Institution: University of Cambridge

Unit of Assessment: 5 Biological Sciences

a. Context

Cambridge research in the Biological Sciences is broad, ranging from the fundamental molecular level to organism population-studies and from prokaryotes to plants and animals. Our non-academic impacts, many of which have international reach, are correspondingly diverse encompassing: (i) commercialisation through licences and spin-out company formation; (ii) national and international policy development in the areas of conservation and infectious diseases of humans and crops; (iii) influencing public understanding and attitude via public engagement activities. The major types of impact vary across our research groupings. Impacts upon policy are associated with Conservation and Epidemiology while commercial and health impacts are associated with a number of groups (see section d). The Museum of Zoology and the University Botanic Garden provide a focus for strong outreach programmes, but public engagement is a feature of all research groupings. A unique feature of our environment is our location at the heart of one of the most globally productive technology clusters (the "Cambridge Phenomenon"). The 158 Life Science companies in the cluster have a combined annual turnover of £2 billion and employ more than 12,000 people. Researchers in this UoA have productive working relationships with many of these companies, including our own spin-outs, with large pharmaceutical companies and with industrial and agricultural biotechnology companies.

b. Approach to impact

Our approach to impact has been shaped by three reports on translation commissioned by the School of Biological Sciences: on commercialisation of biotechnological and biomedical research (2006-07, external chair, Barry Furr, Astra-Zeneca); on translation in the areas of conservation, agriculture and environment (2007-08) and on translation into the clinic (2008). The combined recommendations provide the basis for current translation-related activities, as articulated below. A notable innovation since 2008 has been the introduction of a range of University Strategic Research Initiatives (SRI) and Networks (see also REF5 Environment Statement). These build on areas of existing strength by bringing together a critical mass of expertise from across the University to address large-scale multi-disciplinary research challenges. The SRIs are centrally resourced with a dedicated coordinator, and are dominated by life sciences based themes, with substantial involvement of researchers in this UoA: Neuroscience, Infectious Diseases, Stem Cells, Cancer, Conservation, Food Security and Energy. Each SRI coordinator is an Enterprise Champion (see below) and has a resource budget for driving impact. The coordinators are well networked to facilitate spread of best practice about developing impact across disciplines.

The Cambridge environment for encouraging impact is characterised by strong support for technology transfer, industrial engagement, public communication activity and engagement with policy-makers. Support is provided by dedicated bodies such as Cambridge Enterprise, the Centre for Entrepreneurial Learning, the Cambridge University Technology and Enterprise Club, the Public Engagement team and the Centre for Science and Policy. A key part of the ethos is flexibility in the approach to impact, depending on the nature of the research, the requirements of funders and the motivations of the researchers. This flexibility is central to the wide-reaching success of innovative developments arising from research in biological sciences. Non-academic impact is incentivised in a variety of ways including in the promotions process, where recognition is given to commercialising research, policy development and outreach activities. Another key incentive for achieving impact is the significant income that can be anticipated from commercialisation and consultancy. Our IP policy provides generous return to inventors; 90% of income up to £100,000 goes to the inventor, tapering to 34% for income over £200,000. The University has no restrictions on such income, subject only to the staff member fulfilling their University duties. However, impact activities are also pursued for altruistic motivations of contributing to society, consistent with the University's overarching mission statement. We outline below examples of our range of approaches to impact.

Technology Transfer The University's wholly owned subsidiary Cambridge Enterprise (CE) provides technology transfer, consultancy and seed fund services in support of researchers, inventors and entrepreneurs. CE works within the framework of the University's Intellectual

Property policy which provides flexibility in the strategies for exploitation, including the option to exploit inventions independently of CE and, crucially, a generous return for inventors, incentivising entrepreneurial activity. CE staff regularly visit and give presentations to the institutes and departments in this UoA. They offer researchers advice about all aspects of commercialisation (IP protection, licensing and spin-out formation) and the provision of consultancy services to external clients. A network of Enterprise Champions are based within the departments: David Aldridge (Zoology), Bill Colledge (Physiology, Development and Neuroscience), Andrea Kells (School of the Biological Sciences office), Peter Leadlay (Biochemistry), Eric Miska (Gurdon Institute), Tai Ping-Fan (Pharmacology), Beatrix Schlarb-Ridley (Plant Sciences), Derek Smith (Zoology) and David Summers (Genetics). Many of the Enterprise Champions have successfully commercialised their own research and/or consulted, and are associated with some of our impact case studies. They provide a valuable source of direct advice to colleagues, and a channel of communication between researchers and CE.

The success of the University in technology transfer and provision of trained highly-skilled individuals has been crucial to the remarkable cluster of high-tech businesses surrounding the city. This UoA has contributed many successful spin-out companies, including Astex Pharmaceuticals (NASDAQ: ASTX), KuDOS (bought by Astra-Zeneca for £120m), Mission Therapeutics, DanioLabs, later partnered with Summit, Biotica, CellCentric, Biobullets. Many of these companies contribute to the cluster, providing employment for skilled individuals, some of whom have moved back and forth between companies and the University. Start-up activity is encouraged by the University's liberal policy on the amount of external work academic staff can undertake, which is constrained only by the requirement that 'it must not interfere with the performance of the duties of the office'. This allows staff to engage heavily with start-up activities and to retain a role as the company develops. The UoA has also encouraged fledgling spin-outs to operate initially as embedded companies within departments, allowing companies such as KuDOS, Mission Therapeutics, Cambridge Biotechnology (CBT), De Novo and others to establish themselves before moving out to dedicated space on one of the local science parks. A contemporary example is Iontas, founded by John McCafferty, formerly a research group leader in Biochemistry and a co-founder of Cambridge Antibody Technology. Iontas develops novel antibody therapeutics and has operated within Biochemistry since September, 2012. The 2013 Carpe Diem Start-up of the year award went to Floceleris, located in Genetics and founded by Damien Crowther to exploit breakthrough technology that may enable new treatments and early diagnostics of neurodegenerative diseases.

Licensing of technology is another common route of commercialisation facilitated by CE. Among the numerous examples are the use of MCM proteins as early diagnostic markers for cancer screening (Laskey case study), Activin A reagents to Cell Guidance Systems (Hyvönen, Biochemistry), Xylan modification to Shell (Dupree, Biochemistry), and plant promoters to CERES (Haseloff, Plant Sciences).

Industrial collaboration, consultancy and knowledge exchange We have many productive interactions with biotech and pharma companies in proximity to Cambridge, notably GSK, Astra-Zeneca, Novo Nordisk and Takeda. These interactions are pro-actively brokered by CE and the Cambridge Network (the University is a founding member of the latter) as well as by Departmental Business Days/Evenings. For example, the Department of Plant Sciences hosts research seminars, demonstrating key findings to invited industrial partners. HEIF funding supports the CambPlants initiative to develop and coordinate relevant industry interaction and to promote further joint funding applications with industrial involvement.

The decision by Pfizer to locate Neusentis at Granta Park has stimulated interactions in pain (Peter McNaughton) and stem cell research (Austin Smith). Successful direct collaborations with industry are exemplified by the Academic Incubator agreement with GlaxoSmithKline. In 2012, the University expanded its links with GSK, embarking on a programme of scientific open collaboration to advance drug discovery and the development of new medicines. The programme, facilitated by CE, includes co-locating relevant University researchers with members of the GSK Scinovo team at the Stevenage Bioscience Catalyst (SBC), providing uncomplicated access to GSK drug discovery and development know-how, project management expertise, CRO outsourcing options at preferential rates and commercial assistance with market definition and assessment. McNaughton (Pharmacology) will be moving part of his lab to the SBC to explore the development of novel analgesics based on preventing an interaction between a heat-sensitive ion channel, TRPV1, with

a scaffolding protein, AKAP79. This has been supported, in part, by the University's MRC "Confidence in Concept" award (£600K, 2012).
Links outside big Pharma include interactions with Industrial and Agricultural Biotechnology. Work on lignocellulosic bioenergy (Paul Dupree) has benefitted from a continuing association with Shell Global Solutions, who have provided funding for 14 postdoc-years to date, with the aim of understanding aspects of plant cell wall polysaccharides that cause high costs in release of sugars from cell walls. Alison Smith and Chris Howe have links with Shell and other industrial biotech companies on algal technologies. Kevin Brindle's work on hyperpolarised magnetic resonance spectroscopic imaging of tumour metabolism has benefitted from direct collaboration with GE Healthcare (see case study). William Foster collaborates with the Indonesian oil palm company Sinarmas, to improve management practices across the oil palm industry in relation to conservation of biodiversity and ecosystem services in plantations. Walter Federle collaborates with the global paint company AkzoNobel to develop insect repellent coatings.
In addition to direct roles in technology transfer, many researchers engage in consultancy for companies, charities, public bodies and government with needs for their individual expertise and the facilities embedded in departments. The UoA and the University support this activity by not attempting to regulate it but offering the optional services of CE as facilitators. During the assessment period CE facilitated 36 consultancies between our researchers and external clients. Consultancy helps external organisations to gain access to University expertise and up-to-date research knowledge through short, inexpensive engagements. The relationships can flourish to provide studentships and larger research collaborations. Consultancy helps staff to develop awareness of the needs of industry, provides real life examples for teaching and can provide real data on which to test hypotheses.
Knowledge exchange schemes have included London Technology Network Business Fellowships, held by Beatrix Schlarb-Ridley and Neil Rzechorzek (2008-12) and a NERC knowledge exchange fellowship currently held by Lynn Dicks, Zoology, to support ecosystem services on commercial farms by using evidence to inform land management decisions. James Locke, a junior PI in the Sainsbury Lab, is developing a formal association with Microsoft Research in the general area of synthetic biology. Student Industrial Placements and CASE Studentships (49 held between 2008-13) also foster knowledge exchange.

Influencing Policy A major component of our impact arises from original research that directly informs public policy nationally and internationally. Notable examples of this are in the Strategic Research Initiative areas of Conservation, Infectious Diseases, and Food Security.
The Cambridge Conservation Initiative (CCI) established in 2009 is a unique collaboration between the University and leading international conservation organisations clustered in and around Cambridge. The CCI, including many UoA5 PIs, seeks to transform global understanding and conservation of biodiversity and the natural capital it represents and, through this, secure a sustainable future for all life on Earth. The CCI partners together combine and integrate research, education, policy and practice to create innovative solutions for society and to foster conservation learning and leadership. A major Conservation Campus, where leaders in academia, business, government and NGOs can interact and work together, is now being established in the refurbished Arup building in central Cambridge, together with the development of a new addition to the CCI family: the Cambridge Conservation Research Institute in September, 2013 (further details in REF5 Environment Statement). Our impact case studies contain a number of examples that have had substantial impact with international reach including those based on the work of Balmford, Gardner, Sutherland and Green. Results from horizon-scanning and evidence-based conservation (Sutherland, Zoology) have been used by DEFRA, Natural England and NERC to help identify policies for nature conservation research and action. Several PIs contributed to the UK National Ecosystem Assessment over 2009-11 and the 2011 'Lawton Report – Making Space of Nature', both of which had a major impact on the Natural Environment White Paper released by DEFRA in 2011. Work by Balmford and Green (Zoology, collaborating with PIs across the University and NGO partners) has influenced international policy decisions on species and site conservation through the U.N. Convention on Biological Diversity. Similarly, international climate change policies relating to U.N. Redd (Reducing Emissions from Deforestation and Forest Degradation in Developing Countries) and the U.N. Convention on Climate Change have been influenced by the research of Sutherland, Green, Coomes and Tanner. The conservation management of UK natural resources, by Natural England, the National Trust and RSPB have been enhanced by CCI

research; similarly, nature conservation and sustainable farming practices by local communities, NGOs and farmers in developing countries (e.g. Uganda, Nepal, India, Montserrat and Ghana) have been improved through the application of CCI collaborative research. CCI research provided material for the drafting of the E.U. Renewable Energy Directive in 2009 and the U.N. General Assembly's first Special Session on Biodiversity in 2010. We anticipate that the CCRI will continue to produce world-class research with far-reaching impact.

Research from the Infectious Diseases SRI has major policy impacts; notable examples from our case studies are the work of Derek Smith on antigenic cartography, which has led to Smith's involvement with the World Health Organisation in selection of the appropriate vaccine strains for seasonal influenza to prevent influenza pandemics, and the work of Chris Gilligan and colleagues on mathematical models to inform the control of infectious diseases of plants. Gilligan's models have been used to inform policy in the UK by DEFRA and the Forestry Commission, and in the USA by the US Department of Agriculture. Due to their international reputation, Gilligan's team was selected in 2012 to develop models to inform the control of Ash die-back. The models have been used by both UK and Irish Government agencies.

The Global Food Security initiative has hosted three Public debates on Food Security at Kings Place, London, (Nov 2012 – April 2013), while David Baulcombe led the Royal Society's Working Group on the effect of Biology on technology for sustainable agriculture and food security, which produced an influential report: http://royalsociety.org/policy/publications/2009/reaping-benefits/.

Engagement with policy-makers is critical for our research to result in impact on policy. To pro-actively expand the network of contacts, the University hosts the Centre for Science and Policy (CSaP) which plays an analagous role to that of CE in technology transfer and commercialisation. CSaP promotes engagement between its network members, all of whom share an interest in the relationship between science and policy. Network members include, on the one hand, University researchers, including early career researchers, in sciences and engineering and, on the other hand, policy professionals, politicians and business leaders. In the period 2011-13, CSaP mediated 74 meetings between 20 researchers in UoA5 and UK Government (59 meetings), the European Commission (3) and various industrial partners (12). Among the latter, a meeting with Alan Moodie (GSK) stimulated McNaughton's subsequent interaction with the Stevenage Bioscience Catalyst (above). However, the majority of researchers engaging with CSaP are involved in the Conservation, Infectious Disease, Food Security and Bioenergy areas.

Translation into clinical practice and drug discovery Impacts upon clinical practice are managed through the Cambridge University Health Partners, designated by the Department of Health in 2009 as one of only five Academic Health Science Centres. Some 84 members of staff in Biological Sciences contributed to the application for this award. Indeed, the Schools of Biological and Clinical Sciences work closely together at many levels, with extensive cross-representation and a common Biomedical Research Strategy (see REF5 Environment Statement). The Biomedical and Bioscience campuses have a synergistic relationship, co-locating fundamental research and clinical practice with both business and clinical needs. The ABC (Academia, Business, Clinic) Dinners, involve representatives from all three communities, facilitate meetings in an informal setting, and allow the convergence of disciplinary approaches that were previously viewed as separate and distinct. Cambridge Neuroscience has presented to over 40 industrial contacts in this context.

Dual appointments and provision of laboratory space to Category C staff have been effective strategies for translation by promoting integration of pre-clinical and clinical research. A notable example is the ongoing collaboration between Chris Huang (Dept. Physiology, Development & Neuroscience, PDN) and Andrew Grace (consultant cardiologist at Papworth NHS Foundation Trust and honorary member of Biochemistry) on cardiac ion channels and sudden cardiac death (see impact case study). Grace originally held a BHF Senior Research Fellowship in Biochemistry, but has continuously maintained a research laboratory in Biochemistry since his appointment in 2002 as a consultant at Papworth. Major clinical impacts have been enabled by the intimate relationship between the pre-clinical research programme within this UoA and the clinical research at Papworth. Joint appointments, such as Kevin Brindle's between Biochemistry and the Cancer Research UK Cambridge Institute, have also stimulated interdisciplinary work with impact (see case study). The Centre for Trophoblast Research (Director: Graham Burton), based in PDN, was founded in 2007 to alleviate suffering resulting from placentally-related complications of pregnancy that remain a major cause of maternal and infant morbidity and mortality worldwide. This multi-

disciplinary Centre is recognised as an international resource for placental research and acts in part as a virtual centre to bring together researchers based across Cambridgeshire who share a common interest in placental biology and to facilitate interactions between basic scientists and academic clinicians in Cambridge, nationally and internationally.
UoA5 researchers have obtained substantial funding from the Wellcome Trust Seeding Drug Discovery (WTSDD) Initiative. McNaughton obtained funding, with support from CE, to develop novel analgesics based on selective antagonism of the HCN2 ion channel. Hyvönen and Blundell in collaboration with Venkitaraman (Oncology), Abell and Spring (Chemistry) have obtained several WTSDD and strategic awards to develop: i) fragment-based methods to develop small-molecule inhibitors of RAD51-BRCA2 interaction, to sensitise cancer cells to radiation therapies (£3.5M); ii) inhibitors against interaction of Aurora A kinase with its regulator TPX2 (£2.4M Oct 2013 – April 2016); iii) chemical tools against regulatory interactions in signalling proteins (£2.5M). Hyvönen's lab provides biochemical, biophysical and structural biology expertise, with significant input from senior Research Associates recruited from industry.

Influencing public attitudes and understanding Our researchers are highly active in public engagement, using multiple avenues for outreach. Engagement activities aim to raise awareness of our research, to promote general interest in science and to involve the public in our research. Opportunities are actively pursued through the office of External Affairs and Communications which provides public engagement training for researchers. An online listing of all science public engagement initiatives is made available via the University home page; the Research website provides news, features and discussion about research and engages with the public via its comments section. Staff work with the Press and Communications office to gain publicity for stories based on high profile papers, and often participate in interviews for national newspapers, radio and TV. Examples include the Sunday Telegraph's feature on Rick Livesey's work on generation of cortical neurons via iPS cells (Feb 12, 2012) and involvement of Staff in the Centre for Trophoblast Research in 'The nine months that made you' (Horizon BBC2 August, 2011).
The Museum of Zoology and the University Botanic Garden provide invaluable resources for public engagement, as do the Cambridge Science Centre and "The Naked Scientists". The latter two are independent of the University, but have close links with our researchers. A Young Zoologists Club for 6-13 year-olds based at the Museum of Zoology has over 450 members. The Sainsbury Laboratory, Botanic Garden and the Science and Plants for Schools programme have instituted several notable outreach activities including 'Train the Trainer' teacher training series, and visits by the Sutton Trust Summer School for bright teenage students from non-privileged backgrounds. In collaboration with local companies, events have been held as part of the European Plant Science Organisation (EPSO) annual Fascination of Plants Day, with the aim of enthusing visitors about the importance of plants and highlighting the vital role of plant science in agriculture, horticulture, forestry, environmental conservation, sustainable food production, and use in non-food products such as energy, paper, timber, chemicals, and pharmaceuticals.
The Cambridge Science Centre (CSC) is an educational charity, with newly established (2013) premises in central Cambridge. The CSC hosts hands-on exhibitions, workshops and talks to excite the public about science and technology and collaborates with Cambridge researchers to highlight current research and its impact. The involvement of UoA5 researchers includes Andrea Brand (PDN) on the Board; Beverly Glover (Plant Sciences) and Jim Haseloff (Plant Sciences) have contributed to special events, while Walter Federle (Zoology) and Matt Mason (PDN) are involved in current exhibits/content. Current HEIF financial support contributes to a Gurdon Institute salary dedicated to an outreach officer role as well as costs linked to outreach activities, including engagement via the CSC. The Naked Scientists is a multimedia outreach initiative by Chris Smith (Pathology UoA1). It includes a live, weekly one-hour, audience-interactive science radio programme (BBC Eastern Region, syndicated on 5Live and internationally) that targets the general public. The programme has won many prizes; it takes advantage of both staff and the research activities in UoA5 (e.g. Gilligan, ash die-back) in its comprehensive science coverage.
The Cambridge Science Festival, the UK's largest free science festival, provides an extensive programme of lectures and activities for the general public, attracting over 50,000 visitors over 2 weeks each year. All our departments provide activities; in 2012, the Plant Sciences event was one of the most popular displays with 5,000 visitors. Our researchers contribute to numerous other science festivals, science activities for schools as well as engaging with charities to promote public understanding of biomedical and bioscience issues. A notable example of outreach is provided by

the Moss Table and other biophotovoltaic devices developed under the Bioenergy initiative, which have featured in numerous national and international design and science fairs, including the 2010 Royal Society Summer Science Exhibition (see case study).

c. Strategy and plans

Our future strategy builds upon the approach that we have developed over the past 6 years. Many of our case studies arise from earlier developments and investments – for example in Structural and Chemical Biology in the 1990's. We expect much future impact to result from our successful promotion of a range of life-science focused SRIs. Indeed, a number of mature impacts are already associated with the Conservation SRI, where the time-line between research and policy impacts is short. Examples of early stage impacts include, at the interface of the Stem Cell and Neuroscience SRIs, Rick Livesey's iPS derived cortical neurons, which have promise for the development of therapeutic strategies against neurodegenerative disease. A new SRI in Synthetic Biology, an area where future non-academic impact can be readily envisaged, will be established in November 2013, building upon an existing pool of expertise across the University.

Developments to foster translational work include a new stream of funding to promote impact; the BBSRC Sparking Impact award (2013, £100k p.a.) complements the MRC Confidence in Concept award (2012, £600k). In a new addition to the healthy local environment for Angel and seed funding, the University and partner investors, have established a technology investment company (Cambridge Investment Capital) with funds of £50M to provide follow-on investments in new ventures in the Cambridge area. The recent opening of a central Cambridge office for ideaSpace, a university hub for early stage innovation will also promote impact. IdeaSpace has operated on the West Cambridge site successfully since 2009, providing space and resources to a community of innovators, entrepreneurs and advisors. We will also build upon our successful relationship with Pharma. In particular, AstraZeneca has announced the development of a global R&D centre and relocation of its corporate headquarters to the Cambridge Biomedical Campus by 2016 at a cost of £330m. The R&D centre will host scientists focused on oncology, cardiovascular and metabolic diseases, respiratory, inflammation and autoimmune diseases and conditions of the central nervous system. A productive relationship between AZ and this UoA had already been established by the $210 million acquisition of KuDOS in 2006 (Jackson impact case study), and collaborative negotiations are in hand with teams in UoA5, including the Gurdon Institute. We anticipate that our major investments in Plant Sciences will lead to increased connections with agri-biotech. The University is linked to £3.2M funding for the Eastern England Agri-tech strategy that will be supported by the Regional Development Fund.

We will continue to provide an environment that encourages and promotes impact in a flexible manner. At the same time, John Gurdon's Nobel Prize provides a timely reminder that basic research can lay the groundwork for unanticipated impact well into the future. We will therefore continue to promote an environment that places the highest value on investigator-led curiosity-driven fundamental research, thereby providing a fertile seed-bed for future impact.

d. Relationship to case studies

Our case studies are drawn from 6 of the 9 research themes described in our REF5 Environment Statement. Many of the case studies have more than one type of impact (e.g. licensing and consultancy), but here are classified by the major type of impact. **Six** cases involve technology transfer via spin-out companies, four in drug discovery, one commercialising hyperpolarised magnetic resonance spectroscopy imaging for healthcare, and one in environmental pest control. **Four** case studies involve technology transfer via licensing of technology, including medical diagnostics, recombinant growth factors and software. **Six** case studies are based on policy impacts. Four of these are in the area of conservation, one in control of plant diseases, and one in vaccine selection for seasonal influenza. **Two** case studies have impacts primarily in clinical practice. In addition, seven of the cases classified under "technology transfer" involve drug-discovery or diagnostic development. **One** case study on biophotovoltaic devices primarily has impact upon public understanding of science. Finally, **one** case study has major impacts upon animal welfare (3R's) by reducing the number of mice used in transgenic models.