**Institution: University of Bristol**

**Unit of Assessment: 5 - Biological Sciences**

**a. Context**

Research in this UoA links fundamental studies in biological and biomedical sciences to agriculture, the environment, chemistry, physics, mathematics, social medicine and clinical research. It is organized into six research clusters: Evolutionary Biology, Dynamic Cell Biology, Molecular Biosciences, Animal Behaviour & Sensory Biology, Plant & Agricultural Sciences, and Ecology & Environmental Change. Our case studies showcase our major impacts across these clusters. Infrastructure is in place and continues to be developed to exploit our work through commercial activities, environmental projects and informing the development of evidence-based policies. This approach is reflected in many of our teaching programmes, which include industrial placement opportunities at both undergraduate and postgraduate level. Research from the unit has influenced drug development programmes of pharmaceutical companies, clinical diagnosis, and the strategy for using molecular markers within the wheat breeding community. The end users of our research are diverse and include pharmaceutical and biotechnology companies (AstraZeneca, Trophos, LGC), clinicians, the agriculture industry (RAGT, KWS, Limagrain and Syngenta), SMEs (e.g. Leica Microsystems), animal health professionals, and government and charitable agencies.

There are four broad areas where research has directly benefitted society and the UK economy:

1) *Development of biologically-based tools* – Our research has facilitated increased yields of antibiotic production, provided novel medical diagnostics, reduced costs in animal disease monitoring, significantly advanced agricultural breeding programs (saving research time, reducing cost, and increasing throughput), and has been used to assess environmental status.

2) *Application of fundamental knowledge of biological questions* – Our research has led to improvements in the conservation of threatened species, new diagnostic technology and improved treatment for patients, as well as influencing the direction of industrial investment.

3) *Use of biologically-based models in predictive applications* – Our research has enhanced animal health and welfare through improvements in seasonal disease forecasts, informed industry advice in the treatment of animal disease, and informed and influenced business and government in terms of how resources may change as a result of predicted climate change.

4) *Identification of novel drug targets* – Our research has led to novel therapeutic strategies and drug development programmes for cancer, coronary thrombosis and stroke.

**b. Approach to impact**

Our interaction with those who benefit from our research is evidenced by our integration with, and extensive use of, the major translational infrastructures within the University of Bristol.

*The Elizabeth Blackwell Institute for Health Research* (EBIHR) is currently our specific translational vehicle for all biomedical research across the University. Established in 2012 (with Tavaré as its inaugural Director) it integrates and builds on our previous work in maximising impact of our research. Its role is to identify and nurture new opportunities for interdisciplinary research, in particular by exploiting expertise in the non-medical faculties, and translating that research into effective health outcomes. It is also identifying and supporting our best young non-clinical and clinical talent through a series of fellowship schemes, and creating an environment for effective collaboration with external partners within (e.g. Bristol Health Partners) and outside Bristol (e.g. other universities and industry). Much of its activity was previously overseen by the Severnside Alliance for Translational Research (SARTRE). Established in 2009 by the Universities of Bristol and Cardiff, SARTRE was specifically directed towards a proactive approach to impact, combining and accelerating our efforts in translational research and providing a focal point for interactions with external partners, notably Bio-Pharmaceutical companies.

The EBIHR has multiple programmes for translational development. It hosts workshops and projects aimed at translating basic science into healthcare outcomes, notably across the widest interdisciplinary boundaries. Funding supports both early career and senior fellowships to explore new or emerging activities that address innovation in health research, and clinicians in the early stages of their clinical training to work in basic science labs, enhancing translation of the work. The UoA has also benefited from EBHIR funding totalling £160k through Translational Acceleration and Knowledge Transfer awards to Gaston and Banting, 'investing in young talent' awards to Dillingham

and Hanley, early career fellowship and clinical primer awards to support work in the Martin and Tavaré labs, and a women returners to work award for Hammond. Tavaré also received £420k to develop quantitative analysis of EGF receptor signalling in lung cancer, leading to involvement in an ongoing clinical trial with AstraZeneca. More recently EBHIR has held workshops to develop links with industry, most notably in chemical and synthetic biology.

*The Cabot Institute for Environmental Research* is our central focus for translational activity in the environmental sciences, notably our research clusters in Ecology & Environmental Change and Plant & Agricultural Sciences. The Institute engages with potential beneficiaries and interest groups in areas of environmental and climate change, natural hazards, and food and energy security. To achieve its vision, the Cabot Institute stimulates links across disciplines and with industry and government by developing partnerships, enhancing knowledge exchange across sectors, and building groups of shared interdisciplinary expertise. Research in Plant and Agricultural Sciences research engages closely with end users through the *Food Security and Land Research Alliance*, the *Food and Environment Research Agency* (*FERA*, with which we have a strategic memorandum of understanding and directly funded projects), and the *Lady Emily Smyth Agricultural Research Station* (*LESARS*; of which Edwards is the director). LESARS pump-primes projects, including support for the wheat genome sequencing project, fellowships, PhD studentships and the purchase of capital equipment (e.g. GA2 Next Generation Sequencer).

The work of the two institutes is directly underpinned by the *Research and Enterprise Development (RED) team* which provides University-wide support for impact. Members of RED who work directly with our UoA have experience in development of government strategy (from internships with funders), as well as extensive research and commercial experience. RED organizes workshops with beneficiaries that both shape and develop our impact.

**Examples of our impact strategy:**

Our approach to impact is based on ensuring full and effective interaction of our researchers with relevant parties. To achieve this, we exploit translational awards, organize workshops, and exploit University resources. Specific examples are:

● Research from Gaston led to an EBIHR Translational Acceleration and Knowledge Transfer Award. This enabled filing of a patent for the use of phosphorylated proline-rich homeodomain protein as novel biomarker for cancer diagnosis and prognosis.

● In 2011, the University's Institute for Learning and Research Technology supported the development of a smart phone app that could integrate photographic evidence of leaf-miner moth damage on trees with geo-located data ("LeafWatch", 15,000 downloads since its release).

● A workshop in 2013, supported by the University of Bristol Cabot Institute and RED, helped environmental researchers early in their programs to identify the impact potential of their research, and to learn about resources that would support the development of that impact.

Our published research remains a major route to exploiting commercial potential. Our researchers develop such opportunities through presenting at and organizing national and international conferences, and from membership of policy, strategy and steering groups. Our academics have sat on advisory boards of companies including Merial, Bayer, Pfizer and Novartis Animal Health and have been invited experts on Government appointed Committees. In 2012, Simpson, a NERC Knowledge Exchange Fellow within the unit, secured funding to translate NERC-funded research on climate change and UK fish stocks into management plans. Of 8 NERC case studies developed for the university, 3 arose from research in this UoA. Examples of this strategy in action include:

● Over a period now spanning over 9 years, Halestrap has worked closely with AstraZeneca to exploit his expertise as a world leader in the field of monocarboxylate transporters (MCTs). Halestrap's advice on the activity of a novel immuno-suppressive drug led to the funding of both a research project and a studentship. Arising from this interaction it became apparent that the same drugs might be effective against cancer and, since 2008, a major emphasis of AstraZeneca's cancer programme has been directed towards the MCTs. Halestrap continues to advise on development of MCT4-specific drugs.

● Close collaboration between our UoA and NHS Blood and Transplant (NHSBT) across many years has built a strong research base on the structure and function of red blood cell membrane proteins. This enabled screening of patient samples for a rare kidney disease and the development of enhanced blood genotyping that improves clinical diagnosis and reduces incompatibility issues

between donors and patients. Collaboration continues through NHSBT-funded studentships, a lectureship and substantial programme grant (Toye), and project grants (Brady and Lane).

● Research by Bailey and Foster (2006-2010) on the development of genetic engineering technologies for basidiomycete fungi also began with fundamental research via several BBSRC awards but then expanded into more applied Levy Board funded research along with direct funding from DEFRA leading to the production of the case study "*The Basidio Molecular Toolkit*".

● Also building on fundamental research by Bailey and Foster within Biology, a collaboration with GSK was initiated that led to the development of the molecular tools used to enable *C. passeckerianus* to produce the antibiotic Pleuromutilin (2006-2009).

● Long term research by Tavaré, funded by the MRC, Wellcome and Diabetes UK, led to funding from CRUK (2012) to undertake the preclinical work required to redeploy GSK3 inhibitors from their original purpose (treatment of diabetes) to the treatment of non-small cell lung cancer.

Over the assessment period these approaches have led to many industrially funded research projects including a BBSRC/industry crop club partnership (2011-2013), buy out time (via the BBSRC Science Interchange program) for Edwards to work with Advanta Seeds (2006-present), an EU FP7 grant (Technological Development and Demonstration Activities, 2011), CASE studentships, a Wellcome Trust Seeding Drug Discovery Initiative grant (ProXara, (2007-2009) – including buy out of the PI (Tavaré) to allow him to focus on the drug discovery programme).

**Direct engagement with key beneficiaries, users, and the public.**
The unit also seeks to enhance public awareness of the actual and potential impact of the research through the Centre for Public Engagement and publicising it through the websites and publications of the University (e.g. Cabot Institute and Botanic Garden) and funding agencies (e.g. BBSRC, Wellcome Trust and MRC) and via interactions with the BBC and other media organisations (e.g. The Blue Planet (Partridge); Horizon (Franks); Planet Ant (Franks); Springwatch (Whitney); How to Grow a Planet (Hiscock) and the Eden Channel's documentary "Natural Curiosities" with Sir David Attenborough (Robert)). Many of these events have elicited significant responses; for instance the Attenborough documentary elicited 50,000 hits on the University web site in the 3 days following broadcast and ~1 million tweets and retweets. Members of the unit actively contribute to public engagement in schools and with the general public through Science Cafés and Picnics, science festivals (notably Cheltenham and the Bristol Festival of Nature, the largest Natural History Festival in Europe). The "Urban pollinators" project (Memmott) provides an example of our close integration with national policy making and of media interest in our work.

**Support of staff and use of university resources to achieve impact from research.**
Within the unit, time spent on activities relating to exploitation of research feeds directly into workload models that are used within the annual staff review process. All staff are actively encouraged to explore impact of their work through University workshops, organized by RED, via public engagement through the University Centre for Public Engagement, press office and "press gang" a Faculty-based group trained to help researchers to publicise the wider implications of their work. The UoA has two Impact Directors: Edwards (an ex-employee of ICI and Zeneca) and Halestrap (who collaborates with several pharmaceutical companies including AstraZeneca). They actively encourage impact development and identify potential collaborations and expertise both within the University and the commercial world. Fruitful contacts with pharmaceutical and biotechnology companies are enabled by a degree programme in Biochemistry that includes a year in industry (coordinated by Collinson). Academics regularly visit industrial partners to establish how our research strengths might be harnessed in product development. The EBIHR, Cabot institute, and RED will continue to play a major role in capacity building by identifying talented young staff and providing them with pump-priming funds to develop their research ideas towards prestigious personal fellowships. A major future thrust of both EBIHR and Cabot Institute is the building of novel interdisciplinary research communities, and ensuring that procedures (e.g. human resources, IT and finance) are optimized to enable easier collaboration across organizational boundaries.

**c. Strategy and plans**
The wider dissemination of the results of our research and its potential exploitation is central to our future strategy. We aim to achieve this through continued development of structures that enhance and facilitate multidisciplinary and translational research such as the EBIHR and Cabot Institute. Specific examples of our strategy to develop impact include:

**Develop and strengthen our relationships with beneficiaries.** We will continue to drive access to translational programmes through joint workshops involving key funders (such as BBSRC "Fostering Innovation", most recently held in October 2013) and close liaison with industrial partners (e.g. Eli Lilly, Limagrain Seeds and LGC Genomics). Our core technology development work will continue to integrate directly with SMEs. Examples include funded cooperation projects with Leica Microsystems and FEI driven by underpinning research in the Wolfson Bioimaging Facility (Verkade, Jepson). We will also exploit Faculty-based Academic Business Fellows, who have received dedicated training and mentoring and work closely with colleagues to increase interactions with business. One of our early career researchers, Bass, is developing the clinical use of ultrasound in wound healing through the University Research Commercialisation Initiative. The potential impact for the healing of leg ulcers (a major problem in the elderly) is considerable.

**Embedding impact within graduate training.** We plan to enhance the impact agenda within all of existing programmes. Clear opportunities for Synthetic Biology workshops with end users emerge from the EPSRC integrated Doctoral Training Programmes (Bristol Centre for Functional Nanomaterials and Bristol Centre for Complexity Sciences) as well as the BBSRC Doctoral Training Partnership. MRC Translational studentships, the Wellcome Trust funded programme in Dynamic Cell Biology will be developed towards greater clinical integration through EBIHR. Engaging the next generation of researchers with impact across our programmes will be achieved through up-coming workshops, one example being industry and policy makers in food security and synthetic biology. Our success with CASE awards will continue to drive direct collaboration with industry. Clear examples of significant impact of CASE awards comes from Halestrap's research (some of which has already been translated into preliminary Clinical Trials with AstraZeneca) and ongoing support of work in the Hetherington lab through a CASE studentship from FERA.

**Driving new research areas of great societal importance.** Emergent impacts focus on our areas of strategic development. Synthetic Biology is one of the fastest growing research areas in Bristol, integrating activity across all faculties. Our engagement with industry in this area is critical for the development of new synthetic therapeutic tools; public dialogue is also vital here to ensure full understating of this new research area. Dynamic Cell Biology and Molecular Biosciences clusters seek to capitalise on genomic and epidemiological data to drive translation of our fundamental research to the clinic. Ecology & Environmental Change and Plant & Agricultural Sciences clusters address global challenges of food security and climate change. Major opportunities for future interdisciplinary collaboration have been identified in these areas and the Cabot Institute will be instrumental in supporting our impact strategy. The new £56m Life Sciences building, opening in 2014, provides an outstanding opportunity to invite key stakeholders from industry, government, and other relevant sectors to engage directly with our research.

Significant emerging impact has already been identified within our research portfolio. Toye, in collaboration with NHSBT, is developing technology to grow red blood cells for diagnostic use and transfusion. A patent was filed in 2012 based on the use of induced pluripotent stem cells to generate red cells. This work could overcome major barriers to commercial manufacture of human red cells. Engineering blood cell biology could provide rare cell types for serological testing, produce bespoke red blood cells for patients, and alleviate the shortage of rare blood types.

**d. Relationship to case studies**

Our case studies exemplify the breadth and strength of impact derived from our work. The approach of directing our research towards impact is exemplified by case study *"Ischaemic injury"*. It illustrates how publication and presentation of work carried out from 1993-1998 connected our research to pharmaceutical companies who subsequently consulted Halestrap, invested in his lab, initiated cardioprotective drug development programmes, and stimulated collaborations with clinicians in Bristol. Since 2008, collaborations and consultations with three drug companies have led to an EU FP7 Technological Development and Demonstration Activities grant with two clinical trials being run by the Biomedical Research Unit in Bristol. The case study *"Targeting glycolysis"* also illustrates how ongoing research led to the initial approach by a pharmaceutical company that grew into a long-term collaborative programme. Other case studies illustrate our strategy of developing interactions with partners who can exploit the data, expertise, and resources from our research. Case study "*Erythrocyte membranes"* illustrates how our long-term clinical collaborations enabled the development of better diagnostics and treatment. Case study "*Genotyping tools for wheat breeding*" further illustrates our ability to develop impact through postgraduate training.