Institution: University of Cambridge
Unit of Assessment: 5 Biological Sciences

1. Unit context and structure, research and impact strategy

1.1 Context of UoA5 research in Cambridge

Our UoA5 submission includes over 250 researchers based in the School of the Biological Sciences (SBS). SBS is one of six Schools in the University and is composed of nine academic Departments and four research Institutes, one of which (Cambridge Stem Cells Institute, CSCI) is joint with the School of Clinical Medicine (**Figure 1A**). Each Department houses several groups spanning a range of interests and teaching capabilities appropriate to its remit, whilst the Institutes are foci for particular research areas. Colleagues from the Departments of Pathology, Psychology and Veterinary Medicine are being submitted to UoA1, UoA4 and UoA6 respectively, and most of those in CSCI to UoA1.

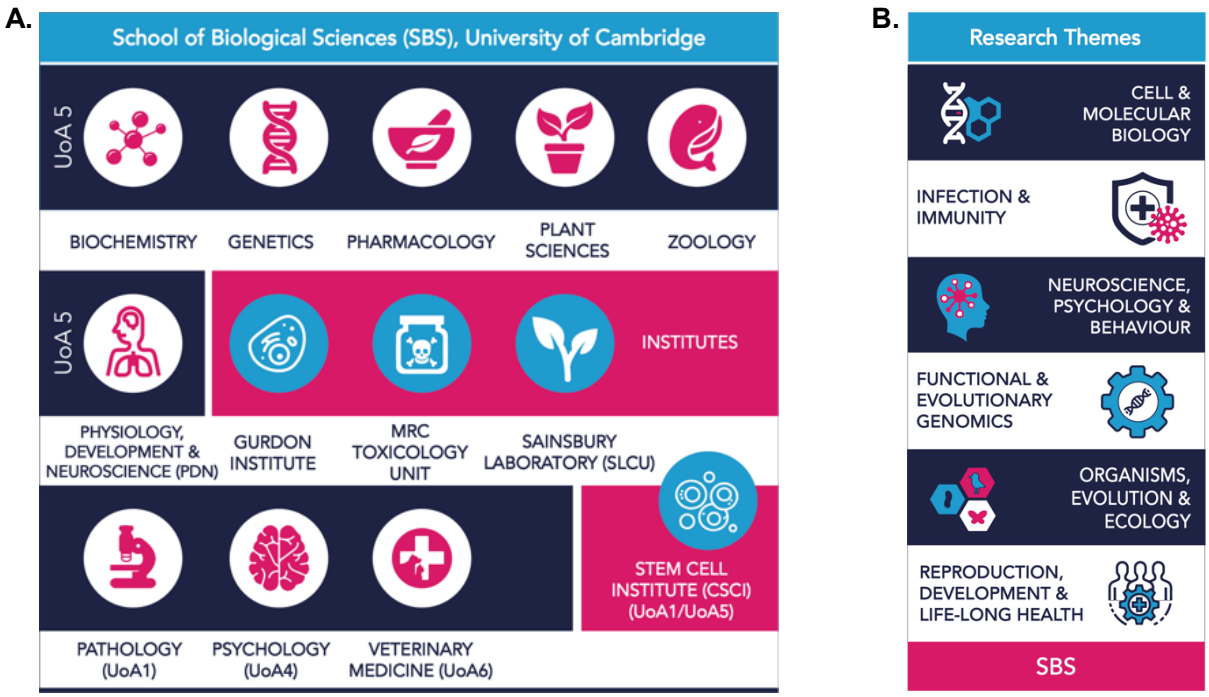


Figure 1. A. Departments & Institutes in SBS and the UoAs to which their staff will be submitted. **B.** Research is broadly organised into six cross-Departmental Research Themes.

Over the reporting period SBS has engaged in extensive discussions about how best to organise its research efforts in broad Themes across departmental boundaries, to provide opportunities for collaborative and multidisciplinary research at all levels of career from senior academics to early career researchers and postgraduate students. As of July 2020, the general research areas are as shown in **Figure 1B**.

Research in SBS is both investigator-led and carried out within larger coordinated teams within and beyond SBS. Additionally, many of our researchers are associated with University-wide interdisciplinary research networks (Section 1.3) that support research, translation and knowledge exchange activities in areas of global strategic importance. More broadly, SBS is a hub for the

wider Cambridge biosciences community encompassing academic and industrial collaborators and partners.

A major strength is our close connections with:

- the Biomedical Campus, which includes the School of Clinical Medicine, Addenbrooke's Hospital (the largest teaching hospital in the region) and the MRC Laboratory of Molecular Biology (MRC-LMB).
- the Wellcome Genome campus, home to the Wellcome Sanger and European Bioinformatics Institutes and other world-leading organisations in genomics and computational biology.
- the BBSRC Babraham Institute & Innovation Campus, exploring the key to lifelong health
- the National Institute of Agricultural Botany (NIAB), the UK's foremost independent agricultural research institute.

More broadly, Cambridge sits at the heart of the largest cluster of high-tech biotechnology and pharmaceutical companies in Europe, many of which have sprung from research within SBS, including Astex Pharmaceuticals and Mission Therapeutics.

1.2 Research objectives during reporting period and for next 5 years

The overriding aim of SBS is to carry out excellent research that addresses fundamental biological questions, and then to translate that research to tackle global challenges: treatment and prevention of disease, provision of food and nutritional security, mitigation of climate change and conservation of biodiversity, support and growth of the bioeconomy. We consider that innovative scientific vision and integration across the breadth of biology-related research are essential to achieve success in both discovery science and its translation. We have used these as guiding principles in developing our research strategy, enabling us to meet our objectives outlined in REF2014. Broadly these were to:

- make academic appointments in key areas of strength to increase critical mass;
- continue to deliver excellent scientific outputs and increase understanding of biological systems;
- encourage and facilitate collaboration within SBS, across the University and with stakeholders, with an emphasis on interdisciplinarity;
- support translation to have impact in tackling real-world problems;
- enhance provision of state-of-the-art technologies and redevelop/establish purpose-built infrastructure.

Below we highlight research achievements and relevant Impact Case Studies (CS) in our six Research Themes and for the cross-cutting research interfacing with Engineering and Physical Sciences. Section 1.3 provide more detail on our translation support, and infrastructure and facilities are covered in Section 3.

1.2.1 Cell & Molecular Biology

Objectives in REF2014 were: to make key appointments of leaders in the field; to enhance research facilities in cryoEM for macromolecular assembly analysis, to increase understanding of

fundamental processes in cells; and to accelerate ways to lead to new treatments for disease, particularly by links with the Clinical School and industry.

Cell and molecular biological research is carried out across SBS, studying aspects of cell function from molecules to tissues. As well as providing unparalleled insight into fundamental processes, an important focus is to extend this knowledge to understand diseases and to allow exploration of novel therapeutic avenues. To support and augment this area, as proposed in **REF2014**, several new appointments were made including *Jussi Taipale* (2017), Herchel Smith Chair of Biochemistry; *Michael Edwardson,* Sheild Professor of Pharmacology; *Anne Willis* (2018), Professor of Toxicology.

Several new cutting-edge facilities in SBS have been installed, including Cryo-electron microscopy (Cryo-EM), augmented proteomics capability, enhanced FACS and Next Generation Sequencing (NGS) services. Cryo-EM has transformed our ability to understand multicomponent complexes at near atomic resolution e.g. the first pseudo-atomic structure of the MacAB-TolC ABC-type tripartite multidrug efflux pump provided insight into the basis for drug resistance in numerous pathogenic bacteria (*Luisi*). Structural biology also underpins the Fragment-Based Drug Discovery approach pioneered by *Blundell* and Astex Pharmaceuticals that has resulted in compounds targeting kinases involved in breast and urothelial cancer, two of which are now commercialised, with a further 5 in trials (Impact CS: Revolutionising drug discovery using a fragment-based approach). More broadly, earlier work developing phage display has led to Impact CS: New commercial ventures to accelerate therapeutic antibody discovery (*McCafferty*).

Much of our discovery science has direct connection with understanding of disease, with a particular focus on cardiovascular disease and cancers, which have major impact on the health and wealth of the nation (N.B. our research on neurodegenerative disease is submitted with UoA4). Several treatments are now in the clinic, including Olaparib (Impact CS: Revolutionising cancer therapy via the DNA-damage response; *S.Jackson*). To consolidate research effort in this area, we fulfilled a **REF2014** objective to support the **Cancer** Interdisciplinary Research Centre (IRC; Section 1.3), including opening of the preclinical “Mouse Hospital” in collaboration with Cancer Research UK to allow testing of new therapeutic targets. This has been augmented by establishment of a postgraduate programme in Cancer Biology. The **Cardiovascular** Interdisciplinary Research Centre (IRC) has also been established, building on previous successes, exemplified by Impact CS: Tackling cardiac rhythm abnormalities to extend and improve quality of life (*Grace)*.

To strengthen our position in therapeutic translation we established the **Cambridge Academy of Therapeutic Sciences** (CATS, Section 1.3), synergizing with the relocation of the MRC Toxicology Unit to Cambridge in 2019, and with extensive industry-funded PhD programmes (Section 2.3) and a Masters in Therapeutic Sciences to educate a new generation of scientists in translational drug discovery. This provides Cambridge with a unique and unrivalled combination of the disciplines necessary to input science into current and future questions that surround the drug discovery process.

Future plans: Cross-theme collaborations and interdisciplinary approaches will be expanded to tackle disease-related biomolecular and cellular questions, with RNA biology a major focus, given

new therapies that are being developed. As well as continued support for School-based facilities, our cancer research will be enhanced by the new €30M IMI-funded 'Immune-Image' consortium that will explore Positron Emission Tomography (PET), Optical Imaging (OI) and Magnetic Resonance Imaging (MRI) to visualise immune cells during treatment. Appointment to the Sir William Dunn Chair in Biochemistry will allow us to maintain our strength at the biosciences-chemistry interface. As part of our strategy to translate our science we will continue to cement interactions with our industrial partners including AstraZeneca (AZ), based at the Biomedical Campus, and via CATS.

1.2.2 Functional and Evolutionary Genomics

Priorities identified in REF2014 were to: appoint a new Professor to a post supported by philanthropy; expand interdisciplinary and quantitative approaches to research in genome biology across the University; develop infrastructure and training in genome informatics and computational biology.

Strategic appointments made in line with **REF 2014** aims include two major Professorships at the interface of evolutionary biology, population genetics and computational genomics: *Richard Durbin* (Al Kindi Professor of Evolutionary and Computational Genomics) and *Eske Willerslev* (Prince Philip Chair of Ecology 2015), leader in the field of ancient DNA and e(environmental)DNA methods. Of note is the analysis of ancient and present DNA to reveal the history of human evolution and migration including in the Americas and Asia (*Willerslev, Manica, Scally*), linking genomics, evolution and anthropology. How heterozygosity influences mutation rate is challenging evidence of introgression of Neanderthal and other *Homo* DNA in modern humans *(Amos)*. This increase in computational and bioinformatics expertise is underpinning extensive training and upskilling in genome informatics across SBS.

Epigenetics is now a major focus in SBS, supported and augmented by the active Epigenetics Club, run by early career researchers with funds from AbCam, and in collaboration with colleagues from the Babraham Institute. Fundamental discoveries are also paving the way for future translation, for example understanding meiotic recombination in Arabidopsis (*I.Henderson*), and hybrid dysgenesis in tomato (*Baulcombe)* will have impacts in plant breeding, whilst the dysregulation of RNA methylation in cancer (*Kouzarides*) has led to extensive industrial collaboration/funding and a start-up company **STORM Therapeutics**.

Research at the interface of **genetics** and **experimental evolution** has identified the evolutionary pressures on pathogens and their hosts (*F.Jiggins*, *Leggett*), and fundamental work on gene drive has led to new disease control measures for malaria (Impact CS: Overcoming regulatory barriers for the implementation of Gene Drive technology to control malarial mosquitos in Africa; *Russell*).

Future plans: New positions are planned in evolutionary biology. Further interdisciplinary activities will be aimed towards nurturing genetic approaches to sustainability, ecology, and biodiversity, as well as strengthening microbial genetics. We will continue to expand and integrate shared facilities including next generation sequencing technologies and the management of even larger datasets. We will play a significant role in the major Darwin Tree of Life project (Section 4.1)

1.2.3 Infection & Immunity

The REF2014 goal was to link researchers in Cambridge and Africa, building on joint programmes of applied research in infection and immunity with further plans to include research in food security

Fulfilling our **REF2014** goal, extensive links to research institutes in Africa have been forged to address disease, frequently supported by the Cambridge-Africa initiative, which funds African scientists to spend time in Cambridge. Most research on human/animal disease will be submitted to UoA1/UoA6, but we have considerable strengths in plant pathology and epidemiology. Projects with BecA-ILRI in Kenya to study plant-aphid-viral interactions (*Carr*) and in Ethiopia to understand landscape level interactions of plant pathogens with both natural and agricultural vegetation (*Gilligan),* have both involved Cambridge-Africa fellows. The Ethiopia project has provided the first quantitative model for dispersal of spores over large geographical areas (*Gilligan*) and the means to assess when and where to start control of an epidemic (*Cunniffe)*, now being used to inform national and related policy on prediction and control of plant disease (Impact CS: Protecting global food production and woodland environments through epidemiological modelling; *Gilligan*). Further important African interactions led to a mathematical model for simulating immunisation strategies in Sub-Saharan Africa and estimating their impact on disease burden and transmission. Revised vaccination programmes based on the findings have saved many lives (Impact CS: Shaping WHO meningitis vaccine guidelines; *Trotter*^{UoA6}). Analysis of antigenic variants of influenza virus is also pivotal in the WHO-led influenza vaccination programme (Impact CS: New generation pandemic and seasonal influenza vaccines; *D.Smith).*

In parallel, fundamental biochemical understanding is leading to innovative approaches to tackle disease. For example, in a collaboration with MedImmune, repurposing an anti-cancer drug by conjugation to a specific antibody cured a stage 1 model of African trypanosomiasis (*Carrington*). The depth and agility of our research base is exemplified by extensive refocusing as a result of the coronavirus pandemic in 2020. In one Department (Biochemistry), seven groups initiated projects to investigate aspects of Covid-19, including development of multiplex serological assays for evaluation of SARS-CoV-2 immunity (*Hyvönen*), structural studies to develop drugs directed against the highly conserved s2m RNA element of SARS-CoV-2 virus (*Luisi*), and new technology to map the secondary structure and RNA interactome of the SARS-CoV-2 genome (*Miska*). Members of the Department are also part of a wider consortium that together will develop and test diagnostic tools for use in Africa.

Future plans: We will continue to work with initiatives such as CATS and the Milner Institute that provide means to interact with clinicians and the pharmaceutical industry to highlight opportunities for research translation into the clinic. For plant disease a significant new focus will be through the newly-established Crop Science Centre (Section 1.2.5).

1.2.4 Neuroscience

REF2014 strategic plans: to concentrate on neurobiology of natural behaviour as a foundation for the Institute of Neuroscience; to combine advanced imaging, molecular engineering, optogenetics, computation, and sophisticated ethological approaches to revolutionize our understanding of animal brains; to make a number of key appointments.

With over 70 researchers in Neuroscience, Psychology and Behaviour Cambridge makes contributions across the subject from neural development to cognitive behaviour. Most are submitted to UoA4, but more fundamental studies in UoA5 include studying neural circuits controlling fertility (*Herbison, Colledge*) and analysis of neural circuits and direct connectivity via electron microscopy, which have revealed novel aspects of behavioural control, including how competitive disinhibition mediates behavioural choice in *Drosophila* (*Zlatic, Cardona*, *Landgraf, Jefferis*). This latter work was made possible by the strategic recruitment of *Zlatic* and *Cardona* from Janelia and the awarding of significant consortium funding. We realised a **REF2014** goal to revolutionize understanding of animal brains by the appointment of 3 new lecturers, who together have combined research across advanced imaging, molecular engineering/optogenetics, computation, and sophisticated behavioural approaches to discover fundamental mechanisms of brain GPS systems (*Krupic*), sensory selection (*Poort*) and olfactory and sensory plasticity (*Galiano*). These complement existing strengths in hippocampal circuitry and synaptic plasticity (*Paulsen*) and form a core segment for the emerging Institute for Neuroscience.

Future plans: Building on the expertise in neural circuits and sophisticated behavioural approaches and the impetus provided by seed-funding for the Institute for Neuroscience, our goal is to establish a collaborative core of neuroscientists that can interact effectively with the breadth of research in UoA4. For example, the collaborative programmes in **connectomics** will extend into circuits of vertebrate brains to complement the **functional studies of neural circuits.**

1.2.5 Organisms, Evolution & Ecology

REF2014 plans were: development of the new Conservation Campus; redevelopment of the Museum of Zoology; recruitments in plant biology, including six new group leaders in the Sainsbury Lab.

The major challenges of climate change and the catastrophic decline in biodiversity are tackled by researchers in **Ecology & Conservation**. The main strategic aim in **REF2014** was to open a new Conservation Campus, achieved in 2016 with opening of the **Cambridge Conservation Institute** (CCI), located in the newly refurbished **David Attenborough Building** (Section 3.2.2), housing University researchers from Zoology, Plant Sciences, Geography and Land Economy together with over 400 staff from nine national and international conservation organisations.

The juxtaposition of researchers and practitioners has facilitated unprecedented coordination of academic ecological research with practical conservation projects globally: from estimation of carbon stocks in forests of Borneo (*Coomes*) to ways to reconcile food demand and biodiversity conservation (*Balmford*), drawn on by parliamentary committees shaping post-Brexit agricultural policies.

Another important initiative from working with the CCI leadership was the identification of a pressing need to increase work on marine fauna and environments. A £2.3M philanthropic donation allowed appointment of a Whitten lecturer in Marine Biology (*Herbert-Read*) along with PhD studentships in this topic. Fresh-water ecology is also an important area; understanding bivalve biology has led to Impact CS: Biobullets for the control of commercially-important pests in the water supply industry (*Aldridge*).

The **Museum of Zoology** was refurbished in 2018 for £4.1M, funded in part by the National Lottery Heritage Fund, providing a new demonstration lab and gallery displays for teaching, state-of-the-art research facilities for work on the collections and dedicated space for a microCT scanner, which is used across the University and by external researchers. The refurbishment has enabled novel approaches in palaeontology that have shifted our understanding of the ecological drivers of snake and reptile evolution (*Head)* and the pioneering reconstruction of the ecology and evolution of Edicarian animals (*Mitchell*).

Building on the success reported in **REF2014** in **Plant Biology**, we have achieved a key goal of making several new appointments, including 4 Group Leaders (*Jones*, *Moyroud, Nédélec, Oldroyd*) and two professorial appointments (*Jönsson, Helariutta*) at the Sainsbury Laboratory (SLCU), a new University Lecturer/Curator of the Botanic Garden (*Brockington*), and 2 unestablished Lecturers joint with the Indian Dept of Biotechnology (*Andreuzza, Yadav*). Moreover, philanthropic donations have endowed the **Russell R Geiger Professor of Crop Science**, with *Oldroyd* the first appointee. The critical mass of over 30 group leaders studying plants, together with extensive collaborative and multidisciplinary interactions, has allowed fundamental discovery science to be highly integrated with a culture of translational and challenge-led approaches. Much work focuses on plant processes that will enable improvements in crop productivity and food security. Translation of these advances will be made possible by the recent establishment of the **Crop Science Centre**, directed by *Oldroyd*, a joint venture with NIAB. Co-location on the NIAB site provides direct access to stakeholders in the agricultural sector, attracting

>£25M external funding from the Bill & Melinda Gates Foundation and Foreign, Commonwealth & Development Office (FCDO).

Future Plans: Significant new appointments will be to the Chair of Plant Ecology and the 1866 Chair of Zoology in evolution and ecology, and Lecturerships in evolutionary biology, providing unprecedented opportunities to expand our unique partnerships in the Cambridge Conservation Initiative to improve global conservation policies and practice. The establishment of the University-wide climate change initiative **Cambridge Zero** in 2019 will underpin a range of future collaborations to explore nature-based solutions for a zero-carbon future. Another significant focus in the next 3 years will be on the Crop Science Centre, with up to 4 Research Fellowships funded by philanthropy, and closer links established with the agricultural sector.

1.2.6 Reproduction, Development and Lifelong Health

REF2014 goals were to: focus on integration of basic research in developmental and stem cell biology with the more translational activities associated with UoA1; build on initiatives already underway, including the new Stem Cell Institute and with large national strategic initiatives; make strategic appointments

The depth of research in stem cells, developmental biology and reproduction in UoA5 has created unique opportunities that have led to key breakthroughs for how animals are formed and function. Impact from several of these discoveries has been realised through the relationship with clinicians and the proximity of the Biomedical Campus. Notably we have achieved **REF2014** aims to harness and build-on our interdisciplinary research, exemplified by the tracing of cellular dynamics in development, maintenance and disease of different organ systems (e.g. *B.Simons, Rawlins, JH.Lee, Huch, Livesey, Brand*), by establishing the role of tissue mechanics in axon pathfinding and morphogenesis (e.g. *Franze, Sanson, Steventon, Harris*) and to breakthroughs in understanding cross-kingdom commonalities between plant development, stem-cells and morphogenesis (*Jönsson, Haseloff, S.Robinson)*.

Other successful interdisciplinary initiatives are the **Centre for Trophoblast Research (CTR**) and recent establishment of the **Reproduction** Strategic Research Initiative (Section 1.3), augmented by appointments in Reproduction (*Herbison*, Professor in Neuroendocrinology, Wellcome Senior Fellow; *Sferruzzi-Perri*, Lecturer PDN) and in Developmental and Stem Biology (lecturers *Steventon*, Genetics; *X.Ma,* Gurdon Institute; *J-H.Lee*, Stem Cells).

Exceptional progress in deciphering mechanisms of **human development, organ function and regeneration,** with widespread impact**,** has been achieved through synergies that have led to new methods to generate organoids from liver (*Huch)*, lung (*Rawlins, Lee)*, endometrium, uterus (*Turco, Burton*) and in making synthetic human embryos (*Zernicka-Goetz)* and gastruloids (*Martinez-Arias).* As well as revolutionizing our understanding of early human development, these advances have been highlighted in the national press as major steps forward in understanding the causes of birth defects, diseases and miscarriages.

Fulfilling a key aim from **REF2014,** basic research in **Stem Cell** biology has been successfully integrated with translational stem cell activities (reported to UoA1), by consolidating the Cambridge Stem Cell Institute (CSCI) in the purpose-built Jeffrey Cheah Biomedical Centre. This

consortium has already been successful in identifying key pluripotency regulators (*Nichols, Hendrich),* defining mechanisms controlling the differentiation of pluripotent stem cells towards hepatic tissue, with consequences for stem cell therapies (Impact CS: Optimised human cell products to improve therapy development; *Vallier*[UoA1]) and elucidating principles of neurogenesis in human cortical development and how they are affected by diseases including Alzheimer's (*Livesey).* Further moves into the patient setting will be fostered now CSCI is located in proximity to research hospitals and industry partners. In parallel, Impact CS: Next generation growth factors for regenerative medicine *(Hyvönen)* is providing materials for stem cell culture.

Future plans We aim to build on existing strengths in (i) **human organoids and synthetic embryos** (ii) **mechanics and tissue biology,** enhancing the interdisciplinarity in these arenas. We will continue to invest in new imaging platforms to capitalize on our scientific advances. Growing investment and recruitment in these fields are complemented by an ambition to establish associated MPhil programmes. The forward strategy is exemplified by the appointment of *Kathy Niakan* (from October 2020) as the Mary Marshall and Arthur Walton Professor of Reproductive Physiology, to harness the successes of the CTR and develop further the Reproduction SRI.

1.2.7 Cross-cutting research activities

As well as objectives within the Research Themes, ***REF2014*** *proposed further development of physical, mathematical and computational approaches to tackle biological problems; and to build an internationally competitive activity in Synthetic Biology across the University*

Physics-Biology interface Building on existing strengths, we have invested significantly in cross-disciplinary research fields especially the Physics and Biology interface, including four new appointments: *Pulach* (Professor of Anatomy, PDN) Mechanobiology of cell shape control, *Sarris* (Lecturer, PDN) Cell navigation in complex tissues, *Xiong* (Group leader, Gurdon Institute) Role of mechanical forces in tissue development, and *Nédélec* (Group leader, SLCU) Systems biology of morphogenesis. Interdisciplinarity is the core of their work and that of many others across SBS, applying insights from theoretical and experimental physics to expose principles of such processes as stem cell dynamics during homeostasis, repair and tumorigenesis, and of regulation by the mechanical environment in plants and animals (*Jönsson, S.Robinson, B.Simons, Paluch*). Work in this latter area of mechanobiology has led to the discovery (*Franze, Chalut*[UoA1]*, Franklin*[UoA1]) that niche stiffness underlies the ageing of CNS progenitor cells. This area of research is considerably strengthened by establishment of the Centre for Physical Biology, launched with seed funding from the University to support pump-priming grants and prizes for PhD students working at the interface.

Mathematical and computational biology - Consistent with a strategic aim from **REF2014**, mathematical modelling is an increasingly important component of our work, for example in understanding the genetics of populations and initiation and control of epidemics, dynamic modelling the properties of chromatin and stochastic modes of cell division in plant and animal development. Progress in this area is facilitated by several joint appointments in the School of the Physical Sciences (*B.Simons, Locke*, *Jönsson*), fostering collaborations and providing a conduit to recruit physics and maths graduates to consider research opportunities in biology. As also proposed in **REF2014**, two virtual organisations, Cambridge Systems Biology Centre and the

Cambridge Computation Biology Institute have been developed extensively to provide masters-level training in integrated genomics and bioinformatics.

Synthetic Biology - The launch (2014) of the EPSRC/BBSRC OpenPlant initiative in plant synthetic biology, joint with John Innes Centre in Norwich, provided a major impetus to establish a significant critical mass of synthetic biology research in Cambridge, with investment in laboratory refurbishment and consolidation of Synthetic Biology Interdisciplinary Research Centre (Section 1.3). Key advances enabled by OpenPlant include the genome-wide analysis of transcription factor binding in individual cell-types in rice leaves (*Hibberd*), and characterisation of the entire transcription factor complement of *Marchantia* (*Haseloff*), as well as projects of relevance to industrial biotechnology, such as elucidation of xylan biosynthesis to improve processing of plant lignocellulose during bioethanol production (*Dupree*), and engineering microalgae to produce plant natural products (*AG.Smith)*. The importance of this emerging area and relevance to the bioeconomy has led to joint appointment between SBS and Engineering of a Lecturer in Synthetic Biology (*Bakshi,* submitted to UoA12) and dedicated Makespace. OpenPlant also supports the Biomaker Initiative providing pump-prime funds for ~60 projects to date for early career researchers to carry out projects at the intersection of biology with electronics, 3D printing, sensor technology and low-cost DIY instrumentation.

Future plans New MPhil programmes will be established within the next 2-3 years in Physical Biology and recruitment of early career researchers who work at the interface will be prioritised. Further initiatives in Synthetic Biology are planned including closer integration with Engineering and potential shared research facilities.

1.2.8 Future strategic plans across Biological Sciences

Research topics presented in earlier RAE/REFs helped to highlight potential synergies across our research landscape. Since REF2014, this has prompted consideration of high-level strategic aims that will enhance interactions across SBS and facilitate both interdisciplinary work and translation of fundamental discovery science to address challenges. This has crystalized into the 6 major **Research Themes** (Figure 1B) that framed the showcasing of our research achievements and are now shaping future plans. Initially conceived in the context of a large-scale building plan (the Biocentrum) it became evident that a more formalised organisational framework will help shape research in SBS and hence form the basis for future estates development (rather than *vice versa* as originally envisaged). Starting in 2021, thematic research activities will be strongly supported in SBS, led by a Deputy Head of School for Research (*J.Simons*^{UoA4}), who has been appointed to drive this forward. A crucial objective is to ensure that existing critical mass, often scattered across individual Departments, is brought together to enable closer working between members (from Academics and Fellows, through ECRs to Postgraduates) in cognate and complementary disciplines. We will also invite associate membership from group leaders from outside SBS and the University in the local area, with many of whom we already have strong collaborative links (Section 4.1).

The Themes are designed to enable greater agility and creative thinking in responding more effectively to major funding calls and global challenges, facilitate strategic planning of philanthropic fundraising and of engagement with industry, translation and impact. Theme members will undertake horizon scanning for grand-challenge funding opportunities with help from a new pre-

award Research Office team, and generate better understanding of requirements for intra- and cross-theme enabling technologies and research facilities. Moreover, the Themes will play a major role in strengthening efforts towards enhancing research culture in SBS, including widening participation, increasing the diversity of those in leadership roles, empowering early-career researchers and professional services staff, and exploring opportunities for institutional incentivisation of open research practices. SBS will invest in additional posts to support these activities.

Biological Sciences at Cambridge is now entering a particularly exciting time. In addition to the Themes, we are also undertaking a large-scale review and re-imagination of our teaching programme, furthering research-led learning in the undergraduate years and launching a suite of Masters courses to cover a wide range of biological disciplines. These priorities, alongside our widening participation agenda and with an increasing focus on research culture, will support further our goals of advanced connectedness, creativity and excellence across the discipline.

1.3 Support for interdisciplinary research

Interdisciplinary research is supported by a range of **cross-School Networks**, enabling SBS researchers to interact with, amongst others, School of Clinical Medicine for translation of biological understanding into the clinic, Physical Sciences and Technology for Synthetic Biology and Physics of Medicine, and Humanities and Social Sciences to promote initiatives in Conservation and Sustainable Development. The Networks address large-scale multi-disciplinary research challenges, strengthen research collaborations and knowledge transfer across disciplines, and increase research capacity and profile by providing a platform for large-scale funding applications, recruitments and international research partnerships. They also enhance ways in which our research feeds into policy underpinning national and international research, innovation and funding agendas.

There are three stages of Network, which although closely related differ in their maturity and scope. Several focused **Strategic Research Networks** (SRNs), such as those in Sensors or Metabolism, provide opportunities for staff to initiate collaborations and network with others in the University. More formal **Strategic Research Initiatives** (SRIs) bring together a critical mass of researchers to start to address one or more challenges; demonstration of success then leads to conversion of the initiative into an **Interdisciplinary Research Centre** (IRC). These initiatives are overseen by the University's Research Policy Committee and receive direct University funding, e.g. for an executive manager and support staff for the SRIs/IRCs.

The commitment of SBS to interdisciplinary research is exemplified by the fact that many of the IRCs have been conceived and/or led by UoA5 researchers, currently ***Conservation*** (Director *Coomes)*, ***Global Food Security*** (Co-Director *Griffiths*) and ***Synthetic Biology*** (Director *Haseloff*), and previously ***Energy*** (Co-Director *AG.Smith).* The success of the IRCs is demonstrated by extensive external research funding. For example, ***Stem Cells,*** whose research impacts disease modelling, drug discovery and regenerative medicine, is funded by the MRC and Wellcome. ***Global Food Security*** was a key player in successful applications for several UKRI-

GCRF projects aimed at translating knowledge of plant physiology to support small-holder farmers in India and sub-Saharan Africa to improve yields and decrease water and nitrogen use. ***Synthetic Biology*** has attracted significant funding to develop low-cost molecular biologicals and equipment like the 3D-printed Openflexure microscope, making innovation in this area accessible to low-resource settings such as in Nigeria and Kenya. ***Cardiovascular*** has been associated with significant research funding from the British Heart Foundation (£6M), building on the relocation of the Royal Papworth Hospital to the Biomedical Campus.

Similarly, the newly-established ***Reproduction*** SRI has secured an international collaboration with the Hubrecht Institute (Netherlands) to develop a new model of the early stages of human development. Another new SRI of note is the ***Cambridge Academy of Therapeutic Sciences*** (CATS), which aims to support the early-stage translation of academic science by linking University staff with industrialists, regulators and policy-makers in therapeutics and provide opportunities for secondments into industry. Success is evidenced by a £2.25M Wellcome Translation Partnership Award (*Willis, Itzhaki*).

1.4 Achieving Impact

Our REF2014 impact submission illustrated the depth and diversity of impact achieved by UoA5 researchers from conservation policy and epidemiology to drug discovery and therapeutic design. These were realised essentially as individual activities rather than as a portfolio. Following REF2014, the strategic decision was made to support SBS researchers' impact activities more proactively. Accordingly, in 2015 the Bioscience Impact Team (BIT) was created with funding from HEIF (£600k over 5 years) to support 3 FTE staff and associated impact activity. BIT provides a dedicated source of general advice and training on translation and impact, provides information on funding options for translation, and assists academics in developing and managing relationships with external partners. BIT has secured ~£1M of direct UKRI funding as Impact Accelerator Awards, enabling a broad range of pump-prime projects, placements, events and other collaborative activities with partners from industry, farming, charities, public bodies and developing countries (Sections 3.5 and 4.1). **Critically, all 11 Impact CSs were developed by dedicated support from BIT over 3 years.**

Similarly, the **CambPlants Hub**, hosted and supported by Plant Sciences and SLCU, with additional funds from HEIF, facilitates networking and research grant applications with agricultural research institutes including Rothamsted Research, John Innes Centre and NIAB, as well as plant breeding and agronomy organisations such as ADAS. Interactions within this Hub helped shape the research focus of the Crop Science Centre, and facilitated an application by NIAB for £2.5M

from the Cambridgeshire and Peterborough Combined Authority for **Barn4**, a purpose-built Cambridge incubator for agritech start-ups.

Driving SBS strategy to encourage and facilitate entrepreneurship and translation of discovery science by its researchers, all Departments/Institutes have Enterprise Champions. These work with BIT and CambPlants to identify and coordinate a range of networking and knowledge-exchange activities for SBS researchers, including with SMEs and larger companies in the Cambridge high-tech ecosystem and elsewhere. They also facilitate links to several University bodies, including the Milner Institute and the Office of Translational Research, which support conversion of ideas from any area of the University into the development of new products and approaches to treatment or prevention of human disease and illness (Section 4.2).

UoA5 scientists have also taken advantage of **Cambridge Enterprise.** This provides seed funds to facilitate commercialisation, focusing on intellectual property management and the creation of spin-out companies, and can invest up to £500K in each new spin-out company. **Apollo Therapeutics**, a £40M collaborative venture between three UK Universities and three global pharmaceutical companies, has directly funded UoA5 researchers (e.g. *St.Johnston*) to help accelerate projects to the clinic. Similarly **Cambridge Innovation Capital (CIC)** has raised £275M to invest in technology and biomedical sciences including therapeutics, diagnostics, digital health and genomics/proteomics. Lastly, **Ceres Agritech**, a collaboration between the Universities of Cambridge, Lincoln, Hertfordshire, Reading and UEA, funded by Research England, provides translational funding for agritech projects, most recently for approaches to generate disease-resistant bananas (*Hibberd)*.

1.5 Open Access & Data Sharing

1.5.1 Data sharing

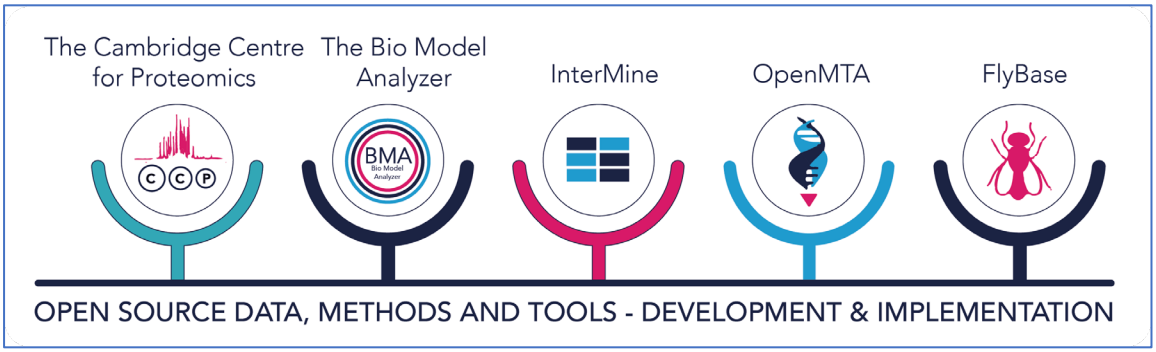
The University is committed to disseminate its research and scholarship as widely as possible and to contribute to society as well as to academic advancement. Its Open Access (OA) Policy Framework and the online OA Service ensure as many outputs as possible are OA, within the constraints of copyright and licensing agreements.

We strongly encourage our researchers to make methods, results, and software widely accessible to the scientific community and beyond. Data not directly published by journals must be deposited in appropriate repositories such as model organism databases (human, *Drosophila*, tomato etc) or other online repositories, such as GEO for sequence data. Alternatively, data can be uploaded to the University's own freely accessible data repository, Apollo, with a specific section for Biological Sciences (which is also the site where PhD theses are lodged). SBS supports data management champions within each Department/Institute (approximately 25 individuals), who provide advice and training for all researchers. Data management is further facilitated by the affiliation of all SBS libraries to the University Library in 2019. This offers an additional support network and coordinated strategy to facilitate navigation through a changing publishing landscape, as well as sharing of best practice between institutions and librarians.

1.5.2 Open-source data, methods and tools

Cambridge bioscientists have been at the forefront of developing novel and innovative ways in which to make tool development and implementation more accessible and usable by others. Some highlights include:

- **The Cambridge Centre for Proteomics (CCP)** developed mass spectrometry methods along with open-source bioinformatics and statistical tools that utilize pattern recognition and machine learning methods to enable robust analysis of organelle proteomics and multi-protein complex data. A recent novel application allows rapid global analysis of the RNA binding proteome
- **The BioModelAnalyzer (BMA) Tool** is an open-source project that merges perspectives from systems biology, formal methods, human computer interaction and design to help biologists engaged in early drug discovery.
- **InterMine** is an internationally accessed flexible data warehouse for the integration of heterogeneous biological data making it easy to access and analyse With InterMine researchers can explore organism-based and other research data provided by many different organizations, moving between databases using criteria such as homology.
- The **OpenPlant Synthetic Biology Centre** pioneered an Open Material Transfer Agreement (**OpenMTA**) in a collaborative effort between the BioBricks Foundation and input from researchers, technology transfer professionals, social scientists, lawyers, and other stakeholders from across the globe. The OpenMTA enables individuals and organizations to share their materials on an open basis.
- **FlyBase** is an online bioininformatics database and the primary repository of genetic and molecular data for one of the most extensively studied model organisms, *Drosophila melanogaster.* FlyBase is the work of a consortium of *Drosophila* researchers and computer scientists at Cambridge, Harvard and Indiana Universities.



1.6 Research Integrity

Underpinning our research is an ethos of openness, where researchers are supported to conduct and publish reproducible research, in an environment that maintains the highest standards of integrity and ethics. The University is committed to Universities UK (UUK) Concordat to Support Research Integrity, and was recognised as a **Leader in Openness around Animal Research 2019-2022** for "*the innovation and courage shown by individuals and their organisations in supporting greater openness around the use of animals in research*". The University promotes good research practice through its Researcher Development Programme and Good Research Practice framework. Governance policies and procedures are overseen by the Pro-Vice Chancellor for Research.

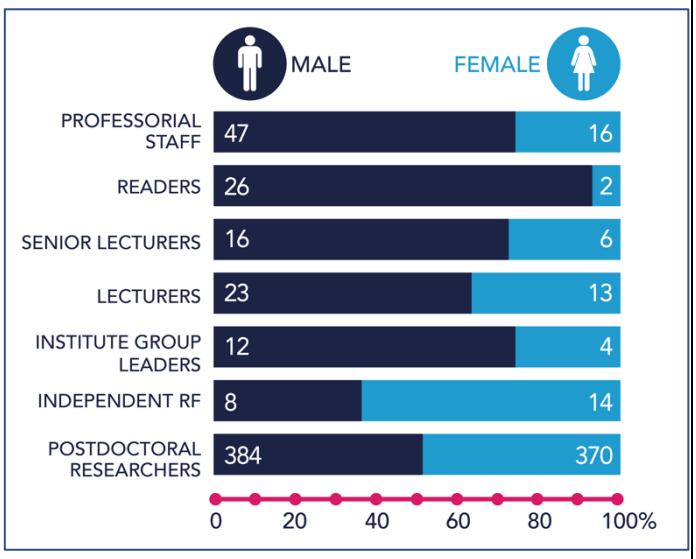
The University is also a signatory to the San Francisco Declaration on Research Assessment (DORA), demonstrating an institutional commitment to ensure that scientific output is measured

accurately and evaluated wisely. In SBS, we implement the key principles of DORA at all stages, from appointment of early-career researchers through career progression and promotions. In 2021 we will adopt a common template for capturing CV, publication and other information, focusing on the narrative as much as metrics.

Multiple training sessions are provided for all staff and students. These address issues of research integrity, legal and ethical obligations, bribery and anti-slavery practices, data protection, GDPR, record keeping, and professional standards. All group leaders are made aware of their role in ensuring the highest standards in research integrity and ethics in the undertaking and delivery of their research and this ethos is cascaded through the research teams. As demonstration of the commitment of SBS, two academics (*Sanson* (PDN), *Laman*^{UoA1} (Pathology)) have been appointed to lead in this area.

2. People

SBS aims to support the breadth and depth of the discipline of biological sciences by attracting and training excellent staff from across the world. We have a substantial and dynamic community of almost 1000 researchers across all career stages (plus ~600 postgraduates). Commitment to our staff is illustrated by tailored schemes to support **Career Development of Researchers** in accordance with the Concordat, which were recognized by the European Commission HR "Excellence in Research" Badge (2015). Information from the University-wide consultation *MyCambridge* (2017) on what it means to work for the University is shaping strategies to foster a motivated workforce in SBS. Evidence that measures are increasing staff satisfaction come from the 2019 staff survey, where 6 of the top 10 questions showing improvement since 2016 were about aspects of job satisfaction, including '*support from the Institution to achieve work/life balance*' (up 22%), '*the opportunity to discuss skills and career development*' (up 11%) and '*management of probation'* (up 8%).



2.1 Academic Staff and Independent Fellows/Group Leaders

Academic appointments are made on the basis of research excellence, whilst ensuring appropriate provision of expertise to teach all aspects of biological sciences. Since 2018, rather than simply remaining within departmental boundaries, recruitments have reflected our broad research Themes (Section 1.1), with increasing emphasis on recruiting interdisciplinary scientists who can nucleate transformational science and long-term impact (*Paluch, Willerslev)*. There have been cross-School appointments between Genetics and Chemistry (*Collepardo*) and with Engineering in Synthetic Biology (*Bakshi*[UoA12]), as well as planned cross-Department appointments (e.g. in Bacteriology, joint between Pathology/Biochemistry, 2021). Our aim in the next 5 years is to increase the proportion of strategic thematic appointments, facilitated by anticipated retirements of 13 senior staff within UoA5.

2.1.1 Recruitment

All ***academic positions*** are advertised widely, nationally and internationally. Electoral Boards (Professorships) involve experts from outside Cambridge and selection panels (non-professorial academic posts) have representation from at least two Departments, and from SRIs/IRCs or other external partners as appropriate. As well as providing relevant scientific expertise, the approach ensures consistency across UoA5. Success is evident from the large number of applicants per position (usually 80-100) and from the achievements of the new appointees in winning significant funding (e.g *Sferuzzi-Perri*, MRC New Investigator Research Grant; *Kromdijk,* UKRI Future Leaders Fellowship, *Paluch*, ERC Consolidator, *Zlatic*, ERC Consolidator and Wellcome Investigator). All those involved in recruitment must complete Equality and Diversity and

Unconscious Bias training, and all panels are configured inclusively. Over the reporting period, there has been a focus on more inclusive advertising, short-listing and interview processes as well, leading to an increase in applications from women and minority groups. In 2014, 21% of academic staff were women. Of the 33 appointments at lecturer level since then, 14 (42%) were women, and overall the proportion of women has increased to 25%. Those who identify as Black, Asian or minority ethnic rose from 2% to 3.3%. A goal for the next period is to consider how to increase further the number of women and ethnic minorities in the faculty.

Research fellows form an important strand of the scientific excellence in many research areas. Applications that synergise with existing strengths are fostered, so that the fellows can build their independent groups in a supportive and stimulating environment. Selection is based on previous achievements and on future research plans. Twenty-two independent fellows joined SBS during the current assessment period with fellowships from for example Royal Society, BBSRC, NERC, Wellcome (Section 3.1), plus 9 Institute Group Leaders (4 in SLCU and 5 in MRC Toxicology Unit). We also offer funded opportunities for researchers to transition towards independence whilst based in established groups. Annually these are 5 Next Generation Fellows supported by the Centre for Trophoblast Research, 4-5 Herchel Smith Fellows, 1-2 Broodbank Fellowships in plant/microbial biology and a range of Colleges' Junior Research Fellowships. All research fellows are supported in their career development as outlined below, with the option to engage in teaching at the undergraduate and postgraduate level to aid progression to future academic posts.

2.1.2 Staff Development Strategy

Mentoring, probation, peer review (appraisal) and training are cornerstones of UoA5 staff development and are deployed for both established and short-term appointments. All new academic staff and independent Research Fellows discuss with their Head of Institution (HoI) expectations for research, teaching and general contribution in relation to probation and promotion criteria. For new Lecturers, these are summarized in the criteria for reappointment, which is usually considered after a 5-year probationary period (the individual may opt for progression or promotion earlier) and is supported by annual meetings with the HoI to discuss progress against the criteria. For Independent Fellows/Group Leaders, annual meetings and review allow effective reporting to the funders. Appointees at all levels are assigned a mentor, usually a senior academic in the same or related Department/Institute. Teaching loads may be adjusted to allow research programmes to be established. Depending on career stage, training includes a required course on supervising postgraduate students in science and involvement in the Pathways in Higher Education Practice scheme. All staff have Review & Development meetings (appraisal) at annual or biannual intervals depending on career stage, and appraiser-training has been significantly augmented, with a considerable increase in numbers of SBS staff reporting that they found their review useful in the 2019 survey compared to 2016. In the reporting period all probationary lecturers passed probation (or were promoted), and most Fellows went on to tenure-track positions in academia (Section 2.2).

For all staff across SBS, there is significant local support for preparing and refining grant applications. These include peer review sessions for responsive mode grants and cross-Department mock interviews for fellowship and investigator award schemes. In 2018, a new self-organised initiative of Research Fellows and newly appointed lecturers was established to provide peer mentoring and support. Over the next period, this initiative will be enhanced by administrative input from SBS and a dedicated web-presence.

2.1.3 Staff Recognition and Rewards for research and impact

A key tenet of the University People strategy is that achievements should be recognised and structured routes provided to progress careers. In accordance, SBS recognises and rewards staff for carrying out research and for achieving impact, primarily through the **Senior Academic Promotions** (now called **Academic Career Pathways) Scheme**, which operates for all academic positions. The case for promotion is assessed in relation to the criteria based on the strength of evidence covering the academic's career. The three elements are Research/Impact, Teaching and Other contributions (apportioned 50:30:20 for promotion to Reader and Professor, and 4:10:10 to Senior Lecturer). Evidence of **international leadership** in research is sought at Professorial level and **international recognition** for Readerships, with reference to originality and contribution to the advancement of knowledge, evidenced by referees from overseas institutions. An 'Additional Considerations' statement by the applicant enables allowance to be made for contextual factors such as parental leave, disability, caring responsibilities, part-time working, and now for the coronavirus pandemic. Support for promotions applications is provided by a peer mentoring scheme. The University's Women in Science, Engineering and Technology Initiative (WiSETI), which provides support for women at all career stages in STEM disciplines, operates a CV-mentoring scheme for those applying for promotion. A particular focus on encouraging women to apply for promotion has led to an increase in the proportion of Professors who are women from 22.4% to 25.4% over the reporting period, above the University average of 22.7%.

2.1.4 Research/sabbatical leave and exchanges outside academia

Sabbatical leave is integral to the University's investment in academic research. Those in established academic posts (including part-time) are entitled to one term of sabbatical leave on full pay for each six terms of service, with no requirement to raise external funds for replacement teaching. Staff use this entitlement to refresh their research outlook and expertise, often at overseas universities. Approximately 60 UoA5 staff took advantage of this over the reporting period.

The University recognizes that secondments have reciprocal benefits for individual career development and for developing the skills of an organisation, and are strongly encouraged across all staff. For SBS, a notable example in the reporting period is secondment of *Dame Ottoline Leyser* to be Director of UKRI (June 2020). Interactions with industry is also actively encouraged. The University is a key component of the entrepreneurial ecosystem around Cambridge. Several UoA5 researchers have spun out companies from their academic research, as evidenced from 6 of the Impact Case Studies, with other examples across all Themes. Many companies are based in local science parks, and academics continue to play key roles in their scientific/technical leadership with no limit on their participation.

2.2 Support and career development for early career researchers

Postdoctoral researchers comprise the largest staff group (35%) in the University, with >750 engaged in UoA5 research. In response to this growth, the University is realising a key aim, stated in **REF2014**, to provide **affordable accommodation for staff** (and post-graduate students), via its £1Bn North-West Cambridge Development. In the first £350M phase, opened in 2015-16, high-quality sustainable housing was provided for over 700 staff members and their families. The Postdoc Academy, established in 2013 to champion the interests of postdocs, is also located there.

The University's Employment and Career Management Scheme, launched in 2011, provides researchers with clear role descriptions for each level of a research career, guidance on pay progression and information on promotions criteria. The probationary period for post-doctoral researchers is 6 months, and the criteria are allied to the specifics in the job description. Regular Career Management Review (CMR) meetings consider development needs and arrangements are made for mentoring and appraisal. Some Departments organize Peer Mentoring groups (e.g. Plant Sciences). Online guidance on CMRs is provided for both PIs and researchers, along with a self-assessment tool for researchers. There is a bespoke Postdoc Life Sciences programme run by the University Careers Service, providing online careers advice, one-to-one sessions with a dedicated Life Sciences advisor, and regular seminars about career options and opportunities within and beyond academia.

The **Contribution Increment Scheme for Researchers** rewards research staff on the basis of outstanding work and/or the need to retain specialist skills. Applications are invited 4-monthly, via HoIs. Individuals can self-nominate or be nominated by their group leader for either a recurrent increment, where significant sustained achievements occur, or a one-off increment for a specific piece of work. The Senior Researcher Promotions scheme rewards achievements of more senior researchers (including Institute Group Leaders), and recognizes transitions to independence and leadership through two stages to Senior, then Principal, Research Associate.

Active programmes and organizations within the University and SBS that focus specifically on supporting postdocs include:

- The ***Postdoc Academy*** coordinates a rich programme of training and development activities, working closely with the University's professional development and careers offices. These include study space, online courses and mentoring from both within and outside academia. For example, ~40% of UoA5 postdocs have industry rather than academic mentors.
- ***Postdocs of Cambridge,*** a University Society for early career researchers, offers guidance on opportunities within and outside Cambridge and organises monthly social and networking meetings. It seeks to represent postdocs on issues surrounding career development and employment conditions.
- ***Entrepreneurial Postdocs of Cambridge***, formed in 2015, supports postdocs in developing business and entrepreneurial ventures (activities include business plan competition, consultancy projects and workshops).

SBS Departments/Institutes run postdoctoral activities focused on scientific themes, such as Life Science Master Classes, a forum for discussion on 'hot topics' and current techniques in Biology. Other examples include:

- Annual postdoc research symposia (PDN) and retreats (Gurdon Institute) with discussions on career development and progression;
- '5-cubed mixers' termly sessions (Biochemistry), 'coffee chalks' (PDN), 'chalk talks' (Genetics) to present research plans and highlight potential for collaborations;
- Teaching experience via a Postdoctoral Teaching Fellowship scheme (Biochemistry).

Together, these activities have increased the sense of community among the postdocs, enabled access to specific pieces of equipment, stimulated collaborations, created knowledge-sharing platforms, and contributed to future science. A very positive indicator of our vibrant training environment is demonstrated by the fact that so many of our Career Development/Research Fellows secured scientific posts in academia or industry:

- in Cambridge (e.g. *Steventon*, Henry Dale, Genetics; *Sarris*, MRC-CDF, PDN; *Sferruzi-Perri*, Dorothy Hodgkin, PDN; *Ahnert*, Lecturer, Chemical Engineering);
- in the UK (e.g. *Bushell*, Beatson Institute; *Branco*, Queen's University, Belfast; *Montgomery,* University of Bristol; *Dicks,* NERC Fellow to UEA – and then back to Cambridge as Lecturer);
- internationally (including: *Braybrook,* UCLA, USA; *Conduit*, Institut Jacques Monod, France; *Huch*, Max Planck, Dresden, Germany; *Gillis*, MBL, Woods Hole, USA; *Gunesdogan*, Sofja-Kovalevskaja-Award, Göttingen, Germany; *D.O'Connor*, Pairwise Plants, North Carolina Research Triangle, USA; *Thorogood,* Helsinki, Finland; *Wigge*, HoD Leibnitz IGZ, Potsdam, Germany).

2.3 Research Students

We have a thriving community of ~570 PhD and ~65 MPhil students from >70 countries. During the assessment period, **1029 PhD degrees** and **287 MPhil degrees** were awarded. Success of our students after graduation is shown in the Graduate Outcomes Survey from HESA, where in 2020, 88.7% had gone on to further study or secured graduate-level employment, entering a range of different job sectors, but showing a preference for scientific destinations.

2.3.1 Recruitment

Recruitment of the highest calibre postgraduate students is achieved by rigorous assessment of applications and panel interviews. We strive to include students from varied backgrounds and with diverse experiences, and all panel members must complete equality & diversity and unconscious bias training. As a result, representation of British Black, Asian and Minority Ethnic postgraduate students in SBS grew by almost six percentage points, taking it just above the national average. To encourage applications from under-represented groups, in 2019 we initiated a summer internship programme (the Experience Postgrad *Life Sciences* programme) aimed at increasing the participation of minority ethnic postgraduate students, with a focus on Black, Black African, Black Caribbean, Bangladeshi, and Pakistani British students.

2.3.2 Funding for studentships

Many students are individually funded through competitive schemes. These include several Cambridge-based Trusts (International Scholarship Scheme, Commonwealth Trust, Overseas Trust, European and International Trust, the Gates Trust) and the Islamic Development Bank. Philanthropic funding since 2015 established new PhD training capacity in Marine Biology and Biology of Asia (9 studentships). International collaborative postgraduate programmes include the Herchel Smith Fund, (4 life-sciences students/year), the NIH-Oxford-Cambridge Scholars Program (8-12 students/year) and, until 2019, the Howard Hughes Janelia Graduate Programme (2-3 students/year).

Collaborations with a range of industrial partners have led to **~50 CASE or equivalent collaborative studentships** funded by the BBSRC or NERC during the assessment period. Since 2014, 15 industrial PhD scholarships have been co- or fully-funded by either AstraZeneca or MedImmune each year. Participation in multiple EU Marie Curie training networks provides links to academic and industrial colleagues across Europe. During the reporting period 8 had Cambridge coordinators, including *ImageInLife* (multilevel bioimaging in vertebrate development; *Zernicka-Goetz*) and DOHART (periconceptional programming of health; *Ferguson-Smith*).

A core strategy of SBS is to obtain and develop topic-focused interdepartmental PhD programmes that recruit cohorts of students, and in many cases offer rotation projects during the first year to give students a broader experience of the subject area. Moreover, they have galvanised establishment of core training courses. This approach has enhanced postgraduate training experience across SBS by opening access to all students. Over the reporting period, the following programmes have operated:

- The BBSRC Doctoral Training Partnership (DTP) (to 2019) admitted 30-35 students plus 11 iCASE students annually and the training programme included a three-month professional internship. The University has been invited to reapply for BBSRC DTP funding in 2022.
- From 2020, an equivalent SBS DTP has been established through joint funding from the University (Vice-Chancellor Awards), Departments across SBS and several Colleges, providing 15-20 awards/annum.
- Four Wellcome PhD Programmes have been based wholly or partly in SBS, each admitting 4-6 students per year: Stem Cell Biology and Medicine, (renewed in 2019 for a further 5 years); Developmental Mechanisms; Mathematical Genomics and Medicine; Infection, Immunity and Inflammation.
- The British Heart Foundation PhD studentship programme in cardiovascular research, admits 4 students per year with an emphasis on interdisciplinary research.
- The NERC DTP is a flagship cross-School programme with Physical Sciences. UoA5 students address the core themes “Biodiversity, Evolution & Adaptation”, and “Ecosystems”
- The CRUK Cambridge Centre, based in the Clinical School, has several students working on basic biology of cancer in Pathology, Pharmacology and Biochemistry.
- The MRC Integrated Toxicology Partnership provides doctoral level training in Toxicology, with 4-5 students/year.

- The MRC Doctoral Training Partnership has four main research areas spanning SBS and Clinical Medicine and includes Flexible Funding to allow students to undertake internships or further training unconnected to their core research. Joint funding from several managed SBS Trust funds enabled the admission of 29 students in 2020.

MPhil students (60-80 per year) mostly apply to individual labs to carry out a research degree and are funded by the Cambridge Trusts or self-funded. Two pioneering SBS MPhil training programmes have been established: 'Basic and Translational Neuroscience' in 2016 and 'Developmental Biology' in 2019 (hosted by PDN). These have a strong taught element in the first term through interactive workshops, followed by a 32-week research project. Recognising the strengths of this format for student learning and cohort-building, including providing bursaries to support Widening Participation efforts, another new MPhil in Therapeutic Sciences was launched in 2019 by CATS, offering student placements in academic spin-outs, consulting firms, biotech or small pharma companies.

2.3.3 Training and support

The Postgraduate School of Life Sciences (PSLS) provides structured training support for all SBS postgraduate students including access to a wide range of courses for PhD students wishing to pursue academic or non-academic careers. The core training includes presentation and writing skills, as well as subject-specific classes, developed to enhance breadth of knowledge and interdisciplinary study. Outreach and entrepreneurial skills are fostered through programmes run by the Office of External Affairs and Communications ('Rising Stars'), the Centre for Entrepreneurial Learning, the Cambridge University Technology and Enterprise Club, (a student-run organisation, hosting talks, workshops, mentoring and networking sessions) and the i-Teams Cambridge scheme, where multi-disciplinary teams of students work with researchers and industry mentors to investigate potential products and markets. Several PhD programmes also include a mandatory placement in a non-academic setting (e.g. BBSRC Professional Internship for PhD Students) and students are supported to work away for research in other institutions to learn new techniques or use facilities, as well as for field work.

Integration into Department/Institute research life provides tailored training, mentoring support and a rich programme of research seminars. Students also benefit from the opportunity to give poster or oral presentations and discuss their work with staff and other research students at symposia, including at student-led events. Specific research forums provide further opportunities for interactions; e.g. the annual Student Conference on Conservation Science, brings international delegates to Cambridge to network and learn new ideas (over 3400 delegates from 136 countries since launching in 2000).

Besides being embedded within a Department/Institute, all students are members of a College, which offers pastoral care and a vibrant social environment with students from all disciplines. Events related to health and wellbeing are organized by a University-wide committee, supporting all University Doctoral Training Programmes. These emphasize available wellbeing resources and how to access them as well as offering more informal opportunities for discipline-agnostic interactions and training.

2.3.4 Monitoring and Assessment

The Postgraduate Office in each Department/PhD programme, along with Directors of Postgraduate Education, monitor student progress regularly through a series of checkpoints, starting with a project feasibility report 1-2 months into the PhD/MPhil, followed by annual progress reports written by the student. Each student has a supervisory team comprising their Principal Supervisor and two academic advisors, who critically assess progress reports, meeting with the student as needed. Assessors are usually colleagues within the host Department but can also be nominated experts in other Departments or outside the University. Students on PhD programmes have additional in-depth progress discussion meetings with management committees and peers.

Supervisors assess academic performance and in discussion with students identify appropriate training courses, reviewing training and development logs to ensure that students are progressing appropriately and developing the skills required for successful completion of the PhD. Supervisors also submit termly reports (available to the student), in which any problems are highlighted. Students can submit a self-evaluation report once a year in Michaelmas (October) Term. Throughout, departmental postgraduate offices invite dialogue with students and supervisors about any issues, as they arise.

For research-only degrees (MPhil or PhD), dissertations are examined by two examiners, one of whom is external to the University. A *viva voce* exam is carried out and the examiners' reports on this and the thesis are forwarded to the student and supervisor. Success rates are >95% and the vast majority complete within the allotted time (>80% PhD within 4 years).

2.4 Equality and diversity

2.4.1 Strategies to support equality and diversity

Several University-wide networks have been developed to provide support and advice to diverse groups, including LGBT+ Staff Network, BAME staff network, Women's Staff Network, SPACE (Supporting Parents and Carers @Cambridge). These networks offer a regular forum to discuss diversity issues at work/study, a safe environment for raising issues and contribute to development of Cambridge's equality, diversity and inclusion policy and implementation of plans. Participation in the Diversity Networks is viewed as a valuable professional development opportunity, with their Chairs and Secretaries entitled to release-time from teaching. Five University Equality Champions are available to members of groups with protected characteristics and provide overall leadership in diversity issues, augmented by School Champions, for UoA5 currently *Itzhaki* (Pharmacology). The University's commitment to inclusivity was recognized by the Employers Network for Equality and Inclusion and by Stonewall, which ranked the University highly in its Top Employers Survey (best places to work for lesbian, gay and bisexual staff), awarding the University's LGBT+ staff network "star performance" status. In 2019 the University was awarded the Race Equality Charter Bronze Award.

All UoA5 Departments/Institutes have received a **Bronze or Silver Athena Swan Award** in the assessment period (the relocated MRC Toxicology Unit will apply in 2022). The applications for, and implementation of, these awards have provided impetus and seeded many grassroots activities and new initiatives within Departments/Institutes and has facilitated sharing best

practices between them. Equality and Diversity training has been mandatory for all UoA5 staff since 2018. Further initiatives include senior academic staff being tasked with identifying scientists from under-represented groups within their respective fields and encouraging and supporting them to apply to Cambridge. Seminars to promote awareness of equality and diversity in UoA5 have included Femi Otitoju ("Unconscious Bias"), Michelle Ryan ("Understanding How Context Shapes Women's Ambition") and Baroness Young of Old Scone ("Tap Dancing on the Glass Ceiling") Annual "Inspirational Women in Science" poster competition and events for international women's day are received with great enthusiasm. To celebrate 2020 Black History Month, a series of events were organised by SBS members, including an exhibition "Past & Present: Black Legacies in STEM" and roundtable discussion "Spotlight on Black Female Scientists in Cambridge".

In all SBS Departments/Institutes, essential meetings are timetabled within core working hours to allow staff working flexibly or delivering/collecting children from school to attend. Transparent documentation of academic work-loads has been prioritized and is being rolled out across SBS to enable fair distribution of loads and appropriate allowances for those working part-time. Staff have generous parental (and shared-parental) leave entitlements, leave for carers, and options of career breaks for up to two years and/or flexible working. For example, since 2014, 36 have taken shared parental leave (20 men/16 women). Since 2014, breast-feeding and baby-changing facilities have been established at multiple locations in SBS that all UoA5 staff can access. The provision of nursery places has increased with three workplace nurseries available.

To support career and professional development following a career break or a period of leave for caring responsibilities, the **Returning Carers' Scheme** provides grants of up to £10K for staff whose primary role is undertaking research. Awards can provide short-term research support, for example to generate preliminary data for grant applications, or to cover expenses of a person looking after an accompanying child while the researcher/academic attends a conference overseas. Since 2014, 74 UoA5 researchers have benefited from this Scheme. An example is *Laura Itzhaki*, who received an award in 2016, was promoted to Professor in 2017, established a start-up company (PolyProx Therapeutics) in 2019 and was appointed Head of Pharmacology in 2020.

Particular evidence of the supportive environment for women bioscientists comes from the numerous prestigious awards and elections to Learned Societies (asterisked in Section 4.5), and the significant number of leadership positions held by female academics in SBS since REF2014 – seven out of ten Heads of Department/Institute (Genetics, Gurdon Institute, MRC Toxicology, PDN, Pharmacology, Plant Sciences, SLCU) and two Heads of School. Another measure is election of women to prestigious Chairs: *Ferguson-Smith* (Arthur Balfour Professor of Genetics, 2017), since appointed interim Pro-Vice Chancellor for Research; and *Leyser* (Regius Professor of Botany, 2020), now seconded as Director to UKRI. Over the next reporting period, we will build on these achievements with the goal of further enhancing diversity and inclusivity in all aspects of staffing and recruitment. Our commitment is demonstrated by the appointment of an SBS academic lead for Equality, Diversity and Inclusion in 2020 (*van-der-Pette*, MRC Toxicology).

2.4.2 Supporting staff and student wellbeing

The goal of the University's Wellbeing Strategy is to improve the health, safety and wellbeing of University staff and to prevent work associated ill health, recognising that values, personal

development and the work environment contribute to overall wellbeing at work. All Departments/Institutes have Wellbeing Advocates (SBS has 25 in total), who attend a Mental Health Lite briefing provided by the charity MIND. The Champions provide information to staff on local and University wellbeing activities and are a source of advice and guidance.

Staff and students can access the University's Occupational Health Service, where practitioners provide confidential advice and support with regards to health problems that could affect or impact on an individual's ability to do their job, for example returning to work after illness, ill-health retirement, or work-related illness and control of occupational hazards. Advice may include workplace adaptations or equipment to support work activities, or referral to other support services e.g. Staff Counselling Service. To improve support for disabled staff and work towards a disability-smart environment, the University joined the Business Disability Forum (BDF), which shares expertise, gives advice, provides training and facilitates networking opportunities. This augments the advice provided to those with registered disabilities by the Disability Resource Centre.

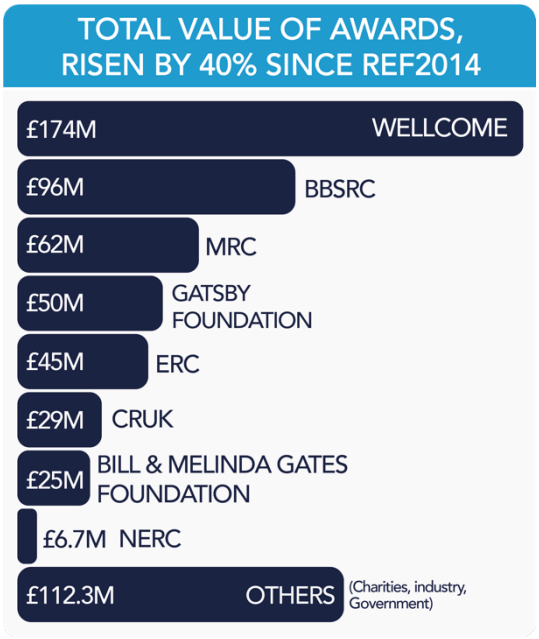
Other University-wide initiatives include Dignity@Cambridge, which provides a framework for respect and good conduct to prevent all forms of bullying, harassment, or discrimination and sustain a positive working environment for all staff. It highlights options available to any individuals who feel they are/have been subject to any inappropriate or unacceptable behaviour. The "Breaking the Silence" initiative, launched in 2017, provides a means for anonymous reporting of harassment and sexual misconduct. Dignity at work is an area of rigorous focus in SBS, initiated when some responses in the 2019 staff survey raised concerns, and will be supported by the newly-appointed academic leads in Research Culture and Equality, Diversity & Inclusivity.

More broadly, many Departments/Institutes organize away days and retreats, with scientific elements, to foster interactions and all host social events (e.g. garden parties/barbecues, Christmas celebrations, children's parties, regular "happy hours") to encourage social cohesion. Recent experiences from the impact of the Pandemic have reinforced our commitment to wellbeing and mental health and in the absence of face-to-face events a series of digital well-being activities have been launched, including the Botanic Garden's "Wellness Wander" and "Wildlife from your Window: Exploring the natural world at home" from the Museum of Zoology.

3. Income, infrastructure and facilities

Over the reporting period, UoA5 institutes and researchers have obtained ~£600M in external funding, underpinned by a further £300M investment by the University and SBS in estates, support posts and facilities.

3.1 Research funding strategies



The research funding strategy in UoA5 is to capitalize on the creative and collaborative environment in Cambridge. Researcher-led applications are actively encouraged and supported by Department-level peer-review schemes, whilst larger collaborative bids are fostered with assistance from SRIs/IRCs, the Impact Teams (BIT, CambPlants) and the University Research Strategy Office. Success is evident from the total value of awards which has increased substantially since REF2014, **rising by 40%**. Our portfolio currently comprises **over 1100 awards** from diverse funders. The most substantial are from Wellcome (£174M), BBSRC (£95.6M), MRC (£62.4M), Gatsby Foundation (£50M), ERC (£45M), Cancer Research UK (£29M), Bill & Melinda Gates Foundation (£25M), and NERC (£6.7M), but also include industry, Government Departments (e.g. DEFRA) and many health-related charities. The awards have generated significant outputs in terms of publications and impact cases, developed important research reagents that are distributed worldwide, led to national and international collaborations, follow-on and commercial funding, as well as enabling evidence-based policy decisions. Many have made major contributions to the health and wealth of the UK and globally.

3.1.1 Investigator-driven, responsive-mode applications

These are a cornerstone of the funding strategy. A number of University training courses provide support and guidance for preparing applications. Grant mentoring and feedback programmes within Departments help develop ideas and ensure that applications are competitive. For example, an average of 23 BBSRC grants are successful each year, placing Cambridge University second in the UK in terms of total BBSRC funding. The strength of our research across the discipline of biological sciences is demonstrated by the range of topics covered by the **31 ERC grants** awarded since 2014, e.g.: ***Starter Grants*** to support work in crop pest resistance (*Schornack*) and mitochondrial genetics (*Ma*); ***Consolidator Grants*** in biophysics (*Paluch*), microbial ecology (*Tanentzap*), epigenetic modification (*Sawarkar*), microbiome (*Patil*) and mechanotransduction (*Franze*) and ***Advanced Grants*** to study C4 photosynthesis (*Hibberd*), plant transgressive inheritance (*Baulcombe),* developmental genetics (*Martinez Arias*) and conservation biology (*Sutherland*). The latter has contributed to the **Conservation Evidence** project (Section 4.2), which provides advice to Government on environmental policy. Investigator led applications also include **large scale programmes of >£5M.** Of particular note are grants of >USD10M to *D.Smith* that have led to improved and next generation flu vaccines (Impact CS: New generation pandemic and seasonal influenza vaccines).

3.1.2 Fellowship applications

Researchers at all stages are encouraged and supported through the Fellowship application process. For example, more than 20 senior researchers in UoA5 have been awarded Senior/Principal/Professorial Fellowships or Investigator Awards from Wellcome, MRC and Royal Society. These are allied to research strands across SBS (e.g. focusing on developmental, *Brand*, *Bray, Sanson, Ferguson-Smith*, and molecular mechanisms, *Pellegrini, Luisi, CJR.Smith, Blundell*) or plant epigenetics (*Baulcombe)*. Outputs include the discovery that exercise reduces the growth of tumours and increases the effectivity of immune cells (*R.Johnson*), featured in the New York Times.

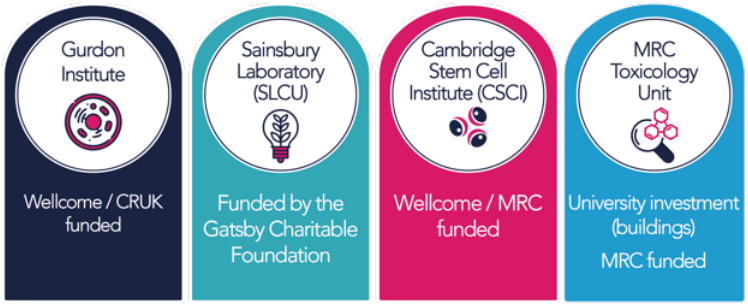
As part of its wider strategy to support early career researchers, SBS has a strong ethos of supporting outstanding individuals to apply for independent Research Fellowships. Regular open competitions in Departments, which actively encourage applications from women and other underrepresented groups, help identify individuals with strong research backgrounds that synergise with activities in SBS. Potential candidates are then supported through the application process, with guidance and advice on grant writing, grant costing and the interview process. Success is evidenced by over 20 independent fellowships (64% women) from Royal Society, Wellcome (Sir Henry Dale), BBSRC David Phillips Fellowships, MRC, NERC and UKRI Future Leader Fellowships. As an illustration of the cutting-edge work from these independent fellows, *Joo-Hyeon Lee* adapted her three-dimensional models of human alveolar stem cells to reveal the infection response to SARS-CoV-2 and in 2020 was awarded a Wellcome Senior Fellowship to capitalize on her ground-breaking work.

3.1.3 Large research consortium grants

Support for interdisciplinary and collaborative grant applications comes from the SRIs/IRCs, as well as the BIT and/or CambPlants Hub. Additionally, the University's Research Strategy Office helps with the response to major funding calls. Notable successes include: the Human Developmental Biology Initiative (HDBI), a £10M Wellcome collaborative project (*Surani, Rawlins, B.Simons,* with CoIs in UoA1 and London) to unravel how human embryos develop in the first weeks/months after fertilisation. This is leading to increased understanding of fertility, birth defects and new avenues for regenerative medicine; the Drosophila Connectomics Consortium (*Jefferis, Landgraf, Zlatic, Cardona*) supported by grants totalling £10M from Wellcome and Janelia Research Farm, and involving collaboration and joint appointments (*Cardona, Zlatic*) with the MRC-LMB. This has provided unparalleled understanding of how functional networks are wired. Several BBSRC sLoLas (>£2M) have also been held over the period (eg *Lilley, Russell, AG.Smith, Hibberd, IR.Henderson, Oldroyd*), on topics from engineering C4 photosynthesis to a spatio-temporal map of the fly interactome.

Large-scale participation extends into translational and international initiatives. Of particular note are: the **Engineering Nitrogen Symbiosis for Africa (ENSA**) programme (led by *Oldroyd;* £18M Bill & Melinda Gates Foundation plus £8M uplift from FCDO) to support the translation of strategies to reduce inorganic N fertiliser use in sub-Saharan Africa; the **Cancer Research Technology Translational Alliance**, awarded a total of USD22M (£1M to Cambridge; *Willis*) to generate drugs to target protein synthesis; and Flybase, providing an essential global resource for *Drosophila* researchers (~ 50,000 users/month) with funding from NIH, MRC, WT £2M in total, *N.Brown*).

3.1.4 Institute funding



An important part of SBS's research strategy has been to invest in its core-funded research institutes, which provide strong, collaborative environments aligned with the funders' strategic missions. Our pre-established institutes (**Gurdon Institute,** Wellcome/CRUK funded; **Cambridge Stem Cell Institute (CSCI)** Wellcome/MRC funded; and **Sainsbury Laboratory (SLCU),** funded by the Gatsby Charitable Foundation) continue to be highly successful in generating extensive amounts of additional research income (£74M to Gurdon Institute, £52.6M to SLCU since 2014). As part of its strategy to increase drug discovery research, the University invested £18M in estate costs and £5M in posts and wider support in its successful bid for the **MRC Toxicology Unit**, which provides a new link between drug discovery and drug safety. Since its relocation in 2018-2019 the Unit has obtained ~£5M in additional research income. The University has also provided seed-funding to establish the **Institute for Neuroscience** (IfN) a research hub intersecting between PDN and Psychology, providing a research coordinator and internal research grants for proof-of-concept work, to facilitate substantive grant applications in basic Neuroscience.

3.1.5 Industrial funding

The University Strategic Partnerships Office works to increase the interactions with our Industrial partners and the co-funding of our discovery science, securing industrial funding for research with direct translational value and/or carried out in the pre-competitive space. These initiatives have contributed to a substantial increase in industrial funding to a current total of £17M. Significant projects associated with SBS include consortia with CATS/Milner (*Kouzarides* £4M) and a translational award from CR-UK linking with Celgene/BristolMyersSquibb (*Willis*).

There is also an emphasis on fostering local interactions. SBS has two designated facilitators who work with local partners, notably AstraZeneca and GlaxoSmithKline, to identify areas for potential funding. For example, AstraZeneca fund both PhD studentships and, through the IMed scheme, postdoctoral fellows. They also support joint projects, including that exploiting human lung organoids (*Rawlins*, £450K).

3.1.6 Endowments and philanthropy

The University's fund-raising team, CUDAR, has actively matched philanthropic support to SBS strategic plans, resulting in significant investments in biological research of >£10M since REF2014. These include several large donations, namely £5M support from Evolution Education Trust for the Milner Institute (Sections 1.4 & 4.2) to carry out target validation and functional genomics; £3M for the Whitten lectureship in Marine Biology and accompanying Whitten PhD studentships in Zoology; £1.5M to endow the Trophoblast Research Fund (PDN), providing fellowships and core laboratory administration and resources; and £3M to endow the Russell R. Geiger Professorship of Crop Science, crucially underpinning a successful application to UKRPIF for the Crop Science Building (Section 3.3.2). More generally, recurrent funding through the Isaac

Newton Trust in response to competitive applications helps match-fund research grants, fellowships and critical infrastructure.

3.2 Addressing Equality & Diversity issues

The University is committed to a positive working environment for all staff and an inclusive research culture. SBS recognises that such pressures as balancing caring responsibilities or dealing with a disability can impact on intellectual space for creative grant ideas. Accordingly, specific schemes have been developed to ensure all staff seeking to obtain grant funding are supported. As detailed in Section 2.4, these include transparent **documentation of academic work-loads** to promote fair allocation of time for research and grant writing activities; research awards under the **Returning Carers' Scheme**; and grant mentoring schemes for women and Black, Asian and minority ethnic staff and fellows. In addition, significant investment to improve accessibility of older premises has been undertaken to enable all researchers to access the space that they require for their research, including ramps to enter buildings, lowering of research benches and hearing loops in meeting rooms. All these features are automatically included in new buildings.

3.3 Institutional and operational support for research and impact

3.3.1 Investment in the estate

UoA5 researchers are primarily based on three adjoining central Cambridge sites in buildings erected mainly in mid-20th century that occupy ~53,000 m^2 (8000 m^2 for teaching). The SLCU is housed in the nearby Botanic Garden. New state-of-the art buildings that operate alongside older and refurbished buildings have significantly improved the estate, notably a tailor-made space for MRC Toxicology Unit (funded £18M University/£7M MRC).

Additional investment in estates has included significant upgrade to existing research areas and to support research facilities. A >£5M upgrade of laboratories, offices, computational biology space and library facilities in Genetics transformed its research infrastructure. Similarly, a dedicated Ancient and Environmental DNA facility and purpose-built neuroscience and behavioural analysis suite were provided through ~£1M investment in Zoology. Importantly, SBS continues to support the research facilities through provision of support posts and matched funding for equipment.

An evolving strategy to improve the Biological Sciences estate for cutting-edge research is being developed with the help of architects, following extensive analysis. Funds permitting, we are aiming to establish a new purpose-built Teaching Hub in West Cambridge for biological and biomedical teaching of all first and second year undergraduates. This will release teaching space embedded in our research buildings for refurbishment and repurposing, with a rolling programme to augment modern research facilities across SBS in the next 5-10 years.

3.3.2 Investment in Organisational Research Clusters

Investment in three broad research clusters was a key aim of **REF2014**, bringing together groups from the University with external partners. They are housed in purpose-built premises with considerable investment from the University and external funders. In all cases, thoughtful use of

shared and social spaces greatly facilitates interactions with neighbouring Institutes and Departments.

- The **Cambridge Conservation Initiative** (Section 1.2.5) is housed in the **David Attenborough Building**, which opened in 2016. The cost of the refurbished building (£55M) was provided by the University, with philanthropic support from MAVA and the Garfield Weston Foundation. This unique collaboration between the University's Conservation Research Institute and the world's largest cluster of conservation organisations is transforming the global understanding biodiversity and the natural capital it represents, catalysing strategic partnerships between leaders in research, education, policy and practice, to secure a sustainable future for biodiversity and society.
- **The Stem Cell Institute (CSCI)** is co-located in the Jeffrey Cheah Biomedical Centre, alongside the **Milner Therapeutic Institute** (Section 4.2) and **Cambridge Institute for Therapeutic Immunology & Infectious Disease**, which both have the translational goal to transform pioneering science into therapies. The Centre, which opened fully in 2020, was funded by the University (£49M), Research England (UKRPIF-£25M) and Jeffrey Cheah (£13M).
- The **Crop Science Centre** was established through a collaboration between Plant Sciences and NIAB to facilitate a step change in translational research in food security and crop science, supporting multidisciplinary research programmes that combine cutting-edge bioscience with innovative agronomy, and take research from the lab to the field. The new Crop Science Building on the NIAB site, with access to field sites and extensive glasshouses, was funded by a £16.9M UKRPIF award and with an additional £3M from the University for plant growth facilities and equipment. Opening in late 2020, ~40 UoA5 researchers are now located there.

3.3.3 Computing and IT

Recognizing the importance of high-performance computing and data storage, the University has invested significantly in both these facilities:

- *High performance computing:* Substantial externally sought and internal investment has established Bio-medical computer and data analytics infrastructure (~£5M). The Cambridge Bio-Cloud Facility benefits all research generating "big data", with immediate beneficiaries including the Cambridge Genomics Services, DNA Sequencing Facility, Cambridge Centre for Proteomics and CAIC, all of which generate large datasets requiring considerable computing power for analysis. The users of the Bio-Cloud also have significant industrial connections, and the high-performance computing service has a proven track record of working with industry.
- *IT:* A major data centre, with various grades of storage, has been built in West Cambridge by the University. New high-speed network equipment and cabling is being installed to provide the necessary high-speed access (e.g. cabling access to the Biochemistry Hopkins and Sanger buildings ~£700K). In addition, SBS faculty are able to apply for research computing and storage resources up to the value of £5K.

3.4 Infrastructure, facilities and expertise for impact

The University has invested over £2M in Research Offices over the reporting period, ensuring that researchers are supported in developing, obtaining funding for and managing their research projects at all levels. Department/Institute research support staff liaise closely with the Research Operations Office and Legal Services, providing the basis for effective grant costings and collaboration agreements. The Research Strategy Office provides funding of up to £10K for larger, multi-institutional grant applications. This has supported several large awards including two led by *Griffiths* (Plant Sciences): £7M GCRF TIGR^{2}ESS grant and the Cambridge hub of the EIT Food Knowledge & Innovation Community (KIC), with ~£2M so far to Cambridge.

As explained in Section 1.4, we achieved a major goal of **REF2014** by providing SBS support for the Bioscience Impact Team **(**BIT). BIT works with researchers on strategic collaboration and knowledge exchange across a variety of sectors, including Pharma, AgBiotech (Crop Science Centre UKRPIF award), Food (EIT Food KIC), Environment and Conservation. The team also liaises with the University's Strategic Partnership Office and Cambridge Enterprise, the University's Technology Transfer Office, to increase the translation of discovery science. In 2016-2017 ~40 grant applications were supported, with 25 successful. These comprised £5K in entrepreneurship activities, £185K for Knowledge Exchange, £10.5M for translational/industrial funding and £10M in international development including GCRF, much of the latter in collaboration with CambPlants (Section 1.4). BIT secured a further ~£1M in 7 BBSRC institutional grants (e.g. IAA, GCRF) and a Flexible Talent Mobility Account (BBSRC). Forty separate projects have been funded with over 50 external partners, mostly industry, leading to significant impacts. For example, an award for "BEST: Bio-Electrochemical System Tour" (*Howe*) to promote knowledge exchange and commercialisation of algal bio-electrochemical systems, secured further grant funding and enabled development of industrial partnerships.

Several University organisations support the translation of UoA5 discovery science (section 4.1) including the Office for Translational Research and the SRIs/IRCs. For example, CATS (Section 1.3) provides free external expertise through its industry Experts in Residence scheme. Over the reporting period 200 meetings have taken place, allowing researchers to obtain an external professional perspective on the translation of their research into the clinic, leading to new relationships with potential industrial partners.

3.5 Specialist research infrastructure and facilities

UoA5 researchers have the benefit of substantial University and SBS investment in shared research facilities and key infrastructure, including Biochemical & Molecular Biology Stores; Electronics workshop; Fly facility; Mechanical workshop; Plant Growth Facilities; Vehicle Pool; and Visual Media Group. In addition, as proposed in **REF2014** several additional state-of the-art methodologies and equipment have been established, either by direct investment into core infrastructure or obtaining external income. Most significant is the substantial £160M investment by the University in its Biomedical Services, to provide new biofacilities for experimentation on a range of animals (zebrafish, cichlids, amphibians, rodents, guinea pigs, rabbits, chickens and other birds, sheep, pigs, horses and primates). These facilities. which underpin research by a substantial proportion of SBS scientists, are supported by 160 staff and trained experts who facilitate home office licence applications. More specialist facilities include:

- ***CryoEM facility:*** Established in 2016 with Talos Arctica and Taitan Krios microscopes (£4M in grants from Wellcome, £2.5M University funding) and a designated Facility Manager (*Chirgadze*) this facility provides a revolutionary tool for the vibrant structural biology community within UoA5 (>10 PIs) and other UoAs. The facility is also used by external commercial users from Big Pharma and small biotech. The acquired data underpin a range of projects that tackle fundamental problems in molecular biology relevant to human health.

- ***Cambridge Advanced Imaging Centre, CAIC*:** Facilities in advanced imaging have been enhanced since 2014 by investment of £3.5M in eleven new microscopes, each representing technology breakthroughs in light and electron microscopy. The Centre has recharged £1.2M to meet expenditure and has been successful in establishing collaborations across Departments and with industry. It has directly won £1.6M, including an EPSRC RSE Fellowship (*Muresan*), and a Wellcome technology development award (*Harris, O'Holleran, Bray, Sanson, Paluch, St Johnston*). Links with industry have been nurtured e.g. with studentships studying drug toxicity using liver organoids (GlaxoSmithKline & MPI-CBG, *Huch*). It has also developed novel imaging approaches that are being commercialised (EPSRC & Cairn Research Ltd). CAIC is complemented by satellite facilities such as the Zoology Imaging Facility, which has a dedicated imaging specialist and a high sensitivity Olympus FV3000 confocal system with super-resolution capacity, via £400K investment from Isaac Newton Trust and Zoology funds.

- ***Algal Innovation Centre:*** This is £500K facility in the Botanic Garden, funded by the European Regional Development Fund project EnAlgae with matched funding from SBS, Directed by *AG.Smith,* it was set up in 2016 to generate pilot data on growing algae at scale under (semi)natural conditions, underpinning commercialisation of algal biomass production. Researchers have since used the Centre to: (i) collaborate with over 30 different SMEs and larger companies in testing a range of equipment and algal-based processes for sustainability solutions; and (ii) run professional development courses in algal biotechnology, each attracting 30-50 participants from academia, industry and policy-makers from around the world.

- ***Cambridge Biotomography Centre***: The high-resolution micro-Computed Tomographic imaging facility, one of only three in the UK, is a multi-user research facility that supports Cambridge researchers as well as the broader national and international academic community. It is funded jointly with Department of Archaeology in School of Humanities & Social Science. The Centre is a core research tool for over £1.5M of externally-funded research grants and has produced at least 70 peer-reviewed publications since 2014.

4. Collaboration and contribution to the research base, economy and society

4.1 Arrangements and support for research collaborations, networks and partnerships and evidence of success

Collaboration is at the centre of the UoA5 research culture in Cambridge, supported by a variety of mechanisms with the University including SRIs/IRCs and central funding to support interdisciplinary research (Section 1.3). Many of these enable collaborations that extend beyond the University to forge partnerships with the wider academic community locally, nationally and internationally. As detailed in Section 3.2.2, important examples are the **Crop Science Centre** joint venture with NIAB, whose establishment was supported by the Global Food Security IRC, and the **Conservation Initiative** underpinned by the Conservation IRC. Robust collaborative links exist with several other publicly-funded research institutes in the Cambridge area, including:

- **BBSRC Babraham Institute** group leaders are members of the Centre for Trophoblast Research, hosting students and fellows (*Kelsey, Reik, Rugg-Gunn*). They also co-organize the epigenetics club. Links are cemented by formal affiliations, such as Honorary Professorship *(Wolf Reik*).
- **Wellcome Sanger/EBI Institute** at Hinxton provides unparalleled opportunities for collaboration on bioinformatics and genomics projects, for example single-cell reconstruction of the early maternal-fetal interface in humans. The "**Darwin Tree of Life**" project (£9.4M Wellcome funding), an ambitious collaboration of ten research institutes and museums including the Sanger, which seeks to sequence all eukaryotic species on the British Isles, is led by *Durbin* (Genetics). The aim for the first phase in 2021 is to collect, 'barcode' and deliver high-quality genomes of at least 2,000 species. This will give new insight into evolutionary processes and uncover new genes, proteins and metabolic pathways to aid the development of drugs for infectious and inherited diseases.
- **NERC British Antarctic Survey** has been combining their expertise of remote sensing using satellite imagery and field logistics with that of plant scientists in algal genomics and biotechnology (AG.*Smith, Davey*) to conduct the first ever survey of the contribution of terrestrial snow algae to primary productivity in Antarctica. This has resulted in a follow-on collaborative NERC grant and extensive links with US & Chilean Antarctic bases.

For **international partnerships**, the University's Strategic Partnerships Office provides impetus and strategic direction to stimulate and support research collaborations between UoA5 scientists and colleagues globally at institutional level. Examples include a collaboration with SMART

Research Institute, Indonesia to mitigate effects of oil palm cultivation on biodiversity (*Turner*); with IKIAM University in Ecuador to facilitate *C.Jiggins'* research on studies of adaptation to montane habitats in butterflies by providing shared insectaries and climate chambers in Ecuador, and a three-way collaboration between Copperbelt University in Zambia, the University of Cape Town and Cambridge on brood parasite behavioural ecology (*Spottiswoode*).

Bioscientists are also active in the **Cambridge-Africa** programme, which supports a range of proactive, coordinated, multi- and interdisciplinary initiatives that strengthen research capacity and scholarship in Africa (examples in Section 1.2.3). Cambridge Enterprise, the Postdoc Academy and the Judge Business School (JBS) also offer a range of courses, programmes and facilities for actual and would-be entrepreneurs and help staff and students commercialise their expertise and ideas for the benefit of the global community. Institutional level interactions are widespread, for example strong links have been forged with researchers and policy makers in **India**, initiated by *Griffiths* as a result of BBSRC-GCRF awards TIGR^{2}ESS and MiLLNETi. These awards, which seek to support small-holder farmers to increase yields and decrease use of fertiliser and water, have led to several other initiatives with the Department of Biotechnology in India, and *Griffiths* has been appointed Advisor to the Vice-Chancellor on strategic partnerships with India.

4.2 Evidence of how staff interact with key research beneficiaries

4.2.1 Interaction with industry

Key beneficiaries of UoA5 research include small and large industrial enterprises. Many of the partnerships established over the reporting period have had significant mutual benefit, informing and supporting further research. For example, in Pharmacology many research groups have projects jointly funded with industrial partners Takeda Pharmaceuticals, Roche, Heptares, Shinogi and Firmenich. Other large multinational companies such as GlaxoSmithKline, AstraZeneca, Microsoft and Toshiba have also directly reached out to UoA5 researchers to establish collaborations, new PhD programmes (Section 2.3) and joint postdoctoral positions.

Collaborations between researchers in UoA5 with industrial partners is encouraged by several means, including the Office for Translational Research, CATS and the Milner Therapeutic Institute. The latter provides a physical hub for translational science and collaboration between academia and industry, with 54 affiliated members bringing diverse expertise and resource to the University. Indeed, the wealth of recent **biological start-up companies** in the Cambridge area constitutes a large component of the research environment, fostering an entrepreneurial spirit in our principal investigators. These, together the larger companies in the region, have provided unparalleled opportunities for our PhD students to gain experience in these environments, with many DTP students undertaking their PIPS with these companies.

4.2.2 Interactions with policy makers

Wide engagement with policy-making and legislation at national and international levels occurs via memberships and governance of learned societies including the Royal Society, the Academy of Medical Sciences, the Prime Minister's Council for Science and Technology and the Department for Environment, Food and Rural Affairs (Section 4.5). An example is expert evidence to the House of Commons Environmental Audit Committee, Invasive Species Evidence Session from *Gilligan*

who was also selected by the Secretary of State as Chair of the UK Joint Nature Conservation Committee. A forward-looking initiative is CATS having a member of the Medicines Health Advisory Board (MHRA) on its steering panel, enabling new discoveries in safety science to be translated into policy.

Our researchers also provide specific data to guide policy: as contributors to the World Wildlife Fund's Living Planet Report 2020, Cambridge zoologists showed that agricultural expansion is a key driver of rapid insect decline globally, helping to inform and alert national and international leaders to deliver policies that protect the planet. The Conservation Evidence project (*Sutherland, R.Smith*), which carries out industrial-scale evidence synthesis, led to the BioRISC initiative (led by *Sutherland, Aldridge*), funded by philanthropy through St Catharine's College, which aims to change approaches to policy making. In 2020 this identified intervention options in the coronavirus pandemic and for reducing the risk of future pandemics, attracting the Environmental Audit Committee to meet in Cambridge. *Balmford's* work on reconciling food demand and biodiversity conservation (drawn on by parliamentary committees shaping post-Brexit agricultural policies) has concluded that linking higher-yield farming to sparing or restoring natural habitats may be most effective. On the demand side the group has devised nudge-based interventions for reducing meat consumption and worked to eliminate ruminant meat from University outlets.

More generally, bioscientists engage with policy makers over diverse issues from stem cells to ecology. Many of these interactions are via the **Cambridge Centre for Science and Policy**, which hosts decision-makers as Policy Fellows; ~50 UoA5 researchers have met >100 Policy Fellows since REF2014. In 2019, the Centre ran roundtable policy discussions on Data, Agritech and Research & Innovation in the food system linking UoA5 scientists with ministers and civil servants from DEFRA to commission an independent review to assist in the first National Food Strategy in 75 years. A further University workshop chaired by Lord (David) Willetts discussed ways to translate University research into increased value capture through innovation. The resulting **Building Innovation Communities** project, organised by CambPlants, ran sandpits between academics and industry on innovation in the potato supply chain, leading to a BBSRC Agri-Food Technology Seeding Catalyst Award to use real-time crop and environmental data to control water flows to potato crops (*Coomes,* Plant Sciences) in collaboration with NIAB, KisanHub, and the Agriculture and Horticultural Development Board (AHDB).

4.3 Wider contributions to the economy and society

4.3.1 Health and Medicine

Our research has contributed to improving health, quality of life and well-being through research that contributes to, and impacts on, drug development and medical interventions, including an increased understanding of the issues that surround medicines safety. Drug development takes many years and life-changing therapeutics that have arisen from earlier University spinouts include **Olaparib** (licensed by NICE for treatment of ovarian cancer in 2015; *Impact CS: Revolutionising cancer therapy via the DNA-Damage response*). New drug developments within the reporting period include the discovery of a small molecule inhibitor of a muscle specific chloride channel, which, by affecting muscle function, has significant potential for treating myasthenia gravis. More broadly, MRC Toxicology Unit has identified a new toxicophore, present in range of

therapeutically relevant drugs, which adversely affects cardiac-cell function. This new information about the toxic substructures within some drugs will reshape drug development programmes in the pharmaceutical industry.

4.3.2 Economic competitiveness of the UK

University research under UoA5 has led to income generation through spinout companies and licencing of its scientific knowledge and creation of new processes, products and services. The University is at the hub of the "Silicon Fen" entrepreneurial ecosystem and many of the new start-ups, directly involving those in UoA5 in the 2014-2020 period, have a focus on health related issues: ***PolyProx Therapeutics*** (focuses on the discovery and development of a proteostatic drugs to treat cancer and neurodegenerative diseases); ***DefiniGEN*** (provides a wide range of human cell products); ***Congenica Ltd***. (aims to revolutionise how diseases are characterised to inform treatment decisions by providing end-to-end genomic analysis in as little as 5-minutes); ***Swift Molecular Diagnostics*** (produces DNA test strips that are as simple to use and as cost effective as a pregnancy test); ***CellCentric*** (focuses on small molecule inhibitors of epigenetic-related pathways to treat cancers); ***STORM Therapeutics*** (aims to tackle disease through the modulation of RNA modifying enzymes); **Qkine** (an enabler of regenerative medicine). These companies exemplify how the transfer of knowledge is supporting industrial research and directly contributing to the economy and job creation.

4.3.3 Conservation and the Environment

Conservation and biodiversity research in the University has demonstrably improved the environment, for example by working with the Indonesian Government to establish ways to monitor carbon stocks in forests (*Coomes*). Closer to home, demonstration by plant scientists (*Glover, Moyroud)* that colour generated by petal surface nanostructures enhances signalling to pollinating bees (widely reported in the press as bee 'Sat Nav' (e.g. *The Guardian* 18 Oct 2017; ITV News 18 Oct 2017)), led to a collaboration with Mole Seeds U.K. Ltd, a major UK supplier of professional quality flower seeds. They formulated a seed mix aimed at strengthening pollinator populations by providing honeybees and wild bumblebees with a steady diet of flowers throughout the spring, summer and early autumn. The seed mix, which was trialled over two years at the University Botanic Garden, was developed by taking into account flower reward, timing, accessibility, visibility and texture, and is now commercially available.

4.4 How the unit engages with diverse communities and publics through its research

4.4.1 Collections

A unique feature for the research landscape in Cambridge is the presence of world-renowned collections within UoA5, which provide an outstanding resource for our researchers and for those from other UK institutions and globally. They also play a key role in outreach and public engagement activities.

- The refurbished **Museum of Zoology**, a key aim of **REF2014**, has vastly improved outward-facing facilities that have supported new education and outreach activities, both in person and online. The Museum attracted 150,000 visitors in its first year of reopening (>50% more than forecast). In 2019, it was awarded 'Best Large Museum in Cambridgeshire' by Museums in Cambridge and was one of six museums (out of 80)

shortlisted nationally for a Kids in Museum award. Its free 'Discovery Talks' provide monthly lunchtime sessions exploring themes from the history of the collection to current zoological research. The Museum also participates in the "Curiosities and Conversations" initiative with Addenbrooke's hospital, engaging dialysis patients in conversations based on specimens from the Museum, as they undergo treatment, and has run specific events for Dementia Compass, Winter Comfort and Cambridge City Council's Children's and Young Persons Participation Services.

- The **Botanic Garden** houses 14,000 accessions and over 8,000 plant species, distributed across a 40-acre landscape and is an exceptional amenity in the heart of the city, with over 300,000 visitors annually (although numbers are currently restricted due to the pandemic), additionally hosting the annual Festival of Plants and many special events. Since REF2014, there has been a major emphasis on providing more direct links and explanations to the work of plant scientists, for example 'How do plants tell the time?' explaining plant circadian biology research (*Webb).* The **Rising Path** project, funded by the Monument Trust, led to a complete overhaul of the Systematics bed for effective research and public communication of the importance of plant variation. In 2019 the **Living Collections Strategy** was launched, which further underpins knowledge of the plant kingdom and efforts to conserve botanical diversity.
- The **Herbarium**, the fourth largest in the UK housing over a million accessions, with >50,000 type specimens, supports research and lends specimens globally. It was recognised as a national and international treasure in the 2019 Strategic Research Review of plant science in Cambridge. Currently supported by the recent appointment of a fixed-term Curator with funds from Plant Sciences, a road-map to identify appropriate research links and a funding model for future sustainability is being developed with CambPlants and BIT. Achieving this will be an aim over the next reporting period.

4.4.2 Public Engagement

Bioscientists actively contribute to University efforts to promote excellence in public engagement, with many researcher-led activities in a range of formats that aim to share information with the public and inspire young people to take up science as a career. A major annual event is the Cambridge **Science Festival**, with talks, events and exhibits staged across a week in mid-March. This can attract upwards of 10,000 visitors, with >2000 visitors to the Plant and Life Science Marquee recorded on one day in 2016. This won the "Customer Experience, Cambridge Business Improvement Districts Award" the same year. One attendee remarked "*Long live the Cambridge Science Festival as a window for the general public to have new insights into our changing world*."

UoA5 researchers also contribute to the **Festival of Ideas**, engaging in a range of public debates and discussions to consult and listen to public views, for example on Synthetic Biology or climate change. From 2021 these two festivals will be united in an interdisciplinary **Cambridge Festival**, which will nevertheless retain strong and distinct platforms for the sciences.

Beyond the Festivals other major avenues for public engagement include:

- **Conversazione**, organised by the Cambridge Natural History Society, an annual exhibition with displays covering all aspects of Natural History. Thousands of community members, students and academics attend the event over 2 days. A Student Prize is awarded annually for "best student exhibit".
- **BlueSci**, a science magazine written and produced by Cambridge students that highlights recent exciting discoveries, often achievements of Cambridge researchers, in a publicly digestible mode. BlueSci also produces short films for social media about various biological subjects from molecular biology to biodiversity.
- **Public visits and activities** arranged within Departments and Institutes, such as the engagement opportunities organized by the Gurdon Institute throughout the year. These enable its students and staff to work with the public on a variety of skills including film, sound or photo editing, social media, project management, creativity, team-work and strategic thinking.
- **SoapBox Science** (2016, 2018 and 2020) involved leading women scientists in the University who presented their work to the public in Cambridge's main shopping area. These highly successful events lead to discussion and lively debate with members of the public.
- Many UoA5 researchers have worked with "**Pint of Science**", a grassroots non-profit organisation enabling researchers to share their research in the pub. The aim is to provide a space for researchers and members of the public to come together, be curious, and chat about research in a relaxed manner.

In addition, individual scientists regularly write blogs, post on social media and speak with broadcast and print media about their work. When a paper on Antarctic snow algae and their response to climate change was published in May 2020, tweets from corresponding author *Davey* were picked by ~500 online or print news outlets worldwide, with 27 news broadcasts and interviews, including the *Telegraph*, *Guardian*, BBC, National Geographic, *New York Times*, CNN and Fox News. Media monitoring software Cision estimates it reached 1.7Bn people globally, with the paper now ranked by Altmetric in the top 5% of all research outputs ever tracked. In 2016, studies on the development of implantation-stage mouse and human embryos (*Zernicka-Goetz*), reported as "a breakthrough in human embryo research" (*The Sunday Times*, July 23rd 2017) "new milestone studies have managed to keep embryos growing for 12 to 13 days" (*New Scientist*, May 2016), was winner of *Science* magazine's 'People's Vote for Scientific Breakthrough'.

4.4.3 Interactions with Primary and Secondary Schools

Encouragement and support for interactions with Schools has led to many initiatives across the range of UoA5 topics:

- **The Gatsby Plant Science Education Programme** (GPSEP), a joint initiative between the Botanic Garden and SLCU, aims to make a demonstrable difference to the teaching and learning of plant science at all ages in the UK. It advocates for inclusion of relevant and

inspiring contemporary plant science in the school curriculum and develops teaching resources to support this.

- **"Young Pharmas**" was initiated in 2019 with 16 sixth-formers from local secondary schools who carried out scientific experiments investigating key concepts in pharmacology over a 3-month period. Young Pharmas continues as an exciting annual outreach scheme providing hands-on practical sessions, to give students studying biology and chemistry the opportunity to experience what a career in science might be like.
- Innovative teaching **'Toolkits'** (e.g. Cell explorer, Unlocking genetic editing), designed to bring contemporary research into GCSE and A-level classrooms in ways that support the biology curriculum, have been co-created by Gurdon Institute scientists. In recognition, in 2020 the Institute was awarded a Silver Engage Watermark from the National Co-ordinating Centre for Public Engagement.
- An extensive programme with over 168 local primary and secondary schools is run by the Museum of Zoology, based in a dedicated 'Learning Lab'. In a project funded by the Esme Fairbairn Trust, three primary schools in North Cambridgeshire engaged with specific butterfly-themed conservation projects. During the lockdown in Spring 2020, the Museum published new resources every fortnight on its blog for home-educating primary school-age children. In June 2020, it staged **Zoology Live!** – a week-long online interactive event for all the family about the animal kingdom. Zoology Live! was Highly Commended in the "Best Film" category at the Family Friendly Museum Awards, the only university museum among the 20 shortlisted nationally for these awards.

4.5 Indicators of wider influence and contributions

Researchers working within UoA5 make a major contribution to the research base by membership, including leadership roles, in UKRI and charity strategic committees, other funders, government committees and industry. Recognition comes from extensive honours, awards and prizes, election to Learned Societies, and invitations to present major lectures. Examples of note since 2014 are listed below (women scientists are indicated with *).

4.5.1 Honours & Prizes

- Dame Commander of the British Empire, for 'services to plant science, science in society and equality and diversity in science': *Leyser**
- CBE, for 'services to plant health in the field of plant epidemiology': *Gilligan*
- OBE, for 'services to biomedical sciences and supporting the careers of women scientists': *Willis**
- Royal Society Medals: Gabor – *B.Simons, Durbin*; Ferrier – *Holt**, Francis Crick - *Jefferis*
- Genetics Society Mendel Medal: *Baulcombe, Leyser**
- Canada Gairdner International Award - *Surani*
- RSPB Centre for Conservation Award: *Gilligan*
- Palaeontological Association Lapworth Medal: *Clack**
- Mortyn Jones Medal: *Herbison*
- The Zoological Society Frink Medal: *Akam*
- Genetics Society of America George W Beadle Award: *Ahringer**
- British Society Developmental Biology Medals*:* Waddington – *Harris*; Cheryll Tickle – *Nichols*, Sanson**

- Champalimaud Vision Award: *Holt**
- *S.Jackson:* FNRS Gagna A. & Ch. Van Heck prize; King Faisal International Prize for Science; Royal Netherlands Academy of Arts and Science Heineken Prize; Fondation ARC Léopold Griffuel Award in Translational and Clinical Research

4.5.2 Honorary Degrees

- *Baulcombe* (Leeds, Edinburgh, Dundee, Helsinki)
- *Gurdon* (Rockefeller)
- *S.Jackson* (Leeds)
- *Leyser** (Aberdeen, Guelph, Norwegian U Science & Technology, Swedish Agricultural)

4.5.3 Election to Learned Societies

- Royal Society: *Ferguson-Smith*, Oldroyd*
- Honorary Membership of British Ecological Society: *Sutherland*
- Academy of Medical Science: *Bray*, Taylor*
- EMBO members: *Willis*, Oldroyd, Paszkowski*, Philpott*, Lilley*, Frye, Paluch*, B.Simons, Brakefield, Nédélec, Zegerman*
- Linnean Society: *Griffiths, Glover**
- British Toxicology Society: *Willis**
- Marine Biological Association: *AG.Smith**
- Leopoldina (German National Academy of Sciences): *Leyser**
- Belgian Academy: *Webb*
- American Academy of Arts and Sciences: *Kouzarides, Durbin*
- US National Academy of Sciences: *Holt**
- Royal Swedish Academy of Sciences: *Clack**

4.5.4 Major invited lectures

Davies: Royal Society Croonian Lecture; *S.Jackson*: Sir Anthony Epstein Annual Lecture, the Sackler Lecture; *Oliver*: Marjorie Stephenson prize lecture; *Guissani,* The Physiological Society GL Brown Prize Lecture; *Spottiswoode**: the Stamford Raffles Lecture at the Zoology Society.

4.5.5 Advisory/strategic roles and Board Chairs

- *Leyser**, Director of UKRI (June 2020), BBSRC Council Member
- *Ferguson Smith*:* Chair MRC Molecular and Cellular Medicine Board Funding Board, BBSRC Council Member, MRC Strategy Board
- *Lilley**: Chair, BBSRC Transformative Technologies Strategic Advisory panel
- *Hibberd:* Member, BBSRC advisory panel Agriculture and Food Security security,
- *Ahringer*, Durbin, N.Brown*: Scientific advisory board of Max Planck Institutes
- K*ouzarides*: Scientific Board of the UK Institute of Cancer Research
- *Baulcombe*: Science Advisory Board of Boyce Thompson Institute (Cornell University), BBSRC Council Member
- *Gilligan*: Chair, Biomathematics and Statistics Scotland
- *AG.Smith**: Member, BBSRC Strategic advisory panel Industrial Biotechnology & Bioenergy

- *Willis*:* Member, National Mesothelioma Centre Advisory Board; MRC-PHE Centre for Environment and Health; MRC Strategy Board.
- *Howe*: AHRC advisory group

4.5.6 Research Council and other Review Panels

During the assessment period, many UoA5 individuals served on committees of national and international funding agencies, Government and policy committees, and interacted with industry. Such collaborations often lead to impact beyond academia; additional examples are given in our Impact case studies and elsewhere Section 4.

Funding agencies

- Wellcome: *Rawlins*, (Wellcome interview committee); *Miska, Ferguson-Smith*, Willis*, Livesy, Vassiliou* (Wellcome Expert Review group); *Brand** (Wellcome Sir Henry Dale Fellowships), *Sanson** (Wellcome Henry Wellcome Fellowships)
- CRUK Science Committee: *Evan*
- BBSRC*: Russell* (Chair, Comm D), *Lilley** (Transformative Technologies Strategy Advisory Panel) *Landgraf, Carr, Lummis*, Mata, Mott**, *Weyand* *(pool of experts)
- MRC: *Frye* (Research committee); *Taylor* (MCMB); *Ferguson-Smith** (Chair, MCMB)
- Leverhulme: *Brand** (Philip Leverhulme Prizes)
- Action Medical Research: *Bray** (Chair)
- European Research Council: *Bray** (Chair, LS3 Starting grants), *N.Brown* (Chair LS3 Consolidators), *St Johnston*, (Chair, LS3 Starting Grants)
- Human Frontiers Science Program: *Herbison*, (2018, Chair, Council of Scientists), *Glover** (2018 Council of Scientists)
- Independent Research Fund Denmark: *Bray** (Chair, Stem Cells/Cell biology)
- European Space Agency and NASA: *Murray* (Panel review, human spaceflight programme):

Government agencies

- *Aldridge*: expert witness to the Environmental Audit Select Committee on invasive species control.
- *Baulcombe*: report to the Council for Science and Technology about genetic modification.
- *Gilligan*: chair of the Nature Conservation Committee for UK and Defra Science Advisory Council, Advisor on disease and pest management to Defra, USDA, Ethiopian Institute of Agricultural Research, Hort Innovation Australia, and Mars Inc.
- *Leyser** has extensive science policy engagement, serving on the Prime Minister's Council for Science and Technology and chairs the Royal Society's Science Policy Expert Advisory Group.
- *MacFarlane*: All-Party Parliamentary Group for Healthy Homes and Buildings
- S*utherland, Aldridge*: engagement with the UK parliament's Environmental Audit Committee
- *Willis**: Cross sector Government Committee on the safety of medicines in pregnancy and medicines

Strategic Collaborations with Industry

- *Colledge*: scientific consultant for Medimmune and Alloy Pharmaceuticals
- *Durbin*: consultant for Dovetail Inc
- *Ferguson-Smith**: advisory board at Swift Molecular Diagnostics, and consultant with Sanofi SA
- *Herbison*: Consultant to Que Oncology
- *Kouzarides*: Scientific Board of Foghorn (Biotech company in Boston)
- *Krupic:* Strategic collaboration with Integrated Fiber Optic Ltd on developing new generation two-photon microscopy for bioimaging sciences
- *O'Holleran*: 3D super-resolution methods now being commercialised (EPSRC & Cairn Research Ltd).
- *Willis**: AZ Drug Safety Metabolism Committee

4.6 Evidence of the Unit's contribution to the discipline of Biological Sciences

Underpinning the sustainability of the discipline, our research is tightly linked to teaching and research training of both undergraduate and postgraduate students, and of highly skilled researchers. Many of these go on to develop careers in biology, ensuring the sustainability of the subject into the future, and the diverse, successful careers they pursue enhance the knowledge economy. As illustration, more than 20 of our early career researchers have moved into research leader positions in academia and industry in the UK and worldwide since 2014 (Section 2.2).

Further demonstration of our impact over the reporting period is the graduation of ~1750 undergraduates in biological subjects associated with UoA5, where the final year modules are all grounded in cutting-edge research carried out by the lecturers. Overwhelmingly positive feedback from students, 98% overall satisfaction in 2020, evidences the excellence of our teaching. Of our final year students, 95% received "Good Honours" and a substantial proportion of them, ~40%, continued to postgraduate study. Similarly, more than half of the 1300 postgraduates since 2014 report next destinations as continuing in research positions. We also regularly contribute to continuing education via the **Institute of Continuing Education**, and through mounting research skills-based courses in bioinformatics, genomics, biotechnology and natural history, supporting life-long learning and professional development of academic and industrial colleagues, as well as members of the public.

The formation of interdisciplinary interfaces is also important to stimulate progress. For example, in Cambridge the physics and mathematical modelling of biological processes has formed into a sub-discipline of biology. Thus, consistent with a strategic aim in **REF2014**, mathematical modelling now forms an important component of much of our work, e.g. in understanding plant development, the genetics of populations, dynamic modelling the properties of chromatin, and stochastic models of cell division for tissue maintenance during development. Indeed, there has been a longstanding interest in research at boundaries of physics and biology, with the establishment of the **Physics of Living Matter** seminar series 17 years ago, which has now grown to a series of international events that attract interdisciplinary scientists from around the world.

The flexibility and innovation of UoA5 researchers enables rapid development of biological solutions to emerging national and international challenges that impact on health, the environment and food security. A pertinent example is the MRC Toxicology Unit collaborating with two NIHR

Health Protection Research Units (run from Imperial College London) on Chemical and Radiation Threats and Hazards and Environmental Exposures and Health, particularly as a result of emergencies. The Unit (*MacFarlane*, *Willi*s), in collaboration with Engineering (*Boies*[UoA12]), are studying the impact of brake and tyre wear on human health, and, with clinicians in London, the effect of the Grenfell Tower fire on the health of the firefighter cohort who attended the fire.

To end, a timely example of how the Cambridge research environment supports excellent science with significant societal impact comes from *Derek Smith* (Zoology). Since the emergence of antigenic variants of SARS-CoV-2, his group have applied their pioneering antigenic cartography approach to these viruses. The group is part of a US NIH-CDC-BARDA consortium generating data intended to inform vaccine choice, with discussions about to start at WHO, and he will chair a Vaccine Science Coordination subgroup of SAGE to consider how to determine when the COVID vaccines need to be updated.