Executive summary

Engineering Biology IRC: 4th year Periodic Report

Vision

The vision of the EngBio IRC is to provide a centralised hub for Engineering Biology research by supporting researchers working across disciplines - at the intersections of biology, engineering, computer sciences, design and bioethics, to consolidate the position of the University as a nationally and internationally recognised centre of excellence in engineering biology.

Challenges

Engineering Biology is a new field, driven by the need to harness biological systems in health and agriculture, and to underpin sustainable growth of the economy. The University of Cambridge has internationally recognised strengths in all areas required for this interdisciplinary field. However, practitioners are housed across the University in Schools and Departments with widely different disciplinary focus. This is a major handicap for building more concentrated interdisciplinary research efforts, which require key academic appointments, shared training, co-localised research efforts and coordinated teaching. Engineering biology needs to find a home in the University where it is "at the centre of the dial".

Strategy

(i) **Support for researcher-led activities**. We have promoted interdisciplinarity and innovation through funding around 200 small-scale projects, informal scientific exchange, training programmes, support for Makerspaces. We have developed a large network of engaged early career scientists and engineers. These activities have been framed around open source principles, and have catalysed a growing set of partnerships outside Cambridge, including Latin America and Africa. Details are outlined in the full report. Funding for the bulk of these activities has been raised from UKRI grants and charitable sources. The IRC provides added value and synergy through coordination and communication - with monthly newsletter (circulation >500), website and meetups (>1,500 registered).

(ii) **Increasing focus on translational research and industry**. As Engineering Biology matures as a field, we are seeing growing opportunities and connections with industry - similar to what happened in Physics and Chemistry a century ago. We are building interactions with industry partners, and looking for support for academic activities where possible.

(iii) **Establishment of a Centre for Engineering Biology**. We are coordinating smaller scale activities with the aim of establishing a building for co-localised research and innovation across the component disciplines. This will require successful acquisition of major funding, to support additional bids to Research England or UKRI, etc.

Current transition

The existing co-Chairs of the IRC (Prof Jim Haseloff and Dr. Jim Ajioka) are passing leadership roles to Dr. Jenny Molloy (CEB) and Prof. Laura Machesky (Biochem). As part of this transition, we have organised a series of Forums that cover latest advances in 'building blocks' for Engineering Biology, with high profile speakers. This marks the full return to in-person activities, and we are using the events to reach out to non-specialists, for a wider reach across disciplines and to build new connections with new companies around Cambridge.

Future activities
Over the next four years we plan to build on the strengths and successes of the current IRC, including open tools and technologies, capacity building and global collaborations. UKRI have three major initiatives on the drawing board, quantum computing, AI/ML and Engineering Biology. Government decisions allowing, we anticipate a full launch of the UKRI National Engineering Biology Programme in 2023. It is likely that this programme will aim to promote UK growth, and provide major new opportunities for funding. The IRC's strategy for the next four years aims to position the Cambridge community to best take advantage of these upcoming opportunities. Our three key areas of focus and following objectives are outlined below.

Fundraising
(i) Expand financial support for IRC activities
(ii) Strengthen relationships with industry
(iii) Raise the profile of engineering biology within and beyond the University

Support for researcher-led activities:
(i) Support researchers in driving their own interdisciplinary projects and initiatives
(ii) Facilitate more effective exchange of knowledge, skills and resources across departments
(iii) Support project-based interdisciplinary learning

Application-inspired research and translation to impact
(i) Support Cambridge researchers to build and share open tools and technologies for capacity building in the global bioeconomy
(ii) Raise profile of the University in technology sharing and availability of OpenMTA accessible tools and training materials
(iii) Facilitate translation of basic research to impact
(iv) Create a (physical) Centre for engineering biology

Prof. Jim Haseloff
Dr. Jim Ajioka
Dr. Jenny Molloy
Prof. Laura Machesky
Dr Steph Norwood

Engineering Biology IRC

SRI award 2013–2019. IRC commenced October 2019.
https://www.engbio.cam.ac.uk/

IRC Vision and Strategy

The vision of the EngBio IRC is to provide a centralised hub for Engineering Biology research at the University of Cambridge by supporting researchers working at the intersections of biology, engineering, computer sciences, design and bioethics and consolidating the position of the University as a nationally and internationally recognised centre of excellence in engineering and synthetic biology research. To achieve this vision, the IRC's has established a strategy (fully outlined in the IRC's application for enhanced IRC status, 2021) which focuses on three key areas: i) fundraising ii) support for researcher-led activities and iii) application-inspired research and translation to impact. The strategy map below identifies how the IRC intends to expand its funding and activities, especially directed towards larger scale outcomes.

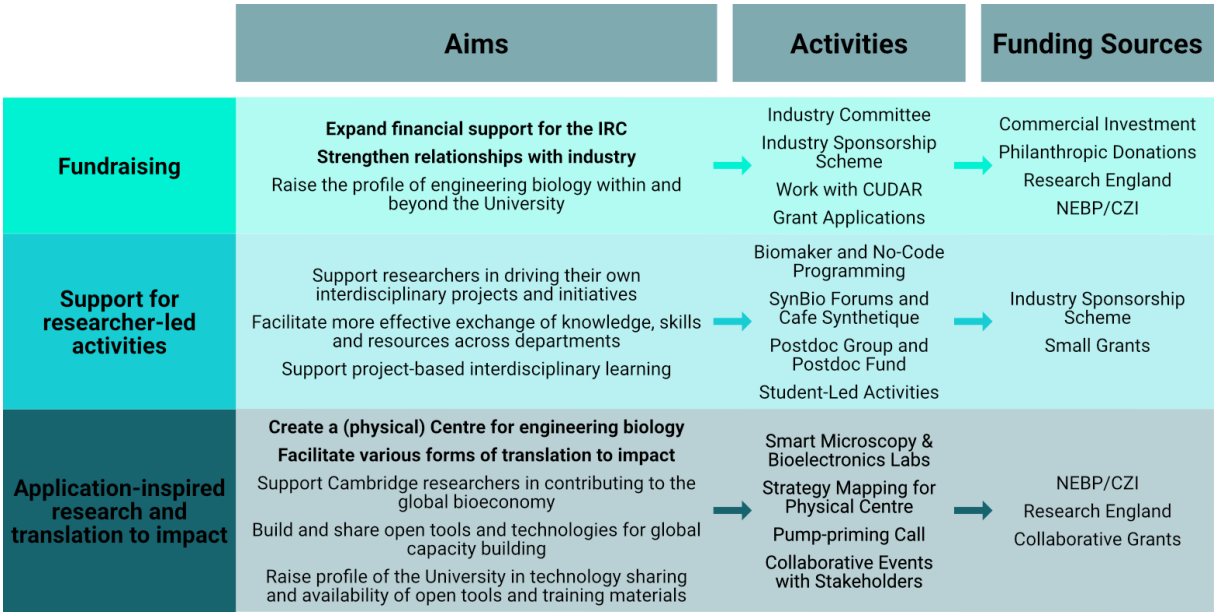

Figure 1: Strategy Map for the Engineering Biology IRC

As part of this strategy, three major ambitions include:

- **Expand Financial Support for IRC Activities & Strengthen Relationships with Industry**

Since its establishment as the Synthetic Biology SRI in 2015, the IRC has been repeatedly successful in bringing external funding into the university, most notably in the establishment of OpenPlant, one of the UK's six National Synthetic Biology Research Centres (SBRCs). Whilst grant funding is able to supply partial or short-term funding for the IRC's activities, a more stable and established mechanism of funding will be required to ensure the future expansion of the initiative. In order to achieve this, the IRC plans to establish a new sponsorship strategy which will leverage our established and developing industry relationships to fund both our current activities and future plans. At the small scale this will take the shape of event sponsorship packages for local start-ups and SMEs, who are keen to establish closer relationships with the university for both collaboration and recruitment. At the large scale the IRC plans to form an industry committee to bring on board a cohort of well-established companies to further our aims of assisting researchers in translation to impact and to act as potential long-term partners and sponsors. Additionally, the IRC's historical and continuing focus on equitable, sustainable and open technologies places the initiative in a good position to secure philanthropic funding, for example via the Chan Zuckerberg Initiative and by working with CUDAR. The IRC plans to explore both of these funding opportunities alongside our plans for industry sponsorship.

- **Create a (physical) Centre for Engineering Biology**

In the past two years the IRC has supported the development of two small interdisciplinary research spaces: the Smart Microscopy Lab in the Department of Engineering, and the Bioelectronics Lab

based at the National Institute of Agricultural Botany (NIAB). The Smart Microscopy Lab, headed by Dr. Somenath Bakshi, brings together experts from across disciplines such as microscopy hardware and software, information engineering, machine-learning, and computer science and utilises the domain knowledge to develop personalised solutions to imaging and analysing biological problems. Adjacent to the Department of Engineering's bioengineering lab and synthetic biology labs, the space aims to provide smart microscopy solutions and services to researchers from across the university. The Bioelectronics Lab was founded at the National Institute for Agricultural Botany by Dr. Richard Harrison, Director of Research, and provides workshop space for researchers at NIAB and the newly established University of Cambridge Crop Science Centre to develop bioengineering projects focused around plant science and agriculture applications and aims to nurture collaborations between biologists and engineers. Continued support for these two initiatives will allow the IRC to encourage cross-departmental and cross-school working in the area of engineering biology and bioengineering. However, the IRC also believes that a larger centralised space for interdisciplinary work in the areas of synthetic biology and genetic engineering (as fundamental tools for the engineering biology discipline) will be an important step forward for the university, allowing it to stay abreast of developments at other UK and international universities. The IRC plans to work closely with the Department of Chemical Engineering and Biotechnology, to determine whether it may be possible to develop such a space in West Cambridge, and are currently exploring funding opportunities to make this possible. Grant funding from UKRI's National Engineering Biology Programme (NEBP) and Research England, as well as industry sponsorship and philanthropic funding are all avenues which are being explored.

- **Facilitate Researcher-led Innovation, Interdisciplinarity and Translational Work**

The IRC aims to achieve this by supporting researcher-led application-driven research, providing training and project-based learning opportunities, and strengthening relationships with industry and other external stakeholders. This includes the continuation of previously successful initiatives, such as the Biomaker Challenge, No-Code Programming for Biology training and Postdoc Fund, as well as a new focus on activities that specifically support researchers in building industry and stakeholder collaborations and understanding the various routes for translating their research into areas of greater societal impact, for example, industry days, collaborative pump-priming calls, training in open practices and workshops with policy and non-profit partners.

Key Achievements

Five of our key achievements over the past three years include:

1. Follow on Funding for OpenPlant

In 2020, and again in 2021, the BBSRC/EPSRC OpenPlant Synthetic Biology Research Centre (SBRC) hosted by the University of Cambridge (UoC), along with the John Innes Centre (JIC) and Earlham Institute (EI), successfully received funding extensions with the total value of £2.2M. Following this, in 2022, OpenPlant PIs Prof. Jim Haseloff (UoC), Prof. Anne Osbourne (JIC), Dr. Jenny Molloy (UoC) and Dr. Nicola Patron (EI) submitted a successful bid for the National Engineering Biology Programme (NEBP) Transition Awards for a total of £1.9M over two years, which will continue the work of OpenPlant in developing open tools and technologies for plant synthetic biology and supporting interdisciplinary research, global partnerships and capacity building activities.

2. Establishment of Smart Microscopy Lab

As outlined above, the IRC has sponsored efforts to build an inter-school facility for Smart Microscopy - an interdisciplinary effort to bring together AI, advanced microscopy and biology. Since its inception and establishment in 2020, the Smart Microscopy Laboratory has run collaborative projects to develop targeted 'smart' image acquisition and image analysis solutions for biological research. These projects span a range of departments and schools and include the use of Machine Learning and Deep Learning methods for analysis of organismal behaviours, the design of imaging chambers and microfluidic devices, and the benchmarking of new imaging technologies. In future, the lab plans to expand its goals to: i) develop the space for interdisciplinary research interactions, ii) create an online hub for community building and resource sharing, iii) facilitate interdepartmental projects and iv) provide training and education opportunities for university staff and students. The lab has submitted a bid to the Chan Zuckerberg Initiative for Advanced Imaging Through Collaborative Projects to fund these ambitions, and the IRC will continue to support their efforts.

3. No-Code Programming for Biology Training Programme

The No-Code Programming for Biology initiative aims to introduce biologists to Arduino-based microcontrollers, sensor electronics, displays and actuators that are useful for measuring and controlling biological systems, as well as to provide the no-code programming tools that can be used to build customised bioinstrument prototypes. Developed largely during the lockdown periods in 2020 and 2021, the programme was designed to work as a remote learning experience to provide biological researchers with both new skills and the confidence to start exploring engineering-based solutions to their research challenges. Since its inception in 2020, over 400 people (largely early career

researchers) have taken part in the training, either via online workshops or through our self-guided handbooks. The materials developed have also been translated into Spanish through a collaboration with researchers at the Universidad Veracruzana (Mexico) and taken up as part of educational and training workshops by various international groups including the Universidad Veracruzana, the Genspace community lab (New York, USA) and the MakerLabCourse for undergraduate students at the Paris Lodron Universität Salzburg (Austria). The initiative has now been extended to multistage, expanded training kits that include new sensors, displays and actuators, and long-distance, low-energy LoRaWAN communications.

4. Biomaker COVID-19 Initiatives

During the 2020 COVID-19 lockdown, the Biomaker initiative was used as a hub to assemble a group of over 80 international scientists and engineers interested in the development of low cost, accessible approaches for coronavirus detection and, in particular, the assembly of instruments, tools and reagents for diagnosis. Members of the group communicated via weekly Zoom sessions, a Basecamp website, forum and mailing lists. Projects emerging from this group include the development of a low-cost open-source air-flow reactor for diagnostics, a quantitative LAMP readout device and open reagent toolkits. These are documented on the Biomaker website and elsewhere online. Collaborations established by this group have contributed to joint funding and ongoing projects with Tsinghua University, a number of African institutions and European partners.

5. Support for Researcher Led Projects (Biomaker, postdocs fund etc.)

In 2021 and 2022, the IRC focussed efforts on supporting researcher-led projects, which provide funding for interdisciplinary teams to build custom biological instrumentation and prototypes, and the establishment of the EngBio Postdoc group and Postdoc Fund, which provides early career researchers at the university with the opportunity to run their own projects in the areas of piloting of application-driven research projects, cross-sector relationship building, training, development of resources and public engagement. In addition, we have supported a number of relevant student-led projects including the Cambridge SynBioSoc's 2022 iGEM project, ReachSci's Global Virtual Programme, which offers participants from different nationalities, social and academic backgrounds the opportunity to conduct independent hands-on research projects, and an upcoming workshop on Biodesign for Digital Health. Since the start of 2019 the IRC has supported 38 Biomaker projects, 4 EngBio Postdoc Fund projects and 3 student-led initiatives.

Additional activities and achievements

(i) Meetings and events organised

Regular meetings over the past three years have included the termly Engineering Biology Forums, which bring cutting edge technology and high-profile speakers to our community, monthly Cafe Synthetique meetups, which provide an informal space for discussion and interaction with members of the community outside the university, and the EngBio Postdoc meetings, which have provided an opportunity specifically for postdocs to meet others outside of their departments. Other events held over the past three years have included a series of annual No-Code Programming for Biology training workshops (see above), and Biomaker events such as the 2020/21 Biomaker Challenge briefing and showcase events, and regular Biomaker virtual meetups during lockdown periods. One-off meetings have included the organisation of a Smart Imaging Sandpit in November 2019, organised in collaboration with CamBridgeSens SRN and Cambridge Global Challenges (CGC) IRC, and a workshop on Cell-Free Biomanufacturing in Crisis Zones in June 2021, organised in collaboration with the Open Bioeconomy Lab. Events are accessible through a dedicated channel (http://www.meetup.com/Cambridge-Synthetic-Biology-Meetup/) which has over 1,500 members worldwide.

(ii) Funding applications supported and awarded

IRC activities have gained support from the £15M OpenPlant initiative, and in return, has bolstered successful funding applications for £2.2M over 2020-2021, and follow-on funding from the NEBP for £1.9M in 2022. In 2021 the IRC was successful in securing 'enhanced' funding from the RPC amounting to an additional £30K p.a. for three years. The IRC has also had two successful applications to the Isaac Newton Trust small grants scheme for IRCs, SRIs and SRNs: for the Smart Imaging Sandpit in 2019, and the EngBio Postdoc Fund in 2020. The IRC also received a £167k Strategic Programme Grant from the Isaac Newton Trust in 2020 as matched funding for Dr Jenny Molloy's salary to 2024 for research on 'Translating Cambridge Synthetic Biology to impact LMIC bioeconomies'.

(iii) Industrial engagement

The IRC has a strong relationship with Cambridge Consultants, who sponsor our Cafe Synthetique events, and has recently been meeting with a number of other local businesses to bring them into the

community including Evonetix, Cambridge Display Technologies, Bit.Bio, Lightcast Discovery, Qkine and Constructive Bio. The IRC plans to expand this portfolio of industry contacts in the near future.

(iv) Strategic and international partnerships

The IRC has a number of international partnerships established primarily through the Biomaker programme, including researchers at the Pontificia Universidad Católica de Chile (Chile), the Universidad Veracruzana (Mexico), Mansoura University (Egypt), University of Pretoria (South Africa), Bahir Dar University (Ethiopia), Kumasi Hive (Ghana), and Tsinghua University (China). The IRC has worked with these institutions both prior to and during the last three years to assist, support and collaborate on Biomaker projects and No-Code Programming for Biology training. Biomaker training materials have also been adopted by international partners at Genspace (USA), and Paris Lodron Universität Salzburg (Austria).

(v) Key policy activities and contributions

The Cell-Free Biomanufacturing in Crisis Zones workshop held in June 2021 aimed to identify key challenges for the development and implementation of cell-free technologies and better understand whether or not they offer a realistic solution to healthcare problems in crisis zones. This included a session exploring policy and regulations surrounding cell-free technologies and healthcare deployment.

(vi) Key early career (PhD and postdoc) activities

The IRC has a strong focus on supporting early career researchers and in the past three years has continued to run previously successful programmes, such as the Biomaker Challenge and Cafe Synthetique, which are highly attended by ECRs, as well as establishing and supporting several new initiatives specifically for ECRs. These include the No-Code Programming for Biology training, the EngBio Postdoc group and Postdoc Fund (including funding workshops on open lab automation and app development for responsible data collection), support for the ReachSci Global Virtual Programme, and an upcoming workshop on Biodesign for Digital Health. Further, the IRC provides an additional voice for the SynBioSoc and, with generous support from the School of Biological Sciences, has helped re-establish a Cambridge team for the 2022 iGEM competition.

(vii) Any other major activities not included above. N/A

Plans, Strategy and Objectives: Oct 2022 – Oct 2026

Over the next four years we plan to build on the strengths and successes of the current IRC, including open tools and technologies, capacity building and global collaborations. We anticipate the full launch of the UKRI National Engineering Biology Programme in 2023. This has been delayed due to negotiations over Brexit, Horizon programme funding and governmental disruption. It is likely that this programme will aim to promote UK growth, and provide major new opportunities for funding. The IRC's strategy for the next four years aims to position the Cambridge community to best take advantage of these upcoming opportunities. Our three key areas of focus and following objectives are outlined below.

I. **Fundraising:**
   - **A. Expand financial support for IRC activities**
   - **B. Strengthen relationships with industry**
   - C. Raise the profile of engineering biology within and beyond the University

II. **Support for researcher-led activities:**
   - A. Support researchers in driving their own interdisciplinary projects and initiatives
   - B. Facilitate more effective exchange of knowledge, skills and resources across departments
   - C. Support project-based interdisciplinary learning

III. **Application-inspired research and translation to impact:**
   - **A. Create a (physical) Centre for engineering biology**
   - **B. Facilitate various forms of translation to impact**
   - C. Support Cambridge researchers in contributing to the global bioeconomy
   - D. Build and share open tools and technologies for global capacity building
   - E. Raise profile of the University in technology sharing and availability of OpenMTA accessible tools and training materials

As described at the start, three of our major ambitions include i) expanding financial support for IRC activities and strengthening relationships with industry, ii) creating a (physical) Centre for engineering biology and, iii) facilitating various forms of translation to impact. Core activities which will help us achieve these aims are outlined below:

- **Expand Financial Support for IRC Activities & Strengthen Relationships with Industry**

Over the next 12-24 months the IRC plans to strengthen our existing relationships and build new relationships with both local industry (synthetic biology/biotech start-ups and SMEs) and large established industry partners. This will include i) encouraging industry contacts to attend to present at our regular meetings, specifically Cafe Synthetique and as demonstrators at the Engineering Biology Forums, ii) establishment of an industry committee to bring on board a cohort of large well-established companies, iii) establishment of a tiered sponsorship scheme to allow both smaller and larger companies to sponsor our events and activities, iv) use of surplus funds to run a collaborative academia-industry pump-priming call in spring summer 2023. Other industry-related activities will include running an engineering biology-focussed industry day or career's fair for university researchers. Additionally, the IRC will continue to explore philanthropic and grant funding opportunities, for example by working with CUDAR and hosting grant workshops ahead of the anticipated launch of the NEBP.

- **Create a (physical) Centre for Engineering Biology**

Over the next 12 months the IRC will continue to explore strategies for establishing a new space for synthetic and engineering biology in Cambridge. This will include scoping the current landscape at the University, outlining the form and focus of such a physical centre, exploring options for a physical location, and identifying potential sources of funding, such as Research England, philanthropic donations (in collaboration with CUDAR), or industry partnerships established via our industry committee. Once the strategy has been outlined, in subsequent years the IRC can focus on gathering the necessary resources and funding and implementing their plans. We strongly believe that this would (i) provide major benefits for scientific and technical innovation and exchange, (ii) match similar initiatives in competing international institutions, and (iii) better position the University to exploit our talents in this new field, which underpins the future bioeconomy.

- **Facilitate Various Forms of Translation to Impact**

The IRC also plans to continue its support for open technologies and researcher-led projects, and has identified a potential gap in opportunities provided by other bodies within the university in providing researchers with support for achieving impact via social enterprises, open-source companies and non-profit organisations. The Engineering Biology community, including several members of the steering committee, have a strong background and experience in this area which the initiative will share with the wider community via new activities such as a focussed seminar series or training workshops. Other activities in this area will include expanding our collaborative work with policy makers, social scientists and humanities initiatives, the Centre for the Study of Existential Risk (CSER), the Centre for Science and Policy (CSaP) and the Kavli Centre for Ethics, Science, and the Public.

Use of Strategic Fund Award

Please find below a summary table of actual and anticipated expenditure over the last 3 year period.

Academic Year	Awarded	Spent	Unspent Balance
2019/20	£55,000	£14,209	£40,791
2020/21	£55,000	£25,905	£29,095
2021/22	£85,000	£57,631*	£27,369
Total	£195,000	£97,745	£97,255

* Includes funds committed for upcoming Engineering Biology Forums.

We made significant savings in 2020/21 due to the COVID-19 related suspension of large and in-person events, producing savings on venue hire, advertising, catering and travel/accommodation for overseas speakers. Further, some of the administrative costs (part of the coordinator salary, and all of the Biomaker costs, £265K) were supported by external grant funding from 2019-2022. In 2021/22 we received the additional £30K enhanced funding, a significant proportion of which was set aside for the hire of an events and communications assistant. A delay in the appointment of this role has meant that this expense has only been incurred since July 2022, resulting in further savings in 2022. The appointment of the events and communications assistant in July has allowed us to expand our capacity, and as such we now have several large projects planned for the next twelve months which will allow us to make the most effective use of our surplus funds. These include a series of Forums in Autumn 2022 featuring a number of high-profile speakers and demonstrators fairs, and a pump-prime funding call in spring/summer 2023 to initiate application-driven collaborative projects and interactions with industry.

Annex: IRC Steering Committee

(a) Steering Committee meetings over the past 3 years

The steering committee meets quarterly. Some meetings in 2020/21 were cancelled due to lockdown restrictions, and has met 10 times in the last 3 years - on the following dates:
1st October 2019, 11th February 2020, 29th September 2020, 8th December 2020, 20th April 2021, 20th July 2021, 2nd November 2021, 1st March 2022, 7th June 2022, 27th September 2022.
Minutes of IRC steering committee meetings can be found here.

(b) Chair(s) and members of the Steering Committee:

Name	Department or other affiliation	School
Prof. Jim Haseloff (previous co-chair)	Department of Plant Sciences	SBS
Dr. Jim Ajioka (previous co-chair)	Department of Pathology	SBS
Dr. Laura Machesky (incoming co-chair)	Department of Biochemistry (starting Nov 2022)	SBS
Dr. Jenny Molloy (incoming co-chair)	Department of Chemical Engineering & Biotech	ST
Dr. Stephanie Norwood (coordinator)	Department of Plant Sciences	SBS
Ms. Vicky Reid (assistant)	Department of Plant Sciences	SBS
Dr. Alexandre Kabla	Department of Engineering	ST
Dr. Andrew Phillips	AstraZeneca	
Mr. Camillo Moschner	Department of Engineering	ST
Mr. Christopher Micklem	Sainsbury Laboratory	SBS
Prof. Florian Hollfelder	Department of Biochemistry	SBS
Ms. Helene Steiner	CEO OpenCell, Royal College of Art	
Prof. Jeremy Baumberg	Department of Nanophotonics	SPS
Dr. Lalitha Sundaram	CSER	HSS
Dr. Lara Allen	Centre for Global Equality	
Dr. Lin Su	Department of Chemistry	SPS
Prof. Lisa Hall	Department of Chemical Engineering & Biotech	ST
Dr. Ljiljana Fruk	Department of Chemical Engineering & Biotech	ST
Prof. Mark Howarth	Department of Pharmacology	SBS
Dr. Pietro Cicuta	Department of Physics	SPS
Dr. Robert Doubleday	Centre for Science and Policy	
Dr. Robert Mullins	Computer Laboratory	ST
Dr. Rosalyn Gregory	Research Strategy Office	
Dr. Somenath Bakshi	Department of Engineering	ST
Dr. Timothy O'Leary	Department of Engineering	ST

(c) External Advisory Board:

Prof. Tom Knight	Founder, Ginkgo Bioworks, Boston, USA
Dr. Michael Daniels	Head of Product Management, Evonetix, Cambridge, UK
Prof. Drew Endy	University of Stanford, Palo Alto, USA
Prof. Tom Ellis	Imperial College, London, UK
Prof. Susan Rosser	University of Edinburgh, Edinburgh, UK
Prof. Anne Osbourn	John Innes Institute, Norwich, UK