Institution: University of Sheffield

Unit of Assessment: 5 - Biological Sciences

a. **CONTEXT**

This UoA covers a broad spectrum of outstanding fundamental biological research, ranging from molecular studies to understanding how organisms interact with the environment at a global scale. We have a long tradition of translating science into benefits for society and have enthusiastically taken the new opportunities offered over the REF period to further embed this commitment into our work. Thus, the impact described in the following sections ranges from collaborations with large pharmaceutical, oil and agri-chemical companies, through development of university spin-out companies, to influencing the policies of governments and non-governmental organisations. Some of these interactions involve conventional joint ventures with industry in which the impact is embedded in the very nature of the research, whereas others are characterised by novel applications of academic research, demonstrating how fundamental, curiosity-driven research can lead to novel applications at a global scale.

b. APPROACH TO IMPACT

Our success in knowledge transfer arises from outstanding fundamental biological research supported by an effective translational infrastructure within a strongly embedded culture of innovation and application. We have advanced our impact strategy over the REF period, building on an already strong profile in translational science. For example, our work in plant cell culture led to the formation of one of the UK's earliest biotechnology ventures (Plant Sciences Ltd. in 1982) while in the biomedical arena, *Andrews* had already in 2001 co-founded Axordia, a spin-out company aimed at commercializing embryonic stem cell lines (which has led to the generation of the first clinical-grade stem cells in the UK- *Case Study Stem Cells*) and in 2000 Artymiuk co-founded Asterion, a spin-out drug development company (see *Case Study Asterion*). In the policy arena, *Woodward's* research notably contributed to the Nobel prize-winning 2007 IPCC report on climate change and his work continues to inform policy decisions in this area, e.g., the recent (2013) European Space Agency's €370M Biomass project to measure global forest biomass. Our approach has been to build on this strong platform of engagement with industry and policy-makers, to promote established pathways to impact, and to nurture and extend new contacts. We have also made strategic appointments to ensure our research both maintains academic excellence and has maximum potential for future impact (e.g., *Davletov's* work on engineering natural toxins with potential to treat chronic pain is an area we are actively supporting).

The impact we have achieved and that is underway

We have focused our impact in three distinct areas that map onto the academic strengths of the UoA (described in the *Environment Template*), with funding and assistance being provided at university, faculty and department levels to ensure that sufficient resource and expertise are available to promote and facilitate impact.

Our work on global climate change, ecology and evolutionary genetics has led to impact on **national and international environmental policy.** Thus, in the present REF period academics have provided advice to: a National Science Foundation (USA) working panel on consequences of greenhouse warming for biocomplexity and biogeochemical cycle, and the Royal Society working group on land carbon sources and sinks (*Beerling*); the UK Government Advisory Committee on Releases to the Environment (*Rees*); DEFRA on TB and badger culling (*Burke*); and a USA national panel on pest control (*Case Study Global Pest*) (*Siva-Jothy*). With respect to **food security**, our work is having a major international impact via our lead and involvement in the $20M Bill & Melinda Gates C4 rice program (*Quick*, *Osborne*) and, in the UK, our research into drought tolerance underpins a BBSRC industrial partnership project with SABMiller (*Gray*), with CASE awards underpinning interactions with technology developers such as Waters (*Fleming*). Novel impact is being developed via research on mammal breeding which supports a project with the government of Burma (Myanmar) on the welfare and sustainable breeding of elephants for the logging industry, which underpins 25% of the country's GDP (*Lummaa*), and our expertise in palynology (*Wellman*) is leading to significant impact in the oil exploration industry in the Middle East via more efficient stratigraphic analysis of drill cores to find oil.

In the area of biomedicine, we have maximised our impact with the commercial sector through a range of industry collaborations, particularly in the areas of **pharmaceuticals** and **stem cells**. These include work with GSK and AstraZeneca on the development of a novel pharmacology screen for adverse gastrointestinal effects (*Grundy,* see *Case Study Irritable Bowel Syndrome*). This work (supported by University KE funding) has led to an assay being developed with Biopta Ltd who specialise in human tissue research. This study was submitted for consideration for the BBSRC Innovator of the Year Award (2009). In addition, *Andrews* won a BBSRC-Industrial Partnership award with Pfizer for work on stem cells, and our development of the SHEF-1 cell line has had considerable impact (Case Study *Stem Cells*). Industrial CASE studentships have been awarded to many academic staff members working in this area (*Grundy*, *Rivolta*, *Johnson*, *Whitfield*) in partnership with Pfizer, GSK, AstraZeneca and others. Excitingly, our Hearing Research led to a £0.58M MRC translational stem cell award (*Rivolta*) for collaboration with Cochlear (a leading cochlear implant company) and our partnerships with the Royal National Institute for the Deaf (RNID) and Deafness Research UK (DRUK) achieved international publicity. This work has led to plans for the establishment of a spin-out company (Acousia Biotherapeutics Ltd) to exploit the potential for sensory hair cell regeneration to treat deafness, with discussions underway with the Boehringer Ingelheim Venture Funds, again an area we are focussed on for future impact.

Our research in biochemistry and microbiology has led to the advanced development of two **biotechnology** spin-out companies in this REF period. Absynth was formed in 2007 based on proof-of-principle data obtained in the *S. aureus* septic arthritis model (*Foster*) and attracted significant initial investment (>£1.2M) from venture capital, regional development sources, and industry. In 2013 Absynth completed a financing round of £0.89M and received a TSB Biomedical Catalyst award of c £2M. Currently Absynth has several proprietary antigens under development for the treatment of bacterial infections and this is an area of significant future impact. Asterion is involved in developing therapeutic biomedical applications and has successfully raised licensing income in excess of £0.5M from companies such as Genzyme and Ipsen (*Artymiuk,* see *Case Study Asterion*), a significant achievement in the biotech field. In addition, our leading expertise in structural biology has underpinned collaborations with Zeneca on novel antimicrobial agents (*Rice*), as well as development of new herbicides with Syngenta, a collaboration built on a series of Industrial Partnership Awards and CASE studentships (see *Case Study New Herbicide).*

In addition to these impacts on policy, medicine and biotechnology, we are significantly involved in **outreach** activities. This includes: talks to over 2500 local schoolchildren/yr from 34 schools (over 5% of Sheffield school children/yr), one third of whom live in disadvantaged areas of the city, including special needs schools. Our activities include both major events (e.g., Christmas lectures) and regular visit days (over 35/yr). As a measure of success, all participating schools have requested repeat visits. We have also contributed to events outside Sheffield, e.g., RCUK Darwin200 exhibition, Festival of Science and Art (2010,) cBBC Live (2014). Numerous PIs are involved in these outreach events, notably *Birkhead*, *Green*, *Smythe*, *Ayscough*, *Whitfield*, *Gray*, *Wellman* and *Osborne*. PIs have published successful science books aimed at the general public, e.g., *Beerling* (The Emerald Planet), who also advised on the BBC series “How to grow a planet” (2012) which was broadcast nationally. Many of our research findings have been highlighted in the national and international press (e.g., *Whitworth’s* work on Parkinson’s Disease, *Rivolta’s* research on stem cell therapies for deafness, and *Rice’s* work on Burkholderia toxin and antibiotic resistance).

To summarise, our strategic research has involved funded collaborations with 22 companies and external organisations, with associated grant income and external funding in excess of £4M. This has been associated with 20 CASE PhD studentships and PIs have contributed to 118 outreach activities with local, national and international impact.

How Impact is Facilitated

Our policy is to fully support individuals who are driving the impact agenda, to encourage and enable staff involvement in impact activities, providing support and facilitation of impact across all levels of engagement with beneficiaries and policymakers.

A primary level of engagement involves building on personal relationships of PIs and stakeholders. As seen in our case study on herbicide development (*Rice*), such long-term relationships are often crucial to achieving impact. Departmental Heads facilitate such interactions by providing PIs time to

develop such links (decreased administration and teaching loads) and, via University Knowledge Exchange resources, funds to facilitate such links. Over the REF period Knowledge Exchange funding of £1.6M has been made available by the Faculty of Science and has provided pump-priming funding for over 15 projects in this UoA, including, e.g., a £0.15M NERC KE project "Integrating Genetics into Conservation" (*Burke*).

A second level of facilitation involves the hiring of impact-related staff. A NERC KE fellow (*Holt*) was employed over part of the REF period (2009-present) with a focus on our environmental and policy-driven research. This fellow has drawn up an impact pipeline which enables a forward-looking strategy to identify impact areas relating to individual PIs and what investment is required to enable additional impact to be achieved. Two external-facing symposia have been organised (Multifunctional Landscapes- 2009; Sustainable Agriculture- 2013) which have led to new relationships with, e.g., Heineken and Tata Steel. In the biomedical field we appointed a Business Research Fellow to cultivate awareness and exploitation of our commercial potential. The post was financed from departmental funds, the MRC Developmental Pathways Funding Scheme and University HEIF. The fellow was key to a MRC Developmental Pathway Funding Scheme award £0.58M (*Foster*) and an MRC Translational Pump Priming Award (£1.5M) for our small molecule screening unit which enables characterisation of potential therapeutics in a model animal system. In addition, she facilitated a Knowledge Transfer project between *Grundy* and Biopta, as well as initiating contacts with SMEs, including Oxitec and Karus.

Based on the success of these KE fellows, we recently established the "**Sheffield Science Gateway**" (http://ssg.sheffield.ac.uk) as a key component of our future impact strategy. This represents a £1.18M investment (2012-15) by University of Sheffield and other sponsors and provides 11 staff specifically aimed at increasing the proportion of contract research and consultancy, with Business Development Managers embedded in the research environment to assist and encourage impact activities. Approximately half of this investment (including 6 staff) is focused on biology-related impact activities. For example, the University was recently awarded £100k Sparking Impact Award (SIA) from BBSRC to fund further KE in the biosciences.

In addition to these structures focused on impact from biological research, our University Research and Innovation Services provide a range of services to facilitate interaction with end-users, ranging from help with organising events to writing contracts, cost estimations and consultancy. For impact involving significant IP, researchers have access to Fusion IP, University of Sheffield's primary vehicle for the direct commercialisation of research activities. Over the REF period, Fusion IP has worked closely with our successful spin-off companies, Absynth and Asterion to raise >£3.5M external funding. Finally, the University has an Impact Strategy Board composed of the Pro-Vice Chancellor for Research and Innovation and senior colleagues which provides a higher-level steer to co-ordinate impact activities across the university. Sheffield has an excellent track record in impact (the University receives a maximum Higher Education Innovation Fund allocation of £2.85M per year, recognising the high level of interactions between Sheffield and industry) and this UoA benefits from and contributes to the adoption of best practice across the University.

Engagement with impact activities is recognised via an annual assessment for all PIs. This forms the basis of a pay and reward mechanism, leading to potential promotion or salary enhancement. It is a holistic process in which all activities are taken into account and impact forms an important aspect of this assessment. As well as direct reward via exceptional contribution awards, impact activities can lead to adjusted workloads, providing PIs more time to build and exploit impact activities by **strategic deployment or secondments**. For example, *Quick* has been seconded since 2009 to the International Rice Research Institute to lead the $20M BMGF C4 rice project. Work on a drug for irritable bowel syndrome was greatly facilitated by an earlier secondment to GSK by *Grundy* (see *Case Study Irritable Bowel Syndrome*).

c. STRATEGY AND PLANS

Our overall strategy is to embed impact activities further into the day-to-day activities of staff in this UoA and, thus, to increase the number and value of our engagements with end-users. To achieve this aim we will build on the excellent foundations described in the previous sections. The fellows hired as part of the **Science Gateway** will be integrated into the host groups, since we believe that only by maintaining a close working relationship between research-focused and impact-focused staff can impact be maximised. These fellows will maintain and build our impact pipeline by helping to identify novel pathways to impact, identifying the resources required, and facilitating the external

expertise required to achieve impact. They will also provide advice on the documentation of impact for RCUK grant proposals and other funding sources. They will provide the key link to investment of University KE resource, which is sector leading.

Our impact activities will be focused on three main areas that reflect the research strengths of the UoA (see *Environment Template*) and which are areas where we already have a strong profile, as evidenced by our case studies. These will be: (**a**) **policy-focused**, in particular climate and environmental policy at both national and international level via participation in working groups and research networks; (**b**) **biomedical science**, in particular neurobiology and stem cells, working with key partners in the pharmaceutical industry, as well as policy advice; (**c**) **biotechnology**, particularly in the area of medical microbiology and, via our strengths in structural biology, with the agri-chemical and pharmaceutical industries. We believe that significant impact can also be achieved outside of the traditional industry/spin-out route. For example, our expertise in classical palynology (*Wellman*) is leading to novel impact on the oil industry, and expertise in mammalian (elephant) reproduction (*Lummaa*) is influencing logging and animal welfare policy in Burma (Myanmar), providing a new dimension to our international and commercial impact. We will use these "non-typical" impact stories to showcase how apparently "pure" academic research skills can have significant international impact.

The impact pipeline will be used to track the progress of the impact studies associated with each academic. This will enable us to provide appropriate resource/advice and to identify and share best practice across the UoA. To ensure this process remains vibrant we will instigate impact events (facilitated by our Science Gateway resource and responsive to the funding landscape) within the normal cycle of staff meetings. This will ensure that impact remains high on the research agenda and provide forums for identifying novel ways of identifying and promoting impact.

We will also continue our extensive and highly successful **outreach** work. This will be managed by three Outreach Co-ordinators and will involve individual visits to local schools and societies, as well as the continued organization of outreach events, primarily focused on young people, informing them about our work and enthusing them with an appreciation of science and its role in society. A high percentage of staff (>40%) is highly active in this important aspect of the impact agenda.

d. RELATIONSHIP TO CASE STUDIES

Our case studies reflect impact resulting both from long-term relationships of individual PIs with other stakeholders and resulting from novel KE activities. For example, the case study relating to government policy on insect control (*Case Study Global Pest*) reflects research in which impact aims were embedded in the essence of the research area and the high academic standing of the PI who was invited to contribute to an international working group. The department provided time for the academic to attend meetings in the USA where the policy document was formulated. Our case study on drug development (*Case Study Irritable Bowel Syndrome*) arose out of work sponsored by a pharmaceutical company (including secondment of the PI to the company involved) over a number of years. This collaboration was facilitated by the excellent research environment provided by the UoA and the academic standing of the PI. Similarly, our work on the development of an agrichemical to replace glyphosate (*Case Study New Herbicide*) arose out of a long-term collaboration with a major company, involving significant investment in research projects, including CASE students. The excellent research facilities provided by the host UoA in the area of structural biology facilitated this impact. The pre-eminent role of the Centre for Stem Cell Biology on the international stage and early recognition of commercial possibilities in this area underpinned our *Case Study Stem Cells*. University and regional development agency pump-priming for a spin-out company facilitated this impact, as did activities of the University IP company. The high standing of the PI involved led to his leading role in formulating guidelines on stem cell applications. Finally, a further spin-out company (*Case Study Asterion*) also arose out of excellent academic research whose translation was supported by University mechanisms to raise funding and promote the company and the drive of the academic colleagues involved.

These case studies, along with those highlighted in part (b), are being used as exemplars to show the diverse means by which impact can be achieved based on excellent fundamental science. Our strategy is to support our mature lines of work and our developing case studies to ensure that impact with excellence is embedded within the research of this UoA.