) a BBSRC-GCRF supported workshop on diagnostics for early career researchers with guest speakers Richard Echodu (Gulu University, Uganda) and Keith Pardee (University of Toronto); iv) an OpenPlant-supported working group on open curriculum development for cell-free synthetic biology; v) submission of several research and capacity building grants to support future work.

SRI and OpenPlant researchers are taking an international coordination role on capacity building and curriculum development in this area and multiple future bids are planned to support research and education activities at scale.

(v) The Cambridge Synthetic Biology Meetup site[1] provides a hub for engagement and has grown by over 200 members in the last 12 months to a total of over 700 with 80-100 active members and 50-100 attending events each month. This includes Cafe Synthetique at the Panton Arms and Science Makers at Cambridge Makespace, which regularly attract varied audiences from both the University and the Cambridge Cluster. Cambridge Consultants have recently become industrial sponsors of the Cafe Synthetique meetings, and the Science Makers events have expanded from prototyping hardware to hands-on biology.

(vi) The SRI has successfully fostered interdisciplinary exchange at the student level through:

a) support of the Synthetic Biology Society through an SRI/SRN small grant and an OpenPlant Fund award for student-led hardware and biology projects.

b) initiating an interdisciplinary Development i-Teams project on paper-based diagnostics using synthetic gene circuits in Michaelmas 2016. The resulting social enterprise Open Diagnostics have raised > £10k through competitive enterprise funding and > £8k through grants supported by the SRI including a BBSRC GCRF IAA award. The team are now part of the Centre for Global Equality Cultivator and are contributing to larger scale GCRF bids.

c) designing a project and mentoring students for the Sensor CDT 2017 Team Challenge. Twelve MRes students worked for 14 weeks to prototype an arsenic biosensor using cell-free synthetic biology and electrochemistry. Feedback from academic assessors was very positive and the project has been presented at Sensors Day and the Biomaker Fayre. Work is now being finalised for publication.

[1] http://www.meetup.com/Cambridge-Synthetic-Biology-Meetup/

**Open technologies for innovation**: We aim to promote the adoption of more open practices for sharing of the new tools required for Synthetic Biology to promote innovation, translational research, and facilitate exchange between academia and industry.

(v) Biomaker Challenge funded forty interdisciplinary teams featuring 140 individuals from across four Schools ( % of total Challenge participants: SBS - 16%, SPS - 12%, CS - 19%, ST - 10%) and from a range of external organisations including the Royal College of Art and Norwich Research Park (22% of total Challenge participants). The aim was to prototype open-source biological instruments as a reciprocal educational opportunity for biologists and engineers and improving their own research. The judges were very impressed by achievements in just four months and over 100 people attended the Open Technology Workshop and Biomaker Fayre exhibit. Awards were presented for:

- Best Technology: A low-cost chromatography system for protein purification.
- Best Biology: PiRMA: A low-cost rodent physiology monitoring bed for preclinical experiments.
- Maker Spirit: A DIY focus stacking system for macrophotography of developing ferns.

An online platform was established at Hackster.io to share designs and reach a larger audience of hardware experts and enthusiasts. The initiative was funded by the Isaac Newton Trust through a joint grant with CamBridgeSens and by the OpenPlant Fund.

(vi) To facilitate exchange and technology transfer, since 2014 the SynBio SRI along with OpenPlant has worked with Dr Linda Kahl of the Biobricks Foundation to draft an OpenMTA: a permissive materials transfer agreement enabling redistribution and commercial use of biological materials. The first transfer was made during 2017, a manuscript on the OpenMTA has been submitted for publication and another paper is forthcoming using the OpenMTA to share materials for a new open source DNA Assembly technique. A series of videos were filmed in Cambridge with case studies of potential OpenMTA users and the work has been presented at international scientific conferences such as SB 7.0 in Singapore, meetings in South Africa and Chile and at technology management conferences such as AUTM annual meetings in the US.

(vii) The SRI and collaborators are convening a CRASSH Faculty Research Group in 2017-18 examining 'Open Intellectual Property Models of Emerging Technologies' for synthetic biology, artificial intelligence and green technologies. This offers an excellent opportunity to expand the SRI's network in the arts, humanities and social sciences and examine the theoretical and empirical potential and impact of our work on open technologies. Attendees in the first term include researchers and professionals from POLIS, Institute of Development, Institute for Manufacturing, Faculty of Law and Cambridge Enterprise along with existing SRI collaborators such as CSER. This interaction also led to a successful application for an ESRC Industrial Strategy PhD studentship on open approaches to IP within synthetic biology firms based with Dr. Frank Tietze in the Institute for Manufacturing and co-advised by the SRI Chair Prof Jim Haseloff.

**Responsible innovation for sustainability and conservation**: Social acceptance remains a major potential limitation for the adoption of GM technologies, and the SRI therefore funds work on the wider implications of the technology at local and global scales.

(viii) The SRI co-organises termly lunch meetings with CsaP and Cambridge Centre for the Study of Existential Risk (CSER) as a node of the Virtual Institute for Responsible Research (VIRI) based at Arizona State University (ASU). Topics during 2017 included the role of responsible research and innovation (RRI) in the Global Challenges Research Fund with guest speaker Simon Trace (previously CEO of Practical Action) and the relationship of RRI to chemical, biological, radiation and nuclear risks. Our activities were presented by the SRI Coordinator at the Annual VIRI Meeting in Arizona.

(ix) The results of a transatlantic Bioengineering Horizon Scanning Exercise convened in 2016 by CSER, the SRI and the Future of Humanity Institute in Oxford has been published in eLife (DOI: 10.7554/eLife.30247). Over twenty individuals selected the highest priority but least recognised technical and social issues in biological engineering that will impact the world in the next 15-20 years. This work formed the basis of a press briefing by

the Science Media Centre and featured on the Radio 4 programme Inside Science, and in an eLife podcast with the Naked Scientists.

(x) The SRI and OpenPlant hosted a workshop on the Nagoya Protocol in late 2016 which is being prepared as a report by the Engineering Life project at the University of Edinburgh. SRI members have also been interviewed as part of projects on potential implications of new synthetic biology research trajectories on the International Treaty for Plant Genetic Resources for Food and Agriculture and the role of social science interventions and responsible innovation in synthetic biology.

**Other achievements:**

xi) Three public engagement events during 2017 focused on making connections with historians, artists and designers. The Cambridge Science Festival event 'Hacking biology through time and space' attracted over 60 people for a historical foray into amateur biology using research-grade technologies: from horticulturists using X-rays in the early 20th century to modern DIY Biology with gene editing. During the Festival of Ideas, sold out events ‘A sense of colour’ and ‘The Colour Institute Art and Science Soiree’ looked at production and use of biological colour and use of colorimeters and spectrometers from a range of disciplinary perspectives including visual arts, chemistry and history.

xii) Members of the SRI and Steering Committee have supported the establishment of Biomakespace, a non-profit community lab on the Biomedical Campus. Some of the first projects to use the space will be the University Synthetic Biology Society, Open Diagnostics, a Biomaker Challenge team and an OpenPlant-supported public engagement project on synthetic gene circuits. Biomakespace has been highlighted at the University Enterprise Network for its potential to support pre-entrepreneurial activity in biotechnology and it offers a space for informal learning opportunities and collaborative research that complements the activities of the SRI.

# 2. Context

Cambridge continues to develop an internationally recognised lead in i) plant synthetic biology, ii) adoption of open practices, iii) development of technologies for international exchange such as the Arsenic Biosensor project and now iv) an emerging role in international coordination of educational and capacity building activities using cell-free synthetic biology. This puts it in a unique position among other UK universities and centres and in a very strong position to take advantage of the £1.5 bn Global Challenges Research Fund. We are therefore directing substantial efforts to seeding collaborations both within Cambridge and with external collaborators, with a focus on Africa and Latin America, and plan to apply to the next large scale capacity-building call from the GCRF.

We expect that future synthetic biology funding initiatives at a national level outside of the GCRF will aim to enhance translational research and applications to drive economic growth, building on the earlier funding of the UK Synthetic Biology Research Centres. Estimates for the growth of the global synthetic biology market are 30-50% pa, with a value of US$ 25-40 bn by 2020 (www.alliedmarketresearch.com). A growing number of companies are emerging directly from academia. For example, Ginkgo Bioworks has grown from a small academic group based at MIT, to raise over $250M and gain a company value of over $500M since 2008.

Most Cambridge research activity is foundational and focused on developing knowledge and enabling technologies. A major role of the SRI is identifying partnerships to take advantage of these translational funds but also looking outside UK government funding to international public and philanthropic opportunities. We are already in discussions with Australia’s Synthetic Biology Future Science Platform, which was funded by AUS$30m in 2017 and is interested in adopting initiatives from Cambridge including the Biomaker Challenge.

# 3. Plans to 2019

The remaining period of the SRI award will be spent creating opportunities for meaningful collaboration and successful research funding bids within the vibrant, interdisciplinary community established during 2013-17. Starting from a small pool of original members, the last four years have seen the SRI progressively expand

activities to bring in participants from across all career stages and all Schools - particularly SBS, SPS, ST and HSS. This expansion now needs to be consolidated and our plans include:

**(i) Strengthening our network of cross-School connections:** we will maintain our programme of monthly networking events and the termly SynBio Forum, but steer their primary focus from attracting new groups to strengthening existing interactions and creating a denser network of collaborators in areas of strategic interest. For example, we collaborate closely with CSER and plan to run a SynBio Forum with the Centre for the Future of Intelligence on 'Synthetic Biology, AI and Emergence'. We also plan an evening with Chris Voigt (MIT), who works on reprogramming bacteria to perform sophisticated sensing and computation. Some of the more informal community building activity initiated by the SRI is now self-supporting through the volunteer-led Biomakespace. The Biomaker Challenge has been our most successful initiative to date in terms of involvement from the Clinical School and we plan to repeat it in 2018-19 with increased cross-connection between the teams.

**(ii) Expanding our programme on cell-free synthetic biology in the following ways**:

a) Building research capacity in Cambridge: We intend to establish capabilities to produce cell-free extract in Cambridge and encourage the expansion of on-going projects using cell-free across the Departments of Plant Sciences, Physics, CEB and Pathology.

b) Gaining funding for GCRF capacity building activities: We are working closely with the Global Challenges Initiative and see great potential for upcoming GCRF calls to fund activities in synthetic biology. In the first instance we are seeking to follow-up the OpenPlant workshop at University of Pretoria in Feb 2017 and the working group meeting in July 2017, which convened support from major cell-free researchers internationally. We will submit a large-scale capacity building grant to develop open source and low-cost curricula for cell-free synthetic biology, using a practical design-build-test model complemented with numerical and computational tools.

c) Early-career community building: We will organise monthly cell-free synthetic biology meetups, which will act both as opportunities to share advances and funding opportunities but also mentoring meetings for groups who are coordinating student-led learning activities and explorations of applications in a development context.

**(iii) Evaluation and documentation of our initiatives for transfer to other organisations:** we have had interest from Australia and South Africa in adopting the Biomaker Challenge and inclusion in our curriculum development activities. The University of Pretoria will run a trial team in 2018. We will therefore put more resources into documenting and communicating these activities. This includes online documentation using widely known platforms such as hackster.io, enabling us to broadcast to and potentially recruit from a larger audience of technologists.

**(iv) Interdisciplinary work on open technologies:** we will continue to promote theoretical and empirical work in the humanities and social sciences to better understand the role and impact of open technologies. The SRI aims to change working practices and narratives about innovation in synthetic biology so evidence and proactive evaluation of that change from an economic, legal and social perspective is important. The results of our CRASSH Faculty Research Group will be written up as a whitepaper or edited collection to form the basis of further grants.

The SRI Award has catalysed strategic engagement and informal recruitment to synthetic biology within Cambridge. We believe that this has resulted in increased recognition, at all levels within the University, that a fundamental shift is taking place in biological research. Engineering approaches could be as transformative in biology as the electronics revolution has been in the physical sciences, and enable rational design and reprogramming of biological systems. This transformation requires the recruitment to the field of biologists, chemists, physicists, computer scientists and engineers together with entrepreneurs and new investment; which requires cross-school coordination and support. The University has acknowledged this, originally through the SRI Award and now through the establishment of a Lectureship in the Department of Engineering with joint support from the Schools of Biological Sciences and Technology. We wish to see this trajectory continue. We are also seeing a shift towards acceptance of open technologies as a viable and impactful model for knowledge transfer in areas beyond software. For example, the University is a signatory of the OpenMTA and WaterScope, the social enterprise built around an open source 3D-printed microscope which received early investment from the SynBio

Fund, was awarded the 2017 Vice Chancellors Impact Award. We anticipate further examples by the end of the SRI Award in 2019.

# 4. Progression to be an Interdisciplinary Research Centre

We intend to seek post-SRI status as an IRC. Governments around the world from the UK to South Africa, China, Australia and Canada are recognising that developing a knowledge-based bioeconomy is imperative to transforming sectors such as agriculture, manufacturing and health to increase economic productivity and tackle the grand societal and environmental challenges of our time. Synthetic biology provides an engine for future bioeconomies and the Cambridge synthetic biology community has much to offer in terms of knowledge, technology and a unique vision of how bioeconomies might be constructed to provide more equitable global benefits.

We envisage the Synthetic Biology IRC developing into the Cambridge Institute for Bioengineering, with a remit to support open source biological engineering that will underpin sustainable and inclusive development for the global bioeconomy. The Institute would i) research foundational biology, engineering, chemistry, physics and computer science; ii) create open enabling technologies and platforms, iii) translate these open resources into impactful applications for public good; iv) research the impact of new innovation and financing models on the bioeconomy, to influence emerging public policy. We aim to establish a UNESCO Chair that will advance this research agenda. UNESCO Chairs[2] 'serve as think tanks and bridge builders between academia, civil society, local communities, research and policy-making' and would clearly communicate the aspirations of the IRC to effect positive change in the wider world.

**Brokering collaborations on engineering biology for global challenges**

In order to deliver this longer term vision, which requires a critical mass of co-localised researchers and facilities, the IRC would initially focus on brokering relationships and collaborations between researchers across departments, building on connections made through the period of the SRI Award. We recognise that faculty within the SRI have different aspects of bioengineering as the primary focus of their lab, but have identified its importance, complementarity and potential. The IRC's early role will be to foster the researchers who could form the core of the Institute, and develop opportunities for reciprocal connections with departments across Schools, enabling more researchers to benefit from opportunities in biological engineering - that reside at the boundaries between disciplines. The IRC will adopt a proactive role in identifying useful and impactful areas of interaction, matching collaborators and funding sources, facilitating proposals and wherever possible, brokering access to the infrastructure and facilities required to progress. This approach would benefit from shared collaborative space as a staging post towards establishing a full Institute and opportunities for that will be explored.

**Coordinating research themes that leverage Cambridge's strengths**

The IRC would support projects and funding applications clustered around research themes such as:

i) Plant synthetic biology: Cambridge has an internationally recognised lead following the award of the £12m BBSRC/EPSRC OpenPlant Synthetic Biology Research Centre in 2014. The base for a new era of plant engineering is being established here by research on *Marchantia* as a model system for plant synthetic biology and development of community-led standards and toolsets. This work offers great potential for Cambridge to maintain its position at the cutting edge of the field. Major applied challenges are also being tackled at the University, such as programmes funded by the Gates Foundation to introduce nitrogen fixation and C4 photosynthesis into new crops with the potential to drastically improve yield and increase global food security.

ii) Sustainable biomanufacturing: Cambridge has potential to become a world-leading research centre for sustainable biomanufacturing through ongoing research on chloroplast engineering and cell-free protein expression. These technologies promise to underpin manufacturing in the bioeconomy and revolutionise large scale production of protein products such as vaccines, therapeutics and high value enzymes, plus compounds

[2] https://en.unesco.org/unitwin-unesco-chairs-programme

such as pigments and nutritional supplements. The advantages are not only economic but also environmental: chloroplasts as self-assembling and self-replicating biological factories can be seen as key potential components of a circular economy, where bioproduction is regenerative and waste-minimising by design. The UK government has committed £162m to develop the manufacturing infrastructure for innovative medicines through the Industrial Strategy Challenge Fund and we see great potential for industrial partnerships in this field.

iii) Cell-free synthetic biology: this area has great potential for biosensors and diagnostics, particularly low-cost, point-of-care tests for diseases and pollutants, as demonstrated by the award of a £1.8m EPSRC grant for research led by Dr. Jim Ajioka. The IRC will continue to develop this highly interdisciplinary work which requires expertise and fundamental research from physics, engineering, computer science, chemical engineering, materials science and other fields.

Beyond these themes, we will provide a hub for exchange and support a broad base of research at the interface of biology and engineering in order to leverage greatest benefit from the unique opportunities provided by the excellent research taking place across the wider University and the Cambridge Cluster.

**Rethinking innovation and impact**

A distinct aspect of the IRC will be embedding open source approaches, social entrepreneurship and innovation for public value as key drivers for knowledge transfer activities and interdisciplinary research with the social sciences and humanities. Our activities will include developing open curricula for synthetic biology, capacity building for growth of the bioeconomy, supporting early career researcher-led development of open technologies and engaging makers and community scientists. We are confident that industry sponsors will also engage on a basis of open exchange as demonstrated i) in drug discovery by the Structural Genomics Consortium, which has partnerships with many major pharma companies and has received over $100m private investment to generate pre-competitive, open access data, tools and technologies; ii) in nanoscience and materials by the SPOMAN Open Science platform within the iNano initiative at Aarhus University in Denmark, where students and companies such as Alfa Laval, Lego and ECCO collaborate on pre-competitive open research. Our approach is unique from our global competitors and Cambridge has the capacity for ground-breaking work in rethinking innovation models for biotechnology.

Our vision cannot be realised without a new integrated approach to research appointments, teaching and space within the University and critically, co-location of researchers and students with the necessary facilities. We therefore believe that an Institute that sits outside of established departments is the way forward for synthetic biology at Cambridge to achieve global impact. We are preparing a case to present to potential donors, as substantial private philanthropic funding will be required to take the vision forward. We are also formulating the steps an IRC would need to take towards this goal and its concrete structure and activities.