Institution: University of Exeter

Unit of Assessment: Biological Sciences

a. Context

Exeter Biosciences is a rapidly growing unit composed of five research groups; *Behaviour*, *Cellular & Chemical Biology*, *Ecology & Conservation*, *Evolution*, and *Microbes & Disease*, as well as a significant cohort of staff in *Environmental Sciences*, returned to UoA7. Since 2008, our research has had international, national and regional impacts on public policy and debate, conservation, commerce, health and wellbeing, and education. This has been underpinned by policies designed to maximise both the relevance and impact of research, and to facilitate translation of primary research to application. Below, using selected examples, we highlight specific impacts of our research that demonstrate its reach and significance.

Impact on public policy and debate: Biosciences academics contribute to policy and debate through advice to government bodies including the Environment Agency, Defra, Dstl and RCUK. For example Rick Titball's work informed the DEFRA 'Review of the Environmental Risks from marketing GM veterinary and Human Medicines Report' in 2008 and his expertise on vaccines was key to his selection as an academic member of the Government Office of Science, Chemical, Biological, Radiological and Nuclear Research and Development Expert Review Panel (2009) and the Society for General Microbiology Review of DEFRA Bovine Tuberculosis Research in the United Kingdom (2008). Annette Broderick and Brendan Godley's sea turtle research has led to governments on both sides of the Atlantic enacting conservation policies based on their migration patterns (see Case Study). Angus Buckling's work on bacteria-virus coevolution motivated a lobbying delegation to the European Medicines Agency to discuss changes in legislation on phage therapy (2011). His work has also led to a clinical trial of phage prophylaxis, which is currently underway at the Queen Astrid Military Hospital, Belgium. Mike Boots' modelling work on the role of squirrelpox virus in invasion of grey squirrels into the UK led to a change in Scottish Natural Heritage conservation policy for red squirrels in central Scotland. James Creswell's meta-analysis of experiments testing the effects of a neonicotinoid insecticide (imidacloprid) on honeybees' stimulated debate in the UK and Dutch parliaments and led to his appointment to the EU pesticide regulation panel. Nick Talbot influenced the Government AgriTech strategy (2013) via contributions to the BBSRC "Food Security" commissioned report and his work with Rothamsted Research. Sarah Gurr contributed to the Beddington Foresight document (2012) "Reducing Risk of Future Disasters; Predicting Biological Hazards" and spoke 'Inside Government' on Food Security (2013).

Impact on commerce: We have forged strong links with various local, national and international Industrial partners (such as Astra-Zeneca, BASF, Celtic Pharma, M&S, Pfizer, PuriCore, Ruthern Instruments, Sandford Orchards, Shell, Syngenta, and Waitrose). These links have enabled research and informed product development. For example, John Love's research on microbial biofuels provided empirical evidence driving ~$200M of strategic investment decisions at Shell UK to adopt a synthetic biology approach to engineered biofuels (see Case Study). Rick Titball's research resulted in candidate vaccines against necrotic enteritis in poultry and Onderstepoort Biological Products are currently testing one of the vaccines. Nick Smirnoff, in collaboration with colleagues in Physics, has provided Syngenta with data showing how prototype agrochemicals are taken up into plant organs. Since 2008, 24 research-based patents have been filed by Biosciences academics. Biosciences has specifically sought to engage with SMEs in the South-West. For example, Ruthern Instruments are marketing a multichannel acoustic monitoring device, devised by Tom Tregenza through his research on insect acoustic signalling. Finally, we have translated research directly into commercial opportunities: three companies, Evanesco, Attomarker, and ISCA Diagnostics have been spun-out of Biosciences by Andrew Shaw and Chris Thornton.

Impacts on society culture and creativity: we engage the public with our science. For example, the winner of BBC Radio 4's 'So You Want to be a Scientist' competition 2010 was mentored by Dave Hodgson; BBC2 produced a series (Band of Brothers) based on Mike Cant's mongoose project which was viewed by 20 million people globally. Our work has had direct educational impacts: Ceri Lewis has translated her work on the Canadian Arctic into a schools information pack, used by over 1200 UK secondary schools, and successfully lobbied the UK government to include oceans education in the new National Curriculum from 2013. Since 2009, our annual 'Britain Needs Bioscientists' conference has used our research to inspire >200 local A-level

students.

b. Approach to impact

Our approach to enabling, supporting, and prioritising impact can be summarised under three headings:

i) Identifying and supporting research areas with potential impact.
ii) Providing a clear message to our undergraduates, postgraduates, and academics that impact is a central aspect of our work.
iii) Providing infrastructure, support, and training to facilitate impact, and prioritising impact activities in workload allocation.

The activities outlined contributed to our submission to the BBSRC Biosciences with Impact Competition in 2010. Our submission was selected for the final stages of the competition and eventually ranked as one of the runners-up receiving two specific commendations for influencing wider university policy and tracking post-doc career destinations.

i) Identifying research areas with potential impact and supporting these areas

Capacity building in areas with potential impact: We have consolidated and enhanced our research in areas pertinent to current and future societal needs which can be addressed effectively by our science. We have just completed our new £30m Environment and Sustainability Institute that has a core mission to contribute to mitigation and management of ecosystem services. As a requirement of its funding, this institute will generate 450 business impacts and has so far completed over 400. For instance, Brendan Godley has worked with ESI staff returned in UoA7 in collaboration with Chelonia Limited to develop their marine acoustic monitoring products. At Exeter much of the capacity building has occurred by recruiting staff (including four Professors) with research interests in infectious disease relevant to both an ageing population and ensuring food security. Pathways to impact documents for RCUK and other funding bodies research grants are internally peer reviewed by a committee to ensure that the potential impact of the research is fully exploited and supported by the unit. Academics discuss their pathways to impact with the University's Policy, Impact, and Performance Manager to ensure the impact of their research is fully realised. Exemplar pathways to impact from experienced staff are circulated amongst junior staff in order to share best practice.

Development of strategic partnerships with end users: Biosciences has forged strong links with the end-user community, with 20% of research income consistently obtained from industry. To ensure greater linkage with these communities we have established several formal strategic relationships with organisations. For example (1) we are one of three UK Universities identified as strategic partners by Shell Research UK for their biofuels research programme, which has funded £11.5M of our research; (2) we have developed a strategic partnership with CEFAS, which is focussed on pathogens, endocrine disrupters found in marine environments, and phytoreactors; (3) our strategic relationship with QinetiQ has been underpinned by the establishment of a £3.2m EPSRC KTA which builds on work on evanescence based sensors to detect biological materials for monitoring food quality and detecting contamination; (4) our strategic relationship with Syngenta, in the control of fungal phytopathogens, has been formalised during the reporting period (through BBSRC industrial partnering awards and CASE studentships), which has allowed the company to access our expertise in general, cell and molecular biology of several notable crop pathogens (Ken Haynes, Nick Talbot, Gero Steinberg, David Studholme); and (5) in 2012 we signed a memorandum of understanding with the Food and Environment Research Agency (FERA) to jointly fund six graduate students working on biodiversity or the intersection of animal behaviour and disease transmission. In addition to these formal links, five of our graduates have used our local networks to find work within South-West environmental & conservation organisations (e.g. Cornwall Wildlife Trust).

ii) Providing a clear message to the undergraduates, postgraduates and academics that impact is important: Our teaching celebrates the societal contributions of our research. In 2011, we were awarded BBSRC support for our Food Security and Sustainable Agriculture Masters programme, led by Chris Thornton. We have introduced a postgraduate Knowledge Transfer module that includes a student assignment to develop commercial awareness. PhD students

participate in the university's impact training for early career researchers (indeed since 2008, 11 of our PhD students have been funded by the European Social Fund specifically to target research that contributes to the local economy. In the newly inaugurated 2012 University-wide annual Impact Awards, Biosciences won the student category for 'The Heart Of Borneo Project: conservation, sustainability and community empowerment'. In this, students worked with the charity Heart of Borneo to set up an 18 strong expedition to promote sustainability and conserve biodiversity in Borneo's fragile environment.

User-Valued-Research Performance and Development Review (PDR); Impact now plays a major role in all promotion decisions. For example Broderick, Love, and Godley were all promoted to Senior Lecturer, Associate Professor, and Professor respectively, predominantly in recognition of the impact of their work. This form of impact activity assessment was first devised in 2009 in Biosciences and was been rolled out across the University in 2011.

iii) Providing infrastructure, support and training to facilitate impact; Biosciences is supported by two Directors of Research (Exeter Streatham and Cornwall campuses) who have the support and development of impact as a key aspect of their roles. They receive support in this area from specialist staff in research and knowledge transfer:

Research and Knowledge Transfer (RKT) support for Impact in Biosciences

The RKT Division was established in 2009 to provide support for knowledge transfer activities via a range of mechanisms such as contract research, consultancy, intellectual property, and commercialisation. Individual RKT staff are aligned to different UoAs to facilitate and support linkage with end-users of research and exploitation of research. Support for Biosciences is provided by five full-time positions, in addition to non-discipline specific RKT staff. RKT are also responsible for central administration of HEIF funding through the Open Innovation Platform. Biosciences PI's draw on Open Innovation resources to facilitate engagement with business and industrial partners. For example (1) Love was awarded £44K to develop stable genetic transformants in *Botryococcus braunii* with Shell Research Ltd and Plymouth Marine Laboratories (2012); (2) Littlechild was awarded £40K to develop stable enzymes for use in laundry detergent, a formulation which secured £120K of industrial funding from Unilever (2011); and (3) Thornton received £15K (2008) and £11K (2012) for patent protection activities surrounding his *Aspergillus* LFD test and £5K (2011) to enable establishment of his spin-out company (ISCA Diagnostics) to market this device.

Since 2011 funding has been available on a biannual basis from the College of Life and Environmental Sciences Strategic Research Fund to facilitate projects costing up to ~£20K. Projects can be funded purely on the basis of their potential to facilitate a significant future impact. For instance in 2011 Brendan Godley was awarded £5K for a project to test an acoustic alterting device designed to reduce fisheries bycatch of dolphins developed with his industrial partner Chelonia Ltd, and Rob Beardmore was awarded £14K in 2012/13 for a project on combination therapies and the dynamics of drug interactions because of its potential for medical application.

We have used RCUK's Pathways to Impact requirements to embed knowledge transfer training into the professional development of our postdoctoral staff. On appointment, postdoctoral researchers agree a bespoke training programme relevant to their individual needs with the Principal Investigator, supported by RKT. The PI ensures that impact activities are considered and acted upon throughout the work. Part of this includes the 'Impact, what is it and why is it important' programme run by RKT for early career researchers.

Biotechnology Advisory Group

In 2009 we established a Biotechnology Advisory Group, which brings together representatives from industry (Paul Sheppard, Enzo Life Sciences; Derek Craston, Laboratory of the Government Chemist; Ross Brown, AstraZeneca), Biosciences academics (Titball, Bates, Aves, Shaw) and senior members of RKT. To date, we have explored how we can more readily meet the needs of industry and following advice gained we have introduced practical exercises on reproducibility in scientific procedures and Quality Assurance as part of our Fundamental Skills for Biosciences

module - which is compulsory for all of our undergraduate students and aims to develop highly skilled people to meet the needs of industry. The group has also provided advice to Shaw on how best to deploy an intellectual property disclosure process, which is in the process of being further developed via an EPSRC KTA.

c. Strategy and plans

During the assessment period we have embedded a culture that recognizes the value and importance of impact. We will maintain and develop this culture to ensure that Biosciences academics identify and exploit the on-going impact of their work; discuss the potential impact of their work; and, importantly, this will continue to be a significant element of academic staff annual review and career progression. In addition, we are fully engaged in a number of University-wide initiatives to encourage and reward impact. We have had several projects (e.g. Ken Haynes & Syngenta and Murray Grant & Germains Seeds) funded by the Universities HEIF funded 'LINK' fund which provides financial support for partnerships aiming to create impact.

We will further develop strategic relationships and extend our repertoire of selected end-users to maximise the impact of research. CASE studentships are invaluable in this respect as they frequently catalyse strategic partnerships. For example, Haynes has a BBSRC CASE studentship with Syngenta, which led to formal discussions about establishing a Syngenta University Innovation Centre at Exeter. Since 2008, we have held CASE studentships with industrial partners including LGC, Pfizer, FERA, PuriCore, Jacobs UK, Syngenta, and Astra Zeneca. We envisage that this portfolio will increase thanks to enduring relationships with Shell, Syngenta, and QinetiQ.

Our existing industrial links will be strengthened by our increased research activity in these areas funded by RCUK and by charities, for example, successive BBSRC Industrial Partnering Awards with Syngenta. We are poised to develop strategic relationships with Defence Science and Technology Laboratory (Dstl), which will strengthen the impact of Biosciences work on infectious and non-infectious diseases of humans (Titball and Thornton). We will develop closer links with the newly-formed Exeter Medical School, exploiting current strengths in Cell Biology and Imagery (Steinberg), diagnostics (Thornton), and will establish a Molecular Diagnostics Group (MDG) to share expertise between Biosciences and the Medical School to foster development of molecular diagnostics assays for differential diagnosis of disease. The multidisciplinary approach, with clinicians, scientists and statisticians will develop molecular and cellular profiles of disease and recovery. The selected group will design diagnostics, perform pilot and full clinical trials and engage with industry in their commercialisation. Sarah Gurr's research focus, on BioProtection (with Chris Thornton and Murray Grant), will open new vistas in crop disease control which will be developed with Agro-chemical companies and her work on pest and pathogen movement in the face of climate change will influence crop protection strategies world-wide.

We are able to respond to nascent and emerging areas of science relevant to our expertise. For example, Studholme's *E-coli* sequencing through 'crowd-sourcing' in response to the recent outbreak of *E. coli* in Germany (2011) delivered this essential information to the medical community very rapidly. Lewis's collaboration with Digital Explorer allowed her to respond to government consultation on environment education with material that could be directly pitched to politicians (2011). We will continue to develop these and other new approaches to impact.

d. Relationship to case studies

The policies described above have helped us to deliver the impacts, highlighted in each case study presented. Research from Exeter has contributed to changes in legislation to safeguard the environment (Broderick/Godley, Galloway, Mumby); been directly applied by industry (Thornton, Love) and influenced school-level education across the UK (Lewis). These case studies are inextricably linked to increased awareness of impact engendered in our staff and the policies we implemented. All staff involved, for example, had dedicated time, directly associated with impacts of their research, allocated within their workloads. Knowledge exchange with industrial partners was facilitated through long-term strategic partnership, co-investment in staff and equipment, and directly embedding industry staff within Biosciences. Biosciences and RKT provided specific advice on legal agreements, patents, business finance and, where appropriate, international legislation. This was augmented with investment from both HEIF and Biosciences funding.