Strategic Research Initiatives at the University of Cambridge

Annual Report – December 2018

Synthetic Biology Initiative

https://www.synbio.cam.ac.uk

ACHIEVEMENTS

1. What has the SRI achieved since your last written report to RPC?

The SynBio SRI continues to play a coordinating role for interdisciplinary scientific exchange in Synthetic Biology in the University. It has established, and continues to organise a series of events to promote interdisciplinary exchange and community building. The Synthetic Biology SRI maintains a website that provides a hub for information exchange (**https://www.synbio.cam.ac.uk**) , and events are advertised through the **Cambridge Synthetic Biology Meetup Group**, which has grown to over 900 members.

(i) **The Synthetic Biology Forums**:
Synbio.cam.ac.uk
This is a termly speaker event featuring high-profile speakers and excellent networking opportunities, held at the Old Divinity School auditorium.

- 24 April 2018: **Harnessing Genetic Regulation for Redesigning Organisms** with Chris Voigt (MIT) and Somenath Bakshi (Harvard)
- 29 Oct 2018: **Engineering Complex Systems in Biology** with short talks by representatives from Microsoft Research, Nvidia and Mathworks followed by keynote presentations by Sabine Hauert (University of Bristol) and Ricard Sole (Universitat Pompeu Fabra, head of the Complex Systems Lab)
- 11 Feb 2019: **Machine Learning for cell biology and genetics** with Brenda Andrews (University of Toronto)

(ii) **Cafe Synthetique**
This is a monthly meetup for the Cambridge synthetic biology community featuring informal talks and discussion in a pub setting.

- 22 Jan 2018: **Low-cost Open Hardware for Biology** (2017 Biomaker Challenge winners, Dominick Macintyre, Marcel Gehrung, Wolfgang Schmied, Stéphanie Polderdijk)
- 19 Feb 2018: **AI and Automation** Clayton Rabideau (CEB) and Gareth Conduit (Royal Society University Research Fellow in the Theory of Condensed Matter Group)
- 19 Mar 2018: **Synthetic Biology Industry Night** (Nicolas Kral of Phytoform Labs, Orr Yarkoni of Colorifix)
- 16 April 2018: **Design, Information and Chemical Engineering** with Lisa Hall (CEB) and Glenn Vinnicombe (Dept. of Engineering)
- 21 May 2018: **Next Generation Synthetic Biologists** curated by SynBio Soc with Om Patange (Sainsbury Lab), Vaclav Beranek (MRC LMB) and Jarrod Shilts (Sanger)
- 16 Jul 2018: **Open Source Innovations in SynBio** with Hadrien Peyret (JIC) and Stephanie Hohn (DAMTP)
- 20 Aug 2018: **Teaching Tools for SynBio** with Philip Boeing (Bento Lab) and Sophie Weeks (Producer, Art & Science Soiree)
- 17 Sept 2018: **The Biomakespace** with Jenny Molloy (Shuttleworth Fellow/Director of Biomakespace)

- 15 Oct 2018: **Innovating SynBio Governance** (Catherine Rhodes of CSER, Sam Weiss of CRASSH)
- 19 Nov 2018: **Engineering Biology for real-world applications** curated by SynBioSoc with Charlie Gilbert (Pathology) and Duygu Dikicioglu (CEB)
- 17 Dec 2018: **Designing Molecular Machines** with Zakir Tnimov (MRC LMB) and Eduardo Gianni (MRC LMB)

(iii) **VIRI Lunches**
The Cambridge node of the Virtual Institute for Responsible Innovation (VIRI) met for termly lunches, organised by the SynBio SRI, to share updates on Responsible Research and Innovation (RRI) activities around the University.

- 20 Feb 2018: Dr Stuart Hogarth (University of Cambridge Dept of Sociology) : **The Impact of Genomics on Diagnostics**
- 11 Apr 2018: Dr Todd Kuiken (North Carolina State University) and Katia Smith Litiere (Biomakespace): **Biosafety in a World Without Walls**
- 11 Dec 2018: Dr Brett Edwards (University of Bath): **From bugs to borgs**

(iv) **2018 Biomaker Summer Challenge**
The Biomaker programme provides funding for interdisciplinary team-based projects at the intersection of electronics, 3D printing, sensor technology, low cost DIY instrumentation and biology - and policy workshops and outreach events. These projects aim to build open technologies and promote development of research skills and collaborations. They tap into existing open standards and a rich ecosystem of resources for microcontrollers, first established to simplify programming and physical computing for designers, artists and scientists. These resources provide a simple environment for biologists to learn programming and hardware skills, and develop real-world laboratory tools. Further, the Biomaker projects provide a direct route for physical scientists and engineers to get hands-on experience with biological systems. We have implemented a free, internationally accessible web-based platform for project documentation and exchange at https://www.hackster.io/biomaker/.
We have run a number of events to bring together researchers from across the University and external businesses and institutes:

- 9 Apr 2018: **Mixer event**: This pre-challenge mixer will be a great opportunity to learn more about the challenge, meet other potential participants and share ideas before the application closes on 11 May. Snacks and refreshments provided. All are welcome!
- 11 Jun 2018: **Training Session 1: Introduction to XOD as a graphical programming interface for Arduino**.
- 25 Jun 2018: **Training Session 2: Interfacing serial devices with the arduino and use of XOD**
- 9 Jul 2018: **Training Session 3: Introduction to advanced sensors - pre-calibrated digital sensors**
- 30 Jul 2018: **Training Session 4: Programming robots and actuators I**
- 3 Sept 2018: **Training Session 5: Programming robots and actuators II**
- 27 Oct 2018: **Open Technology Workshop & Biomaker Fayre:** The Biomaker Challenge culminated in a day-long workshop showcasing and celebrating open source technologies in research and education consisting of a morning of talks followed by a display of projects and award of prizes at the Biomaker Fayre.
  https://www.meetup.com/Cambridge-Synthetic-Biology-Meetup/events/253300382/

(vi) **2018-2019 Biomaker Winter Challenge**
The Winter 2018-9 Challenge invites applicants to develop software nodes for integrating hardware with a new graphical programming interface, XOD. All successful applicants receive a hardware

starter kit, document their projects on the Hackster platform, and will exhibit their results at the February 2019 SynBio Forum. The starter kit includes a low-cost development platform based on the Open-Smart Rich UNO R3 board, which contains a variety of embedded components. The board is Arduino compatible, and can be programmed directly from the graphical programming environment XOD (C++ source code available). XOD nodes can be programmed using C++ (https://xod.io/docs/guide/#making-your-own-nodes), or composed from low-level XOD nodes (e.g. I2C device support, https://xod.io/libs/xod/i2c/). The primary outcomes of the Winter Challenge will be (i) community building, and (ii) development of software nodes for code-free programming of scientific instruments and real-world tools for biology. These will assist interdisciplinary team-building and project development for the 2019 Biomaker Challenge.

- 10 Dec 2018: **Biomakespace Winter Challenge Mixer**: a community event to introduce the challenge, experiment with XOD and the hardware kit, share ideas for projects, and meet potential collaborators. https://www.meetup.com/Cambridge-Synthetic-Biology-Meetup/events/rnvmhpyxqbnb/

(vii) **Cell-Free Biology**
Recent technical advances in the preparation of microbial cell-free extracts have given rise to a new class of highly efficient systems for gene expression that are cheap to deploy and have huge potential benefit for the provision of a wide variety of diagnostics, sensors, vaccines and research materials. Cell-free synthetic biology is thus a topic of growing interest to many groups in Cambridge and the Synthetic Biology SRI has developed a programme of activities to promote and support interdisciplinary work in this space. These include:

Monthly lunches: informal, round-table meetings over lunch, for technical discussions and experience sharing, with themes of:

- Energy cycling
- Genetic circuits and hardware
- Anibal Arce (Federici Lab, PUC)
- Low cost viral diagnostics grant
- Cell-free targeted projects for Biomaker

Workshops/Training Events

- 10 May 2018**: Bead beating demonstration** with Dr Emma Talbot (protocol from the Federici Lab is here.)
- 19 Jul 2018: **Cell-free synthesis of plant proteins workshop**: As part of an OpenPlant fund, Quentin Dudley (Patron group, Earlham Institute, Norwich) initiated a project to compare an in-house E. coli CFPS system (~£1 / rxn) and a commercial wheat germ kit (£12 / rxn) to express plant-derived proteins. This project coordinated with Norwich and Cambridge researchers who assembled DNA plasmids encoding proteins useful to their research projects. This workshop was held to demonstrate a few of the nuances of setting up a cell-free reaction for other Cambridge researchers. https://www.meetup.com/Cambridge-Synthetic-Biology-Meetup/events/252700096/

(viii) **Open Intellectual Property Models of Emerging Technologies**
The SynBio SRI has supported this discussion group, led from CRASSH. The group meets every other week during term time to explore the extent to which open technologies result in equitable sharing of knowledge and cognitive or technology justice. The research group has a range of interests from biotechnologies and diagnostics; 'green' technology and sustainability transitions; governance of risk through to knowledge and technology transfer for international development. They explore together legal issues, economic implications and governance of open technologies across key

sectors, asking how they are established, what motivates the IP owners and ultimately what impact this might have on societies. This facilitates cross-fertilisation between fields and generates interdisciplinary insights and novel research ideas.
http://www.crassh.cam.ac.uk/programmes/open-intellectual-property-models-of-emerging-technologies-and-implication

(ix) **SynBio SRI Newsletters**
The SynBio SRI collates and publishes a monthly newsletter which is distributed via Mailchimp. The archived 2018 newsletter can be found at the following links:

- January 2018
- February 2018
- March 2018
- April 2018
- May 2018
- June 2018
- July 2018
- August 2018
- September 2018
- October 2018
- November 2018

(x) **Strategic initiatives**
Members of the SynBio SRI steering group have initiated a number of activities intended to gain additional resources and develop the field in the University.

(1) Contributed to the appointment of Dr. Somenath Bakshi, Harvard University, as a new cross-School appointee in the Engineering Department.
(2) £7.5M Research England pre-application for PhytoCODE, a research centre for AI application in design and engineering of plant genetic systems. (unsuccessful bid).
(3) £20M GCRF Hub Bid for InFAST, Inclusive Flourishing through Advanced Science and Technology. (unsuccessful bid).
(4) £80K GCRF bid for Biomaker in Africa. (bid under consideration).
(5) Preparing bid for Research England UK-RPIF application, to consolidate Bioengineering and Centre for Organism Design and Engineering (CODE) initiative on West Cambridge site.
(6) Prepared expression of interest for Wellcome Trust PhD programme, based on AI for Biological Design and Engineering. (under consideration).
(7) Negotiating UK-Australian links with University of Adelaide and CSIRO SynBio Future Science Platform, with prospect of student exchange, shared Biomaker platform and scientific collaboration. Preparing £0.5M I3 Research England bid, Jan 2019.
(8) Exploring collaborations with Chinese Academy of Sciences, Shenzhen and Beijing Genomics Institute, Shenzhen over a synthetic plant genome initiative, based on *Marchantia polymorpha* work in Cambridge.
(9) Preparing bid for renewal of BBSRC-EPSRC OpenPlant Synthetic Biology Research Centre. (Funding call tbc).
(10) Dr. Jim Ajioka (Co-Chair of the SynBio SRI Steering Committee) has co-founded Colorifix, based on the biologically engineered dyeing processes for textiles. This is the first Synthetic Biology spin-out from the SynBio SRI community. The company has received a number of

awards and additional funding in 2018, and partnered with Stella McCartney for an exhibition of sustainable fashion at the V&A Museum in April 2018.

CONTEXT

2. What are Cambridge's key strengths in this area in comparison with other leading institutions nationally and internationally? What changes have emerged in the external environment that may affect the SRI? (e.g. new competitors, funding opportunities or risks)

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 and 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 strong position to take advantage of new funding initiatives in these areas.

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 in discussions with the University of Adelaide and Australia's Synthetic Biology Future Science Platform, a national AUS$60m initiative and and looking to build scientific exchange with Cambridge. In addition, we are exploring collaboration with colleagues in Chinese Academy of Sciences and Beijing Genomics Institute, Shenzhen for synthesis of artificial plant chromosomes and reprogramming of the model lower plant *Marchantia polymorpha*.

Our major international competitors continue to expand their investment in biological engineering with strong institutional support in terms of new appointments and infrastructure, usually led from the Engineering schools and faculties. We continue to work towards better integration of Biology and Engineering in Cambridge. As the foundational work in Cambridge matures, we see that efforts shifting towards design of biological systems, and engineering of large scale DNA code. We see a major role for machine learning in this effort.

PLANS

3. What are your plans for 2019?

(i) **Promote interdisciplinary exchange**.
Further develop interactive themes to bring together researchers in Biology, Engineering and Machine Learning for SynBio SRI Forums, meetings and workshops. This includes further development of cell-free biology, imaging and machine learning in the Biomaker programme.

(ii) **Funding for new initiatives**.
Focus efforts on fund-raising, including the opportunities listed above:

(1) Research England UK-RPIF application for Bioengineering and the Centre for Organism Design and Engineering (CODE) initiative on West Cambridge site.
(2) PhD programme based on AI for Biological Design and Engineering.
(3) UK-Australian links with University of Adelaide and CSIRO SynBio Future Science Platform, including a £0.5M I3 Research England bid in Jan 2019.
(4) Collaborations with Chinese Academy of Sciences, Shenzhen and Beijing Genomics Institute, Shenzhen and building a synthetic plant genomics initiative.
(5) Renewal of the BBSRC-EPSRC OpenPlant Synthetic Biology Research Centre.

IMPACT AND THE NEXT REF

4. To which Units of Assessment will your members be contributing in the next REF (assuming the same structure of UoAs as the last REF)?

5. In view of the changes in impact reporting proposed for the next REF, can you identify at least three areas of research within the SRI that would form the basis of impact statements at the level of the UoA or institution?

(i) We have established a common genetic syntax for exchange of DNA parts for plants (Phytobricks), extensible to all eukaryotes (Patron, NJ., *et al*. "Standards for plant synthetic biology: a common syntax for exchange of DNA parts." New Phytologist 208.1 (2015): 13-19), with wide support from the international plant science community. This common syntax for plant DNA parts is at the core of RFC 106, posted at OpenWetWare, and accepted as an international standard for DNA parts in the iGEM synthetic biology competition.

(ii) We have co-developed the Open Material Transfer Agreement (OpenMTA) as a simple, standardized legal tool that enables individuals and organizations to share their materials on an open basis. Developed as a collaborative effort between the BioBricks Foundation and the OpenPlant Initiative, with input from researchers, technology transfer professionals, social scientists, lawyers, and other stakeholders from across the globe, the OpenMTA reflects the values of open communities and the practical realities of technology transfer. “Opening options for material transfer”. Linda Kahl, Jennifer Molloy, Nicola Patron, Colette Matthewman, Jim Haseloff, David Grewal, Richard Johnson & Drew Endy. Nature Biotechnology 36:923–927 (2018). https://doi.org/10.1038/nbt.4263.

(iii) We have established the Biomaker Challenge. The ongoing series of challenges bring together interdisciplinary teams to build low-cost, DIY, open-source sensors and instruments for biology, and is growing from Cambridge, to include teams from Africa and elsewhere in the global south. .

USE OF STRATEGIC FUND AWARD

6. How are you using the funding awarded from the Administered Fund?

SRI Funding 2017/18	Total Budget	Expenditure	Surplus/Deficit
Meetings	20,000	22,188	-2,188
Coordinator	33,000	29,793	4,207
Website	2,000	456	1,544*
Total	**55,000**	**52,437**	**2,563**

* - we expect that the cost of web maintenance will increase as we move the www.synbio.cam.ac.uk site to the Drupal platform next year.

ANNEX: SRI STEERING COMMITTEE

How often has the Steering Committee met in the past 12 months? - Five times

12 Dec 2017
02 Feb 2018
15 May 2018
18 Sep 2018
13 Nov 2018

Minutes available on request.

Please list the Chair(s) and members of the Steering Committee:

Name	Department or other affiliation	School
Prof. Jim Haseloff (Co-Chair)	Department of Plant Sciences	SBS
Dr. Jim Ajioka (Co-Chair)	Department of Pathology	SBS
Alexandra Ting (Coordinator)	Department of Plant Sciences	SBS
Prof. Jeremy Baumberg	Nanophotonics Centre	SPS
Dr. Pietro Cicuta	Department of Physics	SPS
Dr. Lorenzo de Michele	Department of Physics	SPS
Prof. Bill Adams	Department of Geography	SPS
Prof. Lisa Hall	Department of Chemical Engineering & Biotechnology	ST
Dr. Ljiljana Fruk	Department of Chemical Engineering & Biotechnology	ST
Dr. Oliver Hadeler	Department of Chemical Engineering & Biotechnology	ST
Dr. Tim O'Leary	Department of Engineering	ST
Dr. Alexandre Kabla	Department of Engineering	ST
Dr Robert Mullins	Computer Laboratory	ST
Dr. Robert Doubleday	Centre for Science and Policy	NA
Dr. Catherine Rhodes	Centre for Research in the Arts, Social Sciences & Humanities	HSS
Dr. Andrew Phillips	Microsoft Research Cambridge	NA
Prof. Florian Hollfelder	Department of Biochemistry	SBS
Dr. Lara Allen	Centre for Global Equality	NA
Helene Steiner	Royal College of Art	NA
Dr. Jenny Molloy	Biomakespace & Department of Plant Sciences	SBS
Dr. Susana Sauret-Gueto	Post-doctoral researcher representative	SBS
Mr. Gonzalo Mendoza	PhD student representative	SBS
Mr. Bill Jia	Undergraduate student representative, CUSBS	ST
Dr. Rosalyn Gregory	Research Strategy Office	