Institution: University of Warwick

Unit of Assessment: UoA6 (Agriculture, Veterinary & Food Science)

a. Overview

This submission reflects the work of 13 members of the School of Life Sciences (SLS). Work from SLS focusing on Veterinary Science plus Plant and Environmental research that underpins Agriculture and Horticulture is submitted to UoA6, whilst other research activities in the School are outlined under UoA5. SLS was established in October 2010 through the merger of the former School of Biological Sciences (on Gibbet Hill campus) and of Horticulture Research International (HRI, at Wellesbourne). The merger was accompanied by rationalization of staff and resources across the two sites. A new Head, Professor John McCarthy, was appointed in October 2010 to lead an ambitious development programme for SLS. The Life Science development plan is being supported through investment in new academic positions, new facilities and new buildings. The latter include the *Warwick Phytobiology Facility* and the *Warwick Interdisciplinary Biocentre*. Our vision for research and training reflects the modern view of biology as an interdisciplinary science that increasingly incorporates quantitative methods and in which exciting discoveries are driven by the rapidly expanding repertoire of experimental and computational technologies. At the centre of our philosophy is therefore a commitment to an integrative approach that seeks to identify the core principles shared by all forms of life. The integrated nature of the Research Theme structure means that animal, plant and microbial science activities are associated with multiple Themes.

b. Research strategy

The overall strategy for SLS is to promote an ethos of research excellence within a framework that emphasises integrated, interdisciplinary, systems-oriented approaches underpinned by a high degree of interconnectedness between research themes as well as extensive networking between members of the School, thus capitalizing maximally on the collective skill base and synergies within the community. ***SLS has 6 integrative research themes:*** Development, Environment, Food Security, Infection Biology, Molecular & Cell Systems and Synthetic Biology & Biotechnology, all of which act to promote integrative and interdisciplinary research pursued by researchers working in our animal, plant and microbial communities. Our research translates into multiple cases of high impact in areas including Food Security, Biotechnology, Animal & Human Wellbeing, Environment and Big Data, a selection of which are included as Impact Case Studies in this REF submission. The continuing development of core technology capabilities, including computational facilities, genomics, proteomics, metabolomics, microfluidics, high-resolution imaging (EM, light microscopy, flow cytometry) and structural biology, underpins this strategy. The emphasis in the School's vision on the development and application of quantitative technologies maximises our interactions with the internationally acknowledged strengths of the University of Warwick in mathematics, computer science, engineering and the physical sciences. This research strategy also underpins the SLS strategy for training and education. In order to develop the SLS vision, we have made 14 new academic appointments since 2010.

Significant changes to research environment – A key component of the vision for SLS has been to achieve a significantly greater degree of integration in terms of staff environment, shared facilities, support structures, research and training activities. A major step in this direction has involved the construction of a state-of-the-art ***Phytobiology Facility*** on main campus, enabling the majority of the plant scientists to relocate from the (HRI) Wellesbourne site to refurbished laboratories on main campus. A cohort of crop science experts that makes intensive use of field-trials has remained as the recently formed Warwick Crop Centre (WCC) at Wellesbourne. We have also significantly upgraded our Facilities for proteomics, genomics, imaging, microfluidics and computation through strong investment in equipment and infrastructure, as detailed below.

Completion of the first stage of our transformational life science strategy will lead on to stage two: the relocation of life science research into a major new building (the ***Warwick Interdisciplinary Biocentre***) whose construction is due to start in 2014.

Evidence of strong research plans. An essential principle of our research in Agriculture and Veterinary Science is that it is based on, and takes advantage of, the most up-to-date advances in relevant basic sciences. Research in this area is thus carried out in the context of the broader aims and capabilities of SLS. Accordingly, our strategy is to ally our strengths in cropping systems and veterinary epidemiology with the core technologies of genomics, proteomics, metabolomics, biophysical methods, systems and synthetic biology, and computational approaches.

The 6 interdisciplinary, integrative Research Themes in SLS are non-exclusive and promote

interactions across the full range of organisms and systems that our community works on. Research associated with all of our Research Themes is relevant to this UoA6 REF submission. In ***Molecular & Cell Systems***, plant systems biology is a major strength, featuring work on transcription networks (Beynon, Buchanan-Wollaston, Denby, Gifford, Ott) while in the area of molecular & cell biology we have particular strengths in protein trafficking (Frigerio) and biosensors (Napier). ***Development*** has a strong plant representation including work in circadian regulation (Carré), flowering (Thomas, Jackson) and seed biology (Finch-Savage). In the ***Environment*** theme, we have renowned expertise in the study of microbial communities in the soil (Bending, Schäfer H.) whereby metagenomics, proteomics, metabolomics and computational biology are playing an increasingly central role. The ***Infection Biology*** theme features host-pathogen interactions in plants (Beynon, Holub, Schäfer P.). Computational modelling is utilized by our epidemiologists (Medley, Green) to study infections in humans and animals. The theme of ***Synthetic Biology and Biotechnology*** is an exciting domain of research growth that is strongly supported by the UK government and is being expanded in the department through new appointments. We envisage that our capability in plant systems biology, genetic manipulation and applied genomics (Beynon, Barker, Jackson) will contribute strongly to the development of Plant Synthetic Biology over the next few years.

Food Security *is the central focus of our UoA6 submission*. This is a broad theme that spans plant science through to animal health, and encompasses the full spectrum of research from fundamental to applied. Key areas of expertise include work on plant stress responses (Beynon, Schäfer, P., Carré, Denby), plant-pathogen interactions and disease resistance mechanisms (Beynon, Ntoukakis, Bending, Denby, Walsh), plant evolutionary genetics (Allaby, Neve), crop improvement (Thomas, Holub), infectious diseases in livestock (Green), and seedling establishment (Finch-Savage, Neve, Frigerio). WCC facilitates the flow of knowledge and technology through to industry, with specific expertise on pest and disease biology, soil microorganisms and the environmental impact of different farming systems. Examples of high-profile papers published in this area during the review period include: 2 in *Science* (both highly cited papers on the plant immune system); 8 in *Plant Cell* (high resolution transcriptomics of senescence and fungal infection, flowering, mutualistic root infection, ER protein properties, endosperm development, promoter evolution and sequence conservation); 3 in *PNAS* (crop domestication, seed dormancy, transgenic barley 'omic analysis); 1 in *Cell* (gene circuits); 1 in *Nature Chemical Biology* (auxin receptor structure).

As a highly interdisciplinary School, SLS collaborates extensively with the Departments of Chemistry (antibiotic biosynthesis, biodegradation) Computer Science (modelling, big data sets), Engineering (synthetic biology, microfluidics), Maths (systems modelling, epidemiology), Medicine (infection, 'omics, plant metabolites and health), Physics (synthetic biology, solid-state NMR), Politics (biopesticide use), Social Science (food security) and Warwick Manufacturing Group (biodegradation).

The School of Life Sciences is an international leader in the development of genetic and genomic resources in *Brassica* species, which include a range of important arable and vegetable crops. The *Brassica oleracea* genome sequence has been completed in an international effort that included significant input from Warwick. Important traits that are being studied using genetic diversity in *Brassica*, include post-harvest deterioration and phytonutrient content, dormancy, germination and seedling vigour, nitrogen and water use efficiency, flowering time and juvenility, resistance to virus, fungi and insects. Future plans include using systems analysis developed with *Arabidopsis* to discover genes and alleles underlying key agronomic traits to be identified and exploited in translational research. *Brassica* is the first target for translation but knowledge of genes that confer valuable traits will also be applicable in other crops.

SLS hosts the Vegetable Genetic Improvement Network (VeGIN) (Buchanan-Wollaston, Thomas) that brings together genetic improvement research focused on key vegetable crops. The Network encourages collaborations between industry and researchers to address how genetic improvement of crop varieties can contribute to a sustainable increase in food production to meet the twin challenges of food security and climate change. In addition to the lead programme in vegetable brassicas, VeGIN has developed genetic resources and trait information for lettuce, carrots and *Alliums*, which together represent the most important vegetable crops in the UK.

Work on endemic diseases of livestock aims to improve the health and welfare of farmed

animals using epidemiological approaches in a multidisciplinary setting. It couples state-of-the-art statistical and mathematical modelling with microbiology, behavioural studies and social sciences, together with close discussion with farmers and veterinarians to study disease on commercial farms and to ensure that research impacts and reduces disease in farm animals. Current work is focused on footrot in sheep (funders: BBSRC, EBLEX, Defra), mastitis in sheep (EBLEX, BBSRC, NERC) and cattle (BBSRC), and the spread and persistence of Porcine Reproductive and Respiratory Syndrome in pigs (BPEX). By combining basic experimental studies with studies of practice and advanced statistical and mathematical modelling, the group is able to translate epidemiological data into advice for policy makers and to provide a strong evidence base for good governance.

The multiple Impacts of our Research – A notable feature of our community is its capacity to deliver strong impact in multiple areas (as illustrated by our Impact Case Studies). This feature, of course, fits well with government policy on maximizing the translation of the excellent science in the UK into economic growth. The Impact areas of our research include Food Security, Biotechnology (including Synthetic Biology), Animal Wellbeing, and the Environment, and this bodes well for the sustainability of our research activities over the coming years. Following the establishment of SLS, applied and impact-oriented aspects of Agriculture were organised as a separate unit, Warwick Crop Centre (WCC). Based at the University's Wellesbourne campus, WCC is a centre of excellence for strategic and applied research on horticultural crops and forms an interface with the horticultural and wider agricultural industries. WCC leads MSc courses in Environmental Bioscience in a Changing Climate, Food Security and Sustainable Crop Production.

University Research Centres – In order to further promote interdisciplinary research in key growth areas, SLS has taken a leading role in establishing the *Warwick Centre for Integrative Synthetic Biology (WISB)*, the *Warwick Centre for Infectious Disease Epidemiology Research (WIDER)* and the *Warwick Global Research Priority* on *Food*.

Capacity building – Since its creation, SLS has been in a phase of continuous recruitment, making a large number of new appointments in order to build capacity across the 6 research themes and to consolidate our own particular research profile. In doing this, we have both built on established strengths and responded to the changing landscape of national/international research opportunities and priorities. Thus, the establishment and growth of new themes in Molecular & Cell Systems and Synthetic Biology & Biotechnology is in line with current trends in modern bioscience. These are highly inter- and multi-disciplinary areas that complement and feed into the other themes. Much of our current work is high impact. In addition, emerging work related to crop quality and yields will generate commercial and medical impacts (nutrition) over the coming 5 years.

Research student recruitment – During the period of this research assessment, we have attracted PhD students to multiple schemes of interdisciplinary training. Most prominent among these were the following four-year programmes: EPSRC-funded Molecular Organisation & Assembly in Cells (MOAC, extended in 2013 for another 4 years), NERC-funded DTP, EPSRC/BBSRC-funded DTC in Systems Biology (joint between WISB, SLS and Warwick Medical School), and BBSRC-funded DTP. Moreover, a further CDT has been funded by EPSRC in 2013 (*MathSys*, run by Warwick Complexity Centre, WIDER and WSB). In parallel we have recruited students to three-year PhDs, many of them funded by external (international) funding and/or competitive University scholarships. In addition, we have initiated a number of international partnership schemes that support further PhD students at Warwick, including programmes involving Monash University (Melbourne, Australia) and Nanyang Technological University (Singapore). These will be joined by new multinational training programmes with Boston University/Harvard/MIT (synthetic and systems biology) and with São Paulo University (USP, Brazil; synthetic biology and biotechnology). In the latter case, we have established an agreement that enables USP students benefiting from *Science without Borders* funding to pursue PhD training at Warwick without the need to find any further funding. Overall, the development of this combination of new schemes will lead to significant further growth and internationalization of our PhD (and Masters) training programmes.

Promoting a vibrant research culture – We have established multiple mechanisms for promoting active and internationally successful research. These include:

The 6 interdisciplinary research theme leaders organize and facilitate interactions across SLS to support a vibrant research culture and to stimulate collaborative research; we run multiple

international seminar series that attract excellent speakers from across the globe; we mentor via the respective research themes and via regular 1:1 review meetings between academic staff and the Head of School to review progress in research and to discuss potential areas where additional support could be of assistance; Assistant Professors on probation receive support and advice managed through a special programme led by the Deputy Head of School; SLS has appointed a Research Strategy & Development Officer, responsible for managing new processes that enhance research excellence, including an internal grant reviewing system (which is helping PIs optimize the quality of their applications), and an SLS research pump-priming scheme that helps PIs generate preliminary data for new grant applications; a workload model in SLS provides a valuable mechanism to balance contributions to research, teaching and administration for each academic in a fair and logical manner. This also ensures that new appointees (particularly Assistant Professors) are introduced progressively into teaching in a way that helps them build and maintain high quality research activity; for more senior staff, we offer regular opportunities for study leave, during which they can focus intensively on research; finally, we provide extensive support for existing staff (and for external candidates) that wish to apply for Research Fellowships.

c. People, including:

i. Staffing strategy and staff development: SLS has appointed 14 new members of academic staff since October 2010, the majority being returned to Panel 5. Patrick Schäfer (Associate Professor) was appointed to boost the School's capability in plant/soil microbial interactions. Our recruitment strategy has been to build on current research strengths, and to establish new areas of expertise that complement existing ones. These appointments therefore contribute to developing a strong and balanced research (and teaching) programme in SLS that promotes interdisciplinary interactions and networking. At the same time, we are ensuring that our appointments contribute to an appropriate balance of levels of experience (and sustainability) across the academic staff cohort. The new academic appointments have so far been accompanied by start-up investments totalling >£1.4Mio.

Fit to Research Strategy – Our recruitment strategy will continue to play a central role in the realization of our research strategy, since the selection of new appointees will be guided by the priority of securing a balanced set of themes, each manifesting an internationally leading profile in terms of scholarship and research performance. Selection of new recruits will also be guided by the principle of maximizing coherence through complementarity between the research themes and by the principle of maintaining an appropriate balance of research training expertise.

Athena SWAN: SLS has been awarded the Athena SWAN Bronze Award in recognition of its commitment to ensuring equal opportunities for career progression and is now working towards a Silver Award. The University of Warwick has been awarded an institutional Silver Award.

HR Excellence – In 2013 Warwick received a HR Excellence in Research Award in recognition of institutional implementation of the 'Concordat to support the career development of researchers'.

ii. Research students:

Training of Research students – Our training programmes incorporate a diversity of taught modules that provide research training as well as training in transferable skills, and incorporate experimental as well as computational skills. Students on each of our training programmes work within their respective cohorts, all of which promote an ambitious research and training culture. Warwick is the lead on a successful BBSRC DTP (£4.2Mio) shared with Birmingham and Leicester that started Oct 2012. Other major training programmes include the MOAC EPSRC-funded Doctoral Training Centre (DTC), a pioneering programme established in 2003 to catalyse research and training at Warwick across the physical/life sciences interface; and the Systems Biology DTC, a multi-disciplinary centre funded by EPSRC and BBSRC that provides state-of-the-art training in the mathematical and computational skills required to underpin systems biology research.

Total PGR student numbers have increased from 111 FTEs in 2010/11 to 125 in 2012/13 and during the REF period 194.84 were successfully graduated. We are prioritising development in this area and expect to continue to grow these numbers via success in DTP-type competitions and by reaching out to scholars from abroad, for example Brazil, Singapore, Australia and the USA. All PGR students receive an Apple Macbook to ensure that they are well equipped for data analysis and that they are able to access the excellent range of PGR skills training available at Warwick.

Industrial CASE studentships provide postgraduates with a valuable opportunity to undertake a period of research with an industrial collaborator. This not only benefits the student, through providing opportunities for the development of new skills and knowledge, but can also help to

initiate longer-term collaborative research projects. Between the 2008/2009 and 2011/2012 academic years 15 of our PhD graduates had completed industrial CASE studentships as part of their studies. The cross-sectoral knowledge transfer facilitated by these industrial collaborations has resulted in non-academic impacts as well as publications in high-impact bioscience journals. An example of a completed NERC CASE studentship is: *In situ* analysis of the microbial community associated with footrot of sheep (PIs: Green & Wellington; ***Pfizer***; research that contributed to Impact Case Study WSLSA6.1). Further examples of ongoing studentships include: Interactions between river bed morphology, water chemistry and microbial diversity, and its impact on biopollutant degradation (PI: Bending; ***Unilever***); and Deploying virus resistance in *Brassicas* and understanding the interaction between viral VPg protein and *Brassica* eIF4E and eIF(iso)4E (PI: Walsh; ***Syngenta***).

Investment in undergraduate students - We actively encourage our best undergraduates to get involved in research. This we achieve by offering them a wide range of third-year research projects and by giving them the opportunity to engage in research placements during the summer vacation. As with the PGR students, our philosophy is to prepare our undergraduates for the new world of bioscience, in which both experimental and computational skills are increasingly required. Our state-of-the-art Interactive Computational Learning Suite, which contains 120 iMacs coupled to an interactive network, is a valuable asset in the realization of this strategy. We will also start 4-year undergraduate Masters of Bioscience degrees in 2014, which include a 7-month project.

d. Income, infrastructure and facilities

Research Income - The overall trend is that of an increase in research income ***per capita***, starting at ~£158,000 ***per FTE*** in 2008/9 and peaking so far at ~£223,000 ***per FTE*** during the review period. There will inevitably be some fluctuation year-on-year, but our strategy for growth (supported by recruitment) will generate accelerated improvement in these numbers over the coming years. These are pleasing results because the development of our research income has been complex and unusual, largely because of the major changes in staffing and institutional funding status associated with the incorporation of HRI into the University of Warwick. Two changes had a particularly strong impact on the profiles of research activity and income in SLS: a reduction in academic staff from 94 (2008) to 65 (2013), and the progressive withdrawal of Defra funding from former HRI staff. A number of PIs moved to other institutions and a number of PDRAs and technicians left, resulting in a slower rate of drawdown on existing grants. In addition, the portfolio of funding has undergone a metamorphosis – most significantly, funding of plant science by Defra has been progressively withdrawn [for example, leading to a loss of approximately £5Mio ring-fenced funding over four years]. However, the HRI-derived community has been successfully adjusting its funding profile to favour BBSRC, and this trend continues.

Examples of recent major grants that reflect the School's drive towards a more multi-disciplinary approach include: Plant Responses to Environmental STress in Arabidopsis (PRESTA): a 5-year project that brings together leading plant biologists, theoreticians and bioinformaticians from the Universities of Warwick, Essex and Exeter (£5.1Mio, Beynon, BBSRC/EPSRC); Vegetable Genetic Improvement Network (VeGIN): An interactive network of researchers and industry leaders working together to address how genetic improvement of key crop varieties can contribute to a sustainable increase in food production to meet the twin challenges of food security and climate change (Buchanan-Wollaston, Thomas; DEFRA); GARNet: Genomic Arabidopsis Research Network and MASC: Multinational *Arabidopsis* Steering Committee (£1.3Mio, Beynon, BBSRC); What are the roles of oomycete RXLR effectors in the establishment of plant disease? (£1.8Mio, Beynon, BBSRC); A molecular epidemiological approach to combatting footrot, an endemic disease of sheep: a 4-year project supported by CEDFAS (Combatting Endemic Diseases of Farmed Animals for Sustainability) (£1.2Mio, Green, BBSRC); InFER: Likelihood-based inference for epidemic risk (£590k, Roberts [Statistics], Green, BBSRC).

Research support allocated by the University of Warwick – A wide range of additional types of funding (including from the Research Development Fund, Institute of Advanced Study, Higher Education Innovation Fund, SLS Pump-Priming Fund, and BBSRC Sparking Impact Fund) has been awarded to our community by the University, totalling £930k over the review period.

Improvements to Physical Infrastructure - A priority has been to integrate the former HRI community with the main campus community, generating a coherent School on one site. The first stage of this process (completed Feb 2013) involved refurbishment of laboratory space on Gibbet Hill coupled to construction of a Phytobiology Facility (£4.8Mio), providing state-of-the-art plant cell

culture and glasshouse facilities on main campus for plant scientists relocating from Wellesbourne to the Gibbet Hill site. The second stage is construction of the *Warwick Interdisciplinary Biocentre* (***WIB***; University Estates plan: http://www2.warwick.ac.uk/services/estates/projects/timeline). This new building (*to which the university has already committed £25Mio in its Capital Plan*) will function as a leading centre of quantitative, broadly systems-oriented bioscience and synthetic biology and will be a focus of interdisciplinary research located in close proximity to the Departments of Chemistry, Physics, Engineering, Computer Science and Mathematics. Construction of the WIB will represent a major step-change in the quality of the research environment, providing purpose-built laboratories, facilities and shared spaces of a standard appropriate for a world-class *interdisciplinary* bioscience community.

Research support and governance – Research activity within SLS is supported by multiple mechanisms and structures. A Research Committee, attended by the research theme leaders, reviews research progress and strategy on a regular basis, and develops and implements policies designed to promote research activity and excellence. This committee is also attended by our Research Strategy & Development Officer and by the School's Education Strategy & Communications Officer, since it is our philosophy to ensure that research excellence is reflected in teaching excellence. In addition, research excellence is promoted by a rigorous internal grant reviewing system (which maintains a grant success rate of approximately 30% with the Research Councils), an internal research pump-priming system (which provides grants to enable PIs to generate preliminary data for grant applications), and a departmental workload model that ensures that academic staff have adequate time to pursue (and manage) their research.

Equipment - The research environment has been enhanced through a ***total of £10.4Mio*** of (partly SRIF/CIF) investment. The larger items have included: a Genix X-ray beam delivery system, a Becton Dickinson 4 laser influx cell sorter, 3 Conviron walk-in controlled environment rooms, a Zeiss LSM710 confocal microscope, a Solexa genome analyser, an interactive computational training suite, modification of Gibbet Hill labs to accommodate colleagues from Wellesbourne, a photon scanning microscope X2, a DeltaVision Elite microscope, two protein crystallisation robots, a Micro crystal imaging system, Waters Synapt G2 and Xevo mass spectrometers, both with Acquity systems. We have also invested >£1Mio in equipment and refurbishment for our new Biological Mass Spectrometry Facility, which will house new Orbitrap Fusion and Triple Quadrupole Mass Spectrometers plus Liquid Chromatography systems for nano and standard flow applications. A state-of-the-art controlled environment and glasshouse Phytobiology Facility Building (total cost £4.8Mio, including £505k controlled environment equipment, 2013).

Research facilities - We have a number of excellent core facilities available for general use. These include (indicating the number of support staff associated with each): Wellesbourne glass and field trials, total replacement cost around £10Mio (10 staff); Wellesbourne controlled environment facilities replacement cost around £3Mio (1 staff); Animal house equipment and building replacement cost around £5.9Mio (4 staff); Genomics, equipment replacement cost around £730k (1 staff); Imaging facility (EM and confocal) equipment replacement cost around £1.7Mio (1 staff); Proteomics facility, equipment replacement cost around £1.1Mio (1 staff). Specialist facilities at Wellesbourne include over 6 hectares for field trials, a range of glasshouses, polytunnels, frames and tygan houses for plant growth experiments, and an insect rearing unit; the site is serviced by highly skilled technicians and is ideally suited to industry-facing research.

e. Collaboration or contribution to the discipline or research base

We play an active role in multiple partnerships with other Schools, including: Chemistry, Computer Science, Engineering, Maths, Warwick Medical School and Warwick Manufacturing Group. Our partnerships with other institutions in the UK include Liverpool School of Tropical Medicine (LSTM) and the following plant research institutes: JIC, East Malling, IBERS, Rothamsted. Our partnerships with other institutions abroad include CUSP (New York); Singapore (NTU); the FioCruz Institutes in Brazil (Recife and Curitiba); the University of São Paulo, Brazil; Kenya Agricultural Research Institute, Africa; Monash University, Melbourne; Boston University and Harvard, Boston. A major new initiative has been the establishment of a Transatlantic Synthetic Biology Research Triangle involving Warwick, São Paulo and Boston University/Harvard.

Strategic partnership – The University of Warwick is one of only nine strategic partners of the BBSRC. This relationship was forged primarily on the basis of SLS's profile as a leader in research areas (plant systems biology, plant-pathogen interactions, *Brassica*, horticulture and biotechnology) that are relevant to Food Security and Biotechnology.

Collaborative grant funding – Our researchers have ongoing collaborations with a range of partners, both within the UK and beyond. In many cases funded projects are multi-disciplinary in nature and bring together wide-ranging expertise from researchers in academia and industry. Examples of collaborative grants include: Plant Responses to Environmental STress in *Arabidopsis* (PRESTA): a five-year collaboration between the Universities of Warwick, Essex and Exeter (Beynon, BBSRC/EPSRC); GARNet: Genomic Arabidopsis Research Network and MASC: Multinational Arabidopsis Steering Committee (£1.3Mio, Beynon, BBSRC).

National/International resources – SLS provides resources to industry and researchers on a national and international level. Including: *Genetic Resources Unit (GRU)* - a collection of seeds and genetic material from a range of vegetable crops and their wild relatives, including *Allium* and *Brassica* species, to facilitate conservation, characterization, documentation and research on these important species. GRU collections are available for scientific research and education throughout the world. The GRU team collaborate with other gene banks and international organisations, including the Nordic Genebank and the Food and Agriculture Organization of the UN; *Methods of Research Practice in Horticulture (MORPH)* - Software developed by WCC researchers that uses simulation modelling as a decision-making tool for agronomists and growers to optimise yields.

Indicators of wider influence – Our academic staff have been members of committees/bodies of (inter)national significance, including: **External Scientific Committees:** Nuffield Council on Bioethics working party review on new approaches to biofuels (Barker); UK Government Advisory Committee on Pesticides (Bending); Chair UK Plant Sciences Federation Advisory Committee (Beynon). **Learned Societies:** Fellow Society of Biology (Beynon); President of International Society for Seed Science (Finch-Savage). **Research Funding Panels:** Chair of BBSRC Grant Reviewing Committee A and BBSRC Animal Health Research Club (Green); REF panels (Green, Frenguelli); BBSRC Pool of Experts (Bending); BBSRC Committee B (Beynon and Carré). **Prestigious presentations:** Numerous, including Plenary IV International Workshop Seed Ecology Shenyang 2013 (Finch-Savage). **Editorial roles:** Assoc. Editor *PLoS One*, Assoc. Editor *Archaeological & Anthropological Sciences* (Allaby); Board Reviewing Editor *Science* (Medley). **External Examiner:** MSc Epidemiology at Royal Veterinary College 2011-2013 (Green), MSc Biotech & Business Oxford Brookes University (Frigerio), MRes Chemical Biology of Crop Sustainability & Protection 2011-2013 (Napier). **Government:** Our research has informed policy at UK and EU levels. Work with DEFRA provides strategic research supporting policy development in climate change, sustainable production and environmental protection. Experts of the School have been members of, or provide advice to, multiple government advisory panels including: Advisor to government in epidemiology and animal welfare (Green); Evidence to EFRA Select Committee on Food Security (Thomas). At the European level, Thomas co-organised the workshop "Horticulture in the 21st Century" in Berlin, aimed at highlighting the importance of research into Horticulture to policy makers and industry.

Responsiveness to national and international priorities – SLS research is strongly aligned with the national research priorities of Food Security, Industrial Biotechnology, Big Data, Environment (Climate Change), Human/Animal Wellbeing. Indeed, over the REF review period, we have increased our capabilities in these Impact Areas through new recruitment to our 6 Research Themes. The most significant change is that we have built critical mass in Synthetic Biology & Biotechnology, creating thereby one of the UK's major Centres in Synthetic Biology.

Commitment to working with Industry and Other Commercial Funders – SLS has multiple research partnerships with industry, including: ***Syngenta*** – virus resistance mechanisms in *Brassicas* (PI: Walsh), research on seed vigour (PI: Finch-Savage), modelling glyphosphate resistance in *Amaranthus tuberculatus* (PI: Neve); ***Bayer Crop Science*** – CASE studentship on novel informed modelling approaches to investigate evolution and management of herbicide resistance in *Alopecurus myosuroides* (PI: Neve); ***Elsoms Seeds*** – A Knowledge Transfer Partnership to implement genetic Marker Assisted Selection technology in the development of new commercial crop varieties (PI: Barker); ***AHDB*** – Projects on the control of plant pests and pathogens (PIs Chandler, Clarkson, Collier); ***Unilever*** – The role of microbial adaptation in the biodegradation of chemical pollutants and how data from lab-based research can be extrapolated to the field (PI: Bending); ***EBLEX*** – The impact of chronic mastitis on health and productivity in sheep (PI: Green).