Institution: University of Oxford

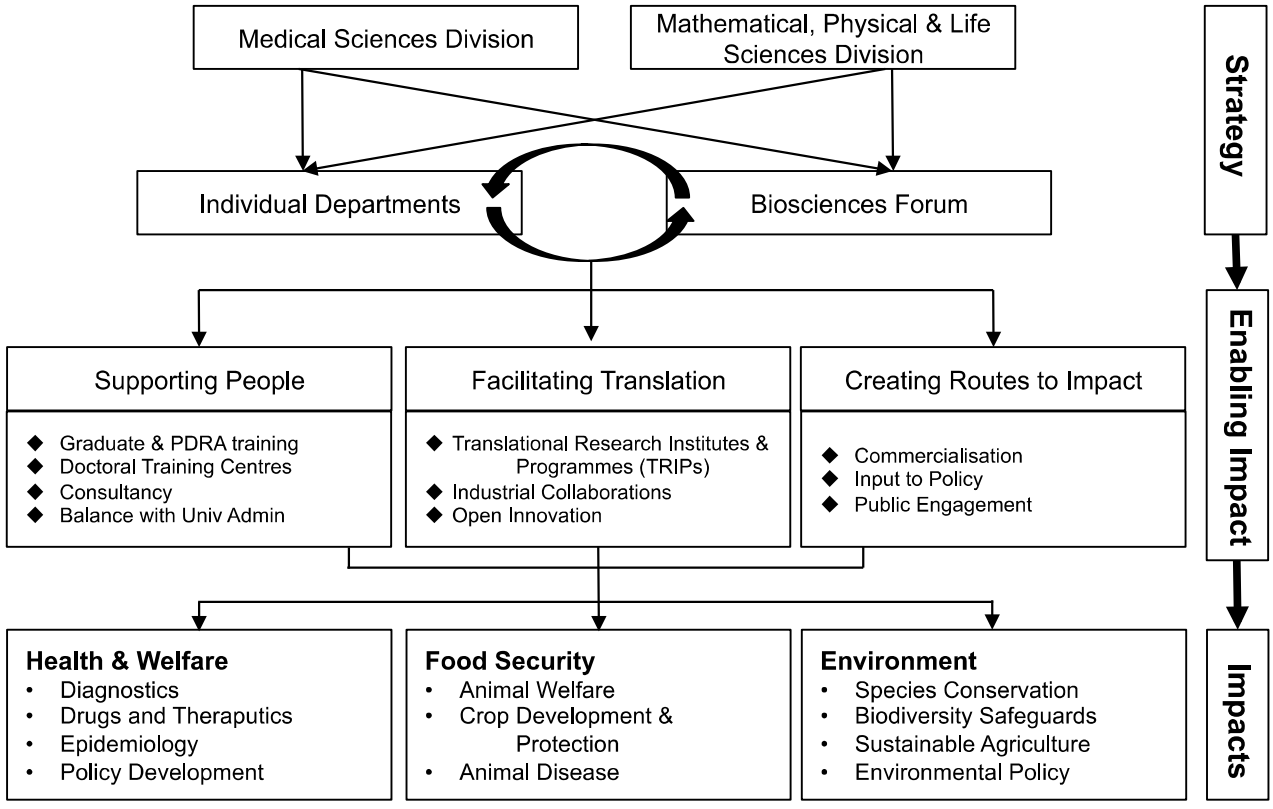
Unit of Assessment: UoA5 Biological Sciences

a. Context

The impact of our research is as extensive as the range of research themes in UoA5, and is focussed in three areas of global importance: **Health and Welfare**, **Food Security**, and the **Environment**. The beneficiaries of our research range from government and non-governmental organisations to local communities and the individuals within them; from large multinational pharmaceutical, agribusiness and energy companies to smaller national companies and start-ups; and from large-scale food producers in the developed world to smallholders in the developing world. Our research has direct and indirect impacts on **Commerce**, **Public Policy** and **International Development**.

As our Impact Case Studies demonstrate, our philosophy is that impact is achieved by bringing together the best in basic and translational research. For example, fundamental research in the Infection, Immunity & Epidemiology (IEE) theme has provided new understanding of how the immune system recognises and controls pathogens; and this insight now underpins several translational projects in the Institute for Vaccine Design and in the Clinical Biomanufacturing Facility. Our delivery of therapeutic antibodies, anti-virals and vaccines from these projects leads to improved health and welfare. Similarly, research in the IEE and Mathematical, Computational & Systems Biology themes examines the epidemiology of infectious disease, allowing global epidemics to be modelled, and policy to be developed; and research in the Ecology and Conservation theme underpins translational projects in the Biodiversity, Plants for the 21st Century, and Wildlife Conservation Research Institutes. These projects extend across diverse global habitats, promoting positive conservation outcomes and informing environmental policy at the level of local, national and international organisations.

The figure below illustrates how impact is embedded within, and emerges from, administrative and research structures in UoA5 at Oxford University.



b. Approach to impact

Our approach to impact is based on the recognition that: (1) academics need particular forms of support to translate fundamental research into impact; (2) translational research depends on specific resources and technologies; and (3) the products of translational research can take many different routes to impact. We therefore focus our individual and institutional efforts in three strategic areas:

- **Supporting People**
- **Facilitating Translational Research**
- **Creating Routes to Achieve Impact**

b1. Supporting People

We provide an intellectual environment that both encourages and enables academics at all stages of their careers to translate high quality fundamental science into impact. Mechanisms are in place, and continue to be developed, to instil a culture of translation and appreciation of research impact by providing (i) *training for graduate students and postdoctoral research assistants (PDRAs)*; and (ii) *strong incentives for academic staff to engage in impact-related activities*.

b1.i *Graduate and PDRA Training*

Graduate students are admitted to a Graduate School and enrol on an extensive array of training across the UoA. Elements of skills training programmes dealing with intellectual property, research ethics and outreach are compulsory for UoA5 students (http://www.medsci.ox.ac.uk/skillstraining; http://www.mpls.ox.ac.uk/skills/gap). PDRAs are also encouraged to attend these courses. Examples of other initiatives to promote graduate student and PDRA participation in impact include encouragement to enter RCUK Young Entrepreneur Scheme (YES) competitions (a UoA5 team were National winners in the 2008 NERC competition), and to participate in events at the Saïd Business School, e.g. the 'Building a Business' course.

Direct engagement by whole cohorts of graduate students with industrial research is mediated through: (i) the EPSRC-funded 'Systems Approaches to Biomedical Science' industrial Doctoral Training Centre (DTC) (44 students admitted since 2009); (ii) the Wellcome-funded Infection, Immunology & Translational Medicine DTC (26 students since 2008); (iii) the Cancer Research UK-funded Medicinal Chemistry DTC (7 students since 2008); (iv) industrial CASE awards (26 BBSRC, 6 NERC, 4 MRC and 1 EPSRC CASE studentships); (v) placements in industry by students enrolled in the BBSRC Doctoral Training Programme; and (vi) the MSc in *in vivo* pharmacology, an MRC-funded programme set up to meet the needs of the pharmaceutical industry. Our training provides a pipeline of skilled researchers for industry and healthcare – between 2008 and 2012 a total of 105 graduate students – 18% of the total – graduated from academic research in UoA5 to a first job in industry (53) or medicine (52).

Our ability to enable and empower graduate students to achieve impact is exemplified by the case of Torsten Reil, a former graduate student in the Zoology Department. In November 2001, with the support of the University's technology transfer company (Isis Innovation Ltd.), he co-founded NaturalMotion, a leading game technology company based in the UK and USA that now has over 200 employees. NaturalMotion's 'euphoria engine' was a breakthrough in real-time character animation and is used in console games such as Grand Theft Auto IV (which has sold >25 million copies and generated >$1B revenue). He communicated his path to impact to a general audience in a 2008 TED talk, and returned to Oxford University in 2012 to deliver seminars about the process by which his work was brought from research to finished product.

b1.ii *Academic Staff*

Staff across UoA5 are strongly encouraged to engage in impact-related activities, and there is a formal process, during annual reviews with department heads, for balancing those activities with internal administrative demands. The two major activities undertaken are the dissemination of science through public engagement (see b3.iii below) and external consulting. Academic staff are allowed 30 days of consulting per year; their input contributes to strategy in industry, NGOs, and to national and international policy (see b3.ii below). Consultancy also broadens the outlook of the UoA's academics, bringing new perspectives and ideas back into the UoA to help guide our impact strategy. To reduce the barriers to consultancy further, administrative support and the legal framework for external consultancy work is provided through Oxford University Consulting (OUC),

a division of Isis Innovation, which acts as a single point of contact to match expertise with needs of user groups.

b2. Facilitating Translational Research

We have three approaches to translate fundamental research into impact: (i) *establish and develop translational research institutes and programmes (TRIPs) that promote interdisciplinary collaborations and facilitate engagement with end-users*; (ii) *collaborate with industry*; and (iii) *initiate open innovation partnerships*.

b2.i *Translational Research Institutes and Programmes (TRIPs)*

Our long-term approach to impact is focussed around the establishment and development of TRIPs. Eleven are active within UoA5 and five were established since 2008. Some TRIPs are based solely in UoA5; others connect with cognate disciplines in the medical, physical and social sciences. Six TRIPs are under the umbrella of the Oxford Martin School (OMS: founded 2005) which comprises a network of scientists, social scientists and economists seeking solutions for 21st Century challenges, and facilitates dialogue with a broad range of international stakeholders including policy makers, environmental groups, and consumers. Annual funding to UoA5 from OMS increased seven-fold over the last five years (from £0.33M in 2008 to £2.27M in 2013), totalled £7.9M, and is projected to continue at this level. TRIPs contribute to impact in the three broad areas that lie at the heart of UoA5: Health and Welfare, Food Security and the Environment.

In addition to TRIPs, competitive funding facilitates translational research via the University's John Fell Fund (http://www.admin.ox.ac.uk/pras/jff/), through Isis Innovation proof of concept awards (http://www.Isis-innovation.com/researchers/UCSF-1.html), and via the University-managed BBSRC Sparking Impact Fund (http://www.admin.ox.ac.uk/researchsupport/findfunding/internal/).

b2.ii *Collaborations with Industry*

Industrial collaborations are initiated in a number of different ways across UoA5:

- Research groups, departments and TRIPs host meetings in Oxford to showcase research activities to representatives from companies. These meetings are organised by dedicated Departmental Research Facilitators, for example in Neuroscience, Cardiovascular Science and Chemical Biology. Since 2008, visits from Syngenta (2009), BP Biofuels (2010), and Roche (2012) have led to the investment of >£1M in translational research projects in the UoA.
- A new venture since 2013 is Oxford Targets, a joint University/Industry group to fund the identification and validation of novel drug targets. The first call for proposals, supported by UCB Pharma, provides funding in the region of £100k-200k for research in neuroinflammation; the second round, also in partnership with UCB Pharma will focus on therapeutic antibodies.
- Departments are encouraged to maintain advisory groups with strong industrial pedigrees. For example the Department of Pharmacology's industrial liaison group includes Tamas Bartfai (Roche/Scripps), Barry Potter (founder Sterix Ltd/University of Bath), Garth Cooper (co-founder Amylin Corp) and Les Iversen (Chair UK Government Drugs Policy Committee).
- Both the Medical Sciences and Mathematical, Physical & Life Sciences Divisions set up Business Development Offices in 2011 to facilitate partnerships between the University and industry. An early example of their effective working is the establishment of Oxford Targets.

Regardless of how discussions are initiated, follow-up negotiations with industry are co-ordinated with strategic direction from Isis Innovation, the University's Research Services Office and the two Divisional Business Development Offices. Since 2008:

- 93 sponsorship agreements were negotiated amounting to £15.2M of research income.
- 290 confidentiality agreements and 79 material transfer agreements with industry were signed.
- formal research collaborations progressed with six major pharmaceutical companies (Abbott, GSK, Lilly, Novartis, Pfizer, Takeda, UCB).

b2.iii *Open Innovation Partnerships*

We have recently initiated open innovation programmes to facilitate pre-competitive research. For example, the Structural Genomics Consortium (SGC; led by Bountra in UoA1 but collaborating with UoA5) is rapidly generating a pipeline of new inhibitors, assays and three-dimensional X-ray structures for novel, therapeutically relevant, proteins. All of these reagents are made freely available to the bioscience community. This 100-strong group, which includes most of the departments in UoA5, has already attracted parallel contributions from 8 large pharmaceutical

companies (GSK, Pfizer, Novartis, Lilly, Abbott, Takeda, Boehringer Ingelheim and Janssen: each contributing $8M over a four year period from 2011-2015); several other organisations wish to join. The consortium enables industrial scientists to work in the University, and Oxford scientists to work in the partner pharmaceutical organisations. So far the group has demonstrated the chemical tractability of new protein families, and has accelerated the initiation of proprietary programmes in many biotech and pharmaceutical companies.

b3. Creating Routes to Achieve Impact

We realise the impact of translational research via three major routes: (i) *commercialisation*; (ii) *input to policy;* and (iii) *user group and public engagement*. Specific processes are in place to support these endeavours.

b3.i *Commercialisation*

Isis Innovation has 40 members of technology transfer staff whose role is to maximise the commercialisation of research, including that from UoA5 departments. Isis staff hold regular 'surgeries' in all UoA5 departments to encourage the discussion of IP associated with research. In addition, they meet with Heads of Department and Research Facilitators to ensure that research is discussed at an early enough stage to optimise our IP position. Where appropriate, Isis helps researchers to identify, evaluate and patent protect their research; to devise marketing strategies for new technologies; to negotiate licence deals and establish spin-out companies. The success of this route since 2008 can be measured by the following metrics:

- Income since 2008 from pre-2008 commercialisation activity included £7.7M resulting from the acquisition of one of our spin-out companies (BioAnaLab) by Millipore in 2009 (Case Study 16).
- 243 invention disclosures were recorded.
- 152 new patent applications were filed across 19 legal territories; 89 patents were granted.
- 39 licences and 33 material sales were negotiated with 50 third parties.
- Muox was established by **Kay Davies** (with Russell and Davies in UoA8). Muox is founded on the discovery of utrophin, and the development of a new screening cell line for finding drugs that increase expression levels of utrophin to compensate for the loss of dystrophin. The company thus aims to develop new therapeutics for treatment of Duchenne Muscular Dystrophy.

b3.ii *Input to Policy*

Our input to policy has historically been driven by individual skills and aspirations. Prominent examples of input to policy over the assessment period are:

- **Angela McLean** was a member of Defra's Science Advisory Council from 2006-11, and led the Council's work on the use of Risk Science, fundamentally changing the way Defra uses science to inform decision-making. She then chaired the Government Office of Science Lead Expert Group for the Foresight Report into Reducing the Risk of Future Disasters (2012).
- **Charles Godfray** chaired the Government Office of Science Foresight Report on the Future of Food and Farming (2011) which championed the concept of sustainable intensification; this is now a major part of UK Government and other organisations' food policy.
- **David Macdonald** has been Chair of Natural England's Science Advisory Committee since 2006, in which role he has led the organisation's approach to evidence-based policy, fundamentally influencing environmental conservation in this country.

In each of these cases, the policy was developed and informed by research done by the individual at Oxford University: **McLean** is the Director of the Institute for Emerging Infections, **Godfray** the Director of the Programme on the Future of Food, and **Macdonald** the Director of the Wildlife Conservation Research Unit.

b3.iii *User Group and Public Engagement*

The majority of academics in UoA5 participate in activities that engage the public with science; most of these activities relate directly to their research. A prominent recent example is the publication of **Frances Ashcroft**'s 2013 Royal Society Winton Prize shortlisted book *The Spark of Life*. This showcased how basic research leads to new therapies, and how patient groups are involved in this process. Our researchers actively engage with a number of such groups, for example the OPTIMA group (Oxford Project To Investigate Memory and Ageing) has extensive interactions with patients and their families. Other contributions include >500 outreach lectures (including lessons in schools & presentations at science fairs), popular science books, and *c*. 450

media interviews. The University Press Office co-ordinates interactions with the media, and both podcasts http://podcasts.ox.ac.uk/ and blogs http://www.ox.ac.uk/media/science_blog/index.html are regularly posted on the University website. Over the assessment period, 131 stories on the main University website and 101 posts on the University's science-blog page have related to research activity in UoA5. These have had a combined total of more than 157,000 hits since January 2011. Outreach activities also exploit the rich resources of the University Botanic Garden, Wytham Woods, the University Farm and the University Museum of Natural History. Over 700,000 people visit these sites each year, benefitting from educational displays and engaging with researchers on open days.

c. Strategy and plans

Oversight and Management of Impact Strategy

In 2012, we established the cross-departmental Biosciences Forum (chaired by the ProVC Research) to co-ordinate activities and strategy in UoA5 with that in physical sciences at the life sciences interface. The Forum was established both to respond to changes in the higher education landscape (e.g. student fee changes, withdrawal of capital funding) and to be pro-active in forming the agenda going forward. Because of the pivotal position of biosciences research, in terms of tackling 21st Century global challenges, the Forum is also providing the means to synergise, co-ordinate and plan impact strategy across the University.

In February 2013, the impact strategy and programme that has been developed by the Forum was shortlisted for entry into the BBSRC Excellence with Impact Competition. A full submission will be made in 2014 and results are due in 2016. The Biosciences Forum will ensure that key targets are met and that strategy evolves in response to emerging new technologies and the needs of stakeholders. The formulated strategy builds on the current approach discussed in section b, and is similarly focussed around Supporting People, Facilitating Translational Research and Creating Routes to Achieve Impact. Each area has short- (end of 2015), medium- (five years) and long-term (ten years) goals. The implementation of strategy will be assisted through the appointment of an Industrial Advisory Board (IAB) (short-term goal) who will meet with the Forum annually.

c1. Supporting People

We aim to embed further procedures that will actively encourage individuals to engage in impact-related activities. Our long-term objective is for all individuals to consider that delivering impact from their research is as important as publishing in scientific journals. This will be achieved by realising the short-term objectives outlined below.

c1.i *Graduate and PDRA Training*

- Include impact awareness training in induction programmes for all new PDRAs; run annual impact workshops for existing staff; and introduce compulsory workshops on the impact agenda to graduate training programmes.
- Include a section on impact in PDRA annual appraisal forms, and in annual assessment exercises for graduate students.
- Provide follow-on grants to enable graduate students to translate research into impact after completion of their thesis.
- Establish an industry exchange programme for PDRAs.

c1.ii *Academic Staff*

- Recognise impact as an important contribution for reappointment of faculty after the initial period of appointment.
- Establish an impact mentoring system.
- Work with the Saïd Business School to provide entrepreneurial training for academic staff.

For all researchers, impact-related activities will be celebrated via regular awards in three categories: (A) substantial impact from a specific piece of research; (B) excellence in generating broad user interactions; and (C) a lifetime award for successfully engaging externally and promoting impact. These awards began operation in 2013; **Simon Hay** and **Marian Dawkins** (Impact Case Studies 10 and 18) were awarded category A and C awards, respectively.

c2. Facilitating Translational Research

Our future strategy aims to enhance and sustain existing activity while initiating new pathways.

c2.i *Translational Research Institutes and Programmes (TRIPs)*
We see two immediate challenges where new TRIPs will be valuable. As other challenges emerge we will respond accordingly.

- The need for novel drugs is becoming increasingly more urgent; probably the biggest challenge in their discovery is the difficulty of validating novel targets for therapeutic development. We have therefore invested £23.8M in establishing a new Target Discovery Institute (TDI) (led by Ratcliffe in UoA1). The Institute will foster close links between university academics and industrial scientists, and will develop high-throughput screening methods to identify and validate key therapeutic targets for industrial exploitation.
- The ability to store, manage and consolidate large datasets is already challenging research capacity. To ensure that the impact of 'big data' is not constrained, the University is planning to establish a Big Data Institute. The institute will provide the physical and intellectual capacity to enable better processing and integration of datasets. This will accelerate the applications of research across UoA5, impacting on core areas of Health, Food Security, and the Environment.

c2.ii *Collaborations with Industry*
Our short- to medium-term objective is to increase the number of companies engaged with UoA5 and at least double our industrial funding. This goal will be realised through the co-ordinated activities of the Divisional Business Development teams. In the long-term we aim to have sustained collaborations with a range of companies that will help us translate research across UoA5.

c2.iii *Open Innovation Partnerships*
The SGC (see b2.iii above) and other open innovation schemes that are currently operating in the University have shown that a pre-competitive forum for rapid, open, data-sharing is attractive to many industry partners. Future SGC strategy is defined by an "Industrial and Academic Board" with representation from all the funder groups. We plan to expand this research model more widely across UoA5. In the short-term we will use the Biosciences Forum and SGC IABs to identify other areas where open innovations schemes would be beneficial for both researchers and stakeholders. The medium-term objective is to initiate further schemes following this model.

c3. Creating Routes to Achieve Impact
Specific plans have been developed to enhance routes to impact in each of the areas of Commercialisation, Policy Input and Public Engagement.

c3.i *Commercialisation*
A number of major initiatives are underway to expand commercial activity:

- Subject to city planning approval, the University's Begbroke Science Park will be enlarged to foster more University collaborations with industry and to incubate businesses.
- The Oxford Science Park (a joint venture between Prudential and Oxford's Magdalen College) will help attract more bioscience businesses.
- The new University–Harwell Oxford Partnership Board, co-convened by the Vice-Chancellor, will enhance joint research and commercialisation activities.

The government has signalled possible co-funding not only for the Begbroke expansion but also for the Oxford Bioescalator, a major new ~£35M initiative presenting a new model for bioscience business growth between the two universities in Oxford, the Oxford University Hospitals NHS Trust and local stakeholders in the healthcare community. The aim is to nurture and scale-up high quality start-ups into substantial viable companies.

c3.ii *Input to Policy*
The Biosciences Forum will oversee implementation of recommendations arising from the EPSRC Impact Award-funded study by **Charles Godfray** and **Angela McLean** into how Oxford can improve its engagement with government and its impact on public policy. These recommendations focus on ways to be more responsive to the needs of policy makers ("pull" rather than "push"), how to influence policy, and how to navigate Whitehall and Westminster.

c3.iii *User Group and Public Engagement*
Many public engagement activities will continue to originate with individuals or in departments but we plan more active support and some cross-UoA activities. For example:

- A dedicated outreach officer will be employed to coordinate across UoA5 (short-term objective).
- Funds will be sought to enable more UoA5 participation in *Oxford Sparks*, Oxford's online public

science platform, and in particular to produce several animations and accompanying resource materials (http://www.oxfordsparks.net/) (short- to medium-term objective).
- Public Engagement support services will be delivered through a new University-wide unit and a partnership with Science Oxford (short- to medium-term objective).
- We will install a new display space in the main court of the Museum of Natural History, which we will use to showcase a rolling programme of research outputs from researchers in University departments, including all departments in UoA5. These exhibitions will be produced in collaboration with individual researchers and in consultation with potential commercial stakeholders. Each new exhibition will be launched with a seminar and reception to which we will invite external stakeholders from the commercial, charity and government sectors, researchers and innovation experts from across the University and beyond. Exhibitions will be open to the wider public after each launch (500,000 visit the museum each year) and integrated with the museum's education programme to enhance reach and participation. One of the first planned exhibits will focus on **Judith Armitage**'s research on bacterial motors. Seminars and exhibitions will be evaluated using visitor interviews and digital audience feedback pods to assess impact and reach, and thus to optimise the showcasing of Oxford University research.
- Our long-term objective is to organise an annual Biosciences Festival for the public (to include the University Museum of Natural History, the University Botanic Garden and Wytham Estate).

d. Relationship to case studies

The submitted impact case studies are closely aligned with the approach and strategy for achieving impact within UoA5, both in terms of the areas and consequences of impact.

d1. Supporting People

A number of the case studies illustrate how long-term commitment to supporting people has enabled individuals to achieve impact from research. For example, Oxford University has long supported **David Macdonald** in his development of the UK's first university-based conservation research group, with resultant impact (UOA05-01) as well as numerous broader policy-based inputs (section b3.ii above), culminating in the award of the Queen's Anniversary Prize in 2011. Two other examples illustrate how a flexible approach to the management of individual employment contracts led to impact: **Luke Alphey** gradually decreased his contracted time as he spun-out Oxitec (UOA05-02) and **William Hawthorne** varied his contracted time in line with the need to carry out externally commissioned surveys (UOA05-03).

d2. Facilitating Translational Research

Many of the case studies arose as a consequence of our active support of institutes and programmes with a focus on translational research, validating this approach as an effective route to impact. Specifically, eight case studies in the broad area of Health and Welfare were developed in five of the more long-standing programmes: Oxford Glycobiology Institute (UOA05-04 & -05); Clinical Biomanufacturing Facility (UOA05-06 to -08); MRC Anatomical Neuropharmacology Unit (UOA05-09); and Institute for Emerging Infections (UOA05-10 & -11). One case study (UOA05-12) resulted from an industrial collaboration that facilitated translational research.

d3. Creating Routes to Achieve Impact

Our emphasis on supporting different routes to achieve impact has produced the five impact case studies for which commercialisation was achieved with the support of Isis (UOA5-13 to -17), the three that changed policy (UOA5-18 to -20) and the three that involved user group engagement in the form of clinical trials (UOA5-21 to -23).

In summary, impacts on **Health and Welfare**, the **Environment**, **Commerce**, **Public Policy**, and **International Development** are strongly represented in the submitted cases. Our focus on **Food Security** as a major area of impact is recent (2011 onwards) but has still delivered two case studies that also impact on Public Policy, and in one case on International Development. Eighteen of our case studies impact on Health and Welfare, with most enhancing Commerce by generating sales revenue for pharmaceutical companies, significant income for the University from patents, and wealth creation from successful spin-out companies. The remaining cases impact on the Environment, Public Policy and International Development.