Institution: University of Warwick

Unit of Assessment: UoA5 (Biological Sciences)

a. Context: The School of Life Sciences (SLS) was established in 2010 through the merger of the former University departments of Biological Sciences and Warwick HRI. The School has broad research strengths, which have recently been structured into six themes: Molecular and Cell Systems, Development, Infection Biology, Environment, Food Security, and Synthetic Biology and Biotechnology (SynBioTech). These themes include studies across a range of organisms spanning bacteria, viruses, fungi, protists, animals and plants. As a result, our research is relevant to a diverse range of audiences with applications in biological and biomedical sciences. SynBioTech is the most recently established of the themes, and so our main current impacts do not fall within this area, although the potential for future impact through industrial collaboration and commercialisation is enormous.

Industry & Commercial: SLS researchers have long-term collaborations with partners from the chemical, agricultural, environmental, pharmaceutical and medical industries. Research within SLS has led to the development of patents and the generation of income for both spin-out companies and international biotechnology organisations through commercialisation of research findings and development of novel technologies.

Outreach & Media: Engaging with the public is encouraged at all levels within SLS, with activities including a school outreach programme and attendance at public science events. Researchers give interviews to the local and national press, and are increasingly using social media to make their findings accessible to a wider audience and to stimulate public debate.

Knowledge Transfer: In addition to our involvement in collaborative research with industry, technical expertise is shared through public access and bespoke short courses for commercial and public sector organisations, and direct engagement with stakeholders ensures that the practical applications of our research findings and technologies are realised.

Government/Policy makers & Advisory: Working with Government Departments has stimulated policy debate, and membership of Advisory Boards has enabled our research findings to inform guidelines in areas such as climate change, antimicrobial resistance and control measures for infectious diseases.

b. Approach to impact: Participation in BBSRC's Excellence with Impact competition (2008 - 2011) acted as a catalyst for the further development of our approach to maximising impact arising from cutting-edge science, increasing awareness and understanding of the importance of impact and enabling identification of areas of strength and weakness. When the new School was formed, a research strategy was established to facilitate the coordination of activities along the basic-applied science continuum. Our integrated research strategy applies multiple technologies to the study of a wide range of biological systems to generate fundamental knowledge and a range of impacts of direct relevance to the wider community. Underpinned by the six research themes, our major impact areas are: Biotechnology, Food Security, Environment, Big Data and Wellbeing. Whilst some of our endeavours align primarily with one impact area, there are also elements of overlap, and some cross-cutting activities, infrastructure and facilities. The School's approach is to support staff and students at all levels, and in all subject areas, to apply their scientific findings, expertise and knowledge to generate broad impact beyond academia. As part of our involvement in the current Excellence with Impact competition (2013-2016) we have appointed a Director of Impact (Cameron) to provide leadership in this important area. We encourage researchers to start with small-scale projects and to engage with stakeholders at a very early stage, such as through CASE studentships or LINK grants, to enable relationships to develop and the potential impact of the project to be assessed, monitored, and maximised, ensuring relevance to end users. In many cases this approach has led to the establishment of robust and sustainable partnerships that have facilitated greater and wider impact.

Industry & Commercial: Researchers in SLS have developed strong associations with a number of companies through activities such as Industrial Partnership grants and CASE studentships. Between 2008 and 2012 15 PhD students graduated from SLS after completing CASE studentships, having undertaken industrial placements with organisations including Pfizer, Waters and ICI. Further CASE studentships are currently underway with the Horticultural Development Company (HDC), Guy & Wright Ltd, and AstraZeneca. Activities such as these have acted as a stepping stone in the formation of longer-term relationships and research collaborations, including research carried out in collaboration with Syngenta to model the development of herbicide

resistance by weeds (Neve; *Case Study WSLSA5.3*). In several cases this approach has led to patents being filed and the generation of revenue through commercialisation of research findings, such as the patenting of physical techniques and genetic traits to enhance seed performance (Finch-Savage; *Case Study WSLSA5.1*), and establishment of the Warwick/Waters Centre for Biomedical Mass Spectrometry and Proteomics (Scrivens), which fosters the development of novel mass spectrometry techniques in addition to providing external parties with access to sophisticated instrumental technologies.

SLS researchers (Dowson, Roper) play a major role in the Science City Research Alliance (SRCA), in particular the 'Translational Medicine 2' programme. The partnership between the Universities of Warwick and Birmingham provides investment in state-of-the-art equipment to enable new interactions with companies, and local beneficiaries to obtain access to the equipment and specialist technical advice. To date SCRA has collaborated with around 150 West Midlands businesses, through activities including workshops, business breakfasts, seminars and *ad hoc* technical assistance. The programme funds six Business Managers, whose role is to facilitate industry interactions and public engagement.

In addition to partnerships with large well-established companies, academics within SLS have also been supported to commercialise their research findings through the formation of spin-out companies. Successful examples include Novolytics (Mann), whose focus is on phage therapy, and Sarissa Biomedical (Dale; *Case Study WSLSA5.4*), which uses innovative technology to develop microelectrode biosensors for rapid point-of-care medical diagnosis. Additional industrial engagement comes from consultancy work undertaken by our researchers, with companies such as PTC Therapeutics (Easton) and Eli Lilly (Green).

Outreach & Media: Students and researchers take part in a wide range of public engagement activities, and interactions with schools are a particular focus. Linking outreach activities to research helps to generate enthusiasm and spark debate, particularly among young people considering a career in science. Examples include:

- Opportunities for sixth form students to experience a university lecture, carry out lab work, and meet undergraduates, as part of the Life Sciences Summer School Programme
- Helping pupils to produce short documentaries as part of the Physiology Bites programme (funded by a Physiology Society public engagement grant; Squires)
- Engaging with local children about food security through school visits (Snitterfield Primary School and Hampton Lucy School)

The general public has a great deal of curiosity for science, particularly topical issues, and we have used our research findings to contribute to a number of public events, including:

- 'Shakespeare on the Brain' (part of Brain Awareness Week in March 2009; Dale)
- A lecture on DNA testing, which enabled attendees to do some 'hands-on' science (Allaby)
- Leading practicals and tutorials at the Gatsby Plant Science Summer School, which brings together high-achieving first-year undergraduates with research leaders to inspire the next generation of plant scientists (Frigerio, Gifford)
- Demonstrating the role of imaging and microscopy in life science research at the Big Bang Fair 2013 (Hands-Portman)

Many researchers within SLS have taken the opportunity to disseminate their research findings to a broad audience through the broadcast and print media, and have also been called upon to give expert comment on topical issues. This includes over 50 interviews on the development of drug-resistant swine flu, and over 80 interviews on the H1N1 influenza pandemic (Easton). Our scientists are increasingly turning to social media channels to communicate their findings, including the use of podcasts and twitter. All media coverage is promoted further on the SLS website, ensuring that it is accessible to all, including potential end-users, long after its first appearance in the public domain.

Knowledge Transfer: Given the breadth of expertise within SLS, knowledge transfer is a significant area of impact. Activities include public access and bespoke short courses delivered to participants from commercial and public sector organisations, ensuring that others can capitalise on the practical applications of our basic research. Stakeholder engagement with groups such as clinicians and charities ensures that our research is designed to meet the needs of end-users. Researchers have organised techniques workshops in areas such as next generation sequencing (Hebenstreit), proteomics and mass spectrometry (India; Scrivens), crystallography (in conjunction with Diamond Light Source; Cameron), and quantitative bioscience (FEBS International Training

Course, Greece; McCarthy); researchers have also participated in cross-sectoral knowledge sharing, including meetings coordinated by Diabetes UK (Squires) and the British Neuroscience Association (Frenguelli).

Government/Policy makers & Advisory: A number of SLS researchers sit on Committees and Advisory Boards, and have influenced wide-ranging aspects of policy and management guidelines. This has been most successful where our researchers have engaged with policy makers at an early stage and on an on-going basis to ensure that the route to potential impact is identified, assessed and monitored. Examples include: Environmental Advisor to the Foreign and Commonwealth Office for Overseas Territories (Sheppard; *Case Study WSLSA5.2)*; Member of the Scientific Advisory Committee for Epilepsy UK (Frenguelli); Member of the Intergovernmental Panel for Climate Change (Sheppard); Member of the Joint Committee on Vaccination and Immunization Influenza Sub-panel for the Department of Health (Medley); Chairman of the Technical Benchmarking Panel, Chemical and Biological Detection Department, DSTL Porton Down (Scrivens); Member of the DEFRA Antimicrobial Resistance Coordination (DARC) Committee on extended spectrum beta-lactamases (Wellington); Collaboration with DEFRA on the adoption of non-invasive testing to monitor control measures for bovine tuberculosis (Wellington; *Case Study WSLSA5.5*).

Institutional and School support: The items mentioned above are a small selection of examples to illustrate the commitment within SLS towards impact-orientated research. A major factor in realising these achievements is the support, facilities and infrastructure provided by both the School and the University, including:

- Coordination and simplification of stakeholder engagement through research centres, such as *Warwick Infectious Disease Epidemiology Research Centre* (WIDER), *Warwick Centre for Integrative Synthetic Biology* (WISB) and the University's *Global Research Priorities* Programme (GRP), which focuses on significant global challenges. SLS academics play a major role in the GRPs on *Science and Technology for Health* (Easton) and *Food* (Collier), both of which contribute to all impact categories, but particularly industrial engagement, knowledge transfer and societal benefit.
- Central roles within the University to support the advancement of impact activity, including Business Development Officers to assist with commercialisation, patents and licensing; the Communications team, who have extensive contacts with the broadcast and print media; the International Office, who help to support the exchange of people, ideas and information as part of overseas projects; and the Knowledge Transfer Partnership Manager and Advisor.
- SLS has its own dedicated Education Strategy and Communications Officer and Research Strategy Development Officer, whose roles include the development of outreach activities and impact-orientated research, respectively.
- Opportunities for dissemination of research findings beyond the academic community through the Warwick Research Archive Portal (WRAP; http://wrap.warwick.ac.uk/) and the University's Knowledge Centre (http://www2.warwick.ac.uk/knowledge/)
- Training in impact, engagement and dissemination through the central Learning and Development Department.
- Financial support in the form of the Warwick Impact Fund, which aims to increase the University's capacity and capability to deliver world-class innovative impact, and the BBSRC Sparking Impact Fund, which supports knowledge exchange and commercialisation activities.

c. Strategy and plans: We recently entered a period of review to consider how research and impact within SLS has developed, and identify potential areas of expansion for the future. Over time, as we have recruited new members of staff and developed existing and new collaborations, both within Warwick and beyond, the main areas of impact have evolved to Biotechnology, Food Security, Environment, Big Data and Wellbeing. Overall, our vision is to embed a culture that values impact at all levels and places it as an integral activity within the School's research agenda. This increasing emphasis on impact will be further assisted by our participation in the current BBSRC Excellence with Impact competition, which will see the provision of impact training and resources, sharing of best practice with other Departments, and improved recording, monitoring and communication of activities. The University's recent Sparking Impact award has also provided pump-priming support to several projects involving knowledge exchange and commercialisation activities led by academics in SLS and other departments. As a strategic partner of BBSRC, we expect that the increased dialogue on research planning will enable us to develop a sound

approach that is in-keeping with the Research Council's priorities, placing us in a strong position to receive further funding and support from them for our impact activities.

Robust underpinning scientific research will remain the basis of all impact activity, but we will capitalise on existing relationships, such as those developed through CASE studentships, to expand current projects and networks, and to reach out to new partners and stakeholders. The development of our new SynBioTech research theme, through the recruitment of experts in the field (Soyer, Jaramillo, Corre), establishing collaborations with other departments (Engineering, Chemistry) and institutions (including Bristol University; Boston University/Harvard, USA; University of São Paulo, Brazil; and the bioengineering company DNA2.0) through *WISB* and the BBSRC Network in Industrial Biotechnology and Bioeneergy, and establishing new facilities, equipment and resources, will be a key factor in driving forward research-led impact in this as-yet unexplored area. The development of all of our research themes, each driven by a Theme Leader, will give greater direction to our research, enabling opportunities to be identified and capitalised upon, and projecting a more coherent outward-facing profile to facilitate wider collaboration.

Our strategy is to continue to provide support to facilitate impact activities, whilst ensuring that these activities are captured and communicated. Incorporating impact activities into aspects such as recruitment, promotion, and objective setting within annual reviews, will ensure that it remains at the top of everyone's agenda and that high achievers are recognised. In addition to showcasing success stories in the SLS newsletter and incorporating impact into the plans to redesign our externally facing website, we will also redevelop our intranet to provide staff with resources to help them generate impact from their research. Further support for the advancement of impact activities will come from the newly appointed 'Outreach Officer' (Moffat) and SLS 'Impact Director' (Cameron). In the short-term we will provide access to cutting-edge technology, in the form of a Biological Mass Spectrometry Facility, shared with Warwick Medical School, and in the longer term we plan to move SLS to a new building on the main University campus, which will provide improved research facilities, better centralised support for our researchers, and greater potential for collaboration both within Life Sciences and with neighbouring departments. We will continually monitor and assess our impact strategy, adapting our approach as necessary to ensure that the achievement of impact from research is facilitated effectively, and opportunities are maximised.

d. Relationship to case studies: Our research expertise is relevant to a wide number of audiences with applications in biotechnology, agriculture, environment and biomedical sciences. Our Research Strategy facilitates impact by bringing together scientific expertise in underpinning themes and channelling this towards our five impact areas of Biotechnology, Food Security, Environment, Big Data and Wellbeing. Researchers are encouraged and supported to contribute to at least one impact area, and to undertake a broad range of impact activities, as demonstrated by the diversity of our case studies. A particular focus is to develop sustainable collaborations that generate a range of long-term impacts beyond academia.The five submitted case studies demonstrate how research in a specific area can lead to a variety of impacts and they exemplify our approach of: using small-scale projects to initiate the development of sustainable impact activities; early and on-going stakeholder engagement to realise the full potential of the project; and maximising opportunities for impact through high quality end-user-driven basic research.

Case Study WSLSA5.4 shows how basic neuroscience research was applied to develop a practical solution to a clinical need, through the formation of a spin-out company and engagement with clinicians. *Case Study WSLSA5.1* demonstrates how a small-scale collaborative research project on seed vigour led to a longer-term larger-scale industrial collaboration that enabled exploitation of Intellectual Property and commercialisation of research findings. *Case Study WSLSA5.3* outlines how collaborative research with industry and early interaction with end-users resulted in changes in international crop management guidelines. *Case study WSLSA5.2* shows how long-term engagement with Government departments and policy makers during research led to the establishment of the World's largest Marine Protected Area. *Case study WSLSA5.5* demonstrates how basic research into wildlife disease control management and monitoring is being applied to a major global challenge and has impacted on Government guidelines as a result of continuing discussions. These case studies reflect the research excellence within SLS, the extent of our networks and external interactions, and the commitment within the School to making a difference above and beyond improving academic knowledge.