Institution: University of Nottingham

Unit of Assessment: 6; Agriculture, Veterinary and Food Science

a. Context

Impact 2008-2013: The Schools of Biosciences (SBS) and Veterinary Medicine and Science (SVMS) engage in world-leading research focused upon improving human and animal nutrition and health, environmental sustainability and economic efficiency. In this context, both Schools have established research strategies that promote engagement of researchers with non-academic stakeholders in clinical and commercial settings; in particular the livestock, crop, agri-food and plant biotechnology sectors. SBS has long-standing experience of working with business, translating research into products and innovative technologies. For example, in the late 1980s SBS researchers developed the basis for hairpin RNA gene silencing, which is now a standard commercial technique for genetic modification in plants. For SVMS (established 2006), the majority of current impact activity is at a relatively early stage of development, or is the translation of work carried out by researchers prior to joining UoN. Development of formalised strategies to ensure the impact of research has built upon a long-held implicit understanding that our research should have an influence that extends beyond academia. The embedding of external stakeholders in the funding, design and completion of research projects typifies this implicit approach. This ensures that the dissemination and translation of research findings is a pre-planned deliverable (e.g. UoN work with DEFRA and Fera to develop new diagnostics for plant disease led directly to rapid deployment of in-field testing by Fera). A key driver of the new strategies and processes that we developed between 2008 and 2013 was the participation of SBS in the BBSRC Excellence with Impact competition (EwI).

The beneficiaries of UoN research: A portfolio of 12 case studies exemplifies the scope of activities in which our researchers participate (section d), but does not reflect the entirety of the interactions and influence that UoN researchers have upon the end-users of research. Some research outcomes do not follow a linear approach as the drive to patent and accelerate commercialisation of outcomes has preceded academic publication, and there are many such examples of work in both Schools. Microbiologists in SBS, working in association with Quadralene Ltd, developed a biofilm remover to eliminate bacterial contamination of plastics in dental chair units. This won the 2010 Lord Stafford Award for Innovation following release of the product (Bioclear®) onto the market. Other early stage outcomes include discoveries by immunologists in SVMS that have influenced vaccine development by Zoetis and Lohmann Animal Health, stimulating new approaches to management of *Salmonella* in chickens and bovine mastitis.

Our bioscience and veterinary research has an important role to play in social and economic well-being, on a national and international scale. UoN-led advances in agriculture and crop technology help fight world hunger. Our innovations in food and nutritional science lead to improvements in human and animal health. Enhanced evidence-based veterinary practice improves animal welfare and innovative technology boosts the competitiveness of British business. The primary beneficiaries of UoN research therefore lie firmly in the food, biotechnology and agricultural sectors, along with veterinary pharmaceuticals and clinical practitioners. Evidence includes:

- *Global food security and international development*: UoN is a leader in global food security research, as recognised by a 2011 Queens Anniversary Prize. Developing solutions to the problems of food insecurity is a key focus for our researchers in Plant and Crop Science, Food, Animal and Nutritional Sciences, Environmental Science, Industrial Biotechnology and Integrative Systems Biology. UoN, in partnership with the Malaysian Government, has been a driving force behind the Crops for the Future Research Centre (CFFRC) in Malaysia, which focuses on identification of under-utilised crop plants that have the potential to be grown for human sustenance, or on a commercial basis for food, pharmaceuticals or biomaterials in the climates of the future. The contribution of UoN to understanding the complex relationship between plant genotype and phenotypic traits has enabled the breeding and selection of crop varieties to tackle the challenges for future scenarios of sustainable agricultural production. For example, Azotic Technologies, a UoN spin-out, has commercialised sustainable nitrogen fixing technology developed in SBS, which will reduce overuse of fertilizer. UoN played a lead role in the tomato genome sequencing project which has been actively used by Syngenta and other global plant breeding/biotechnology companies to establish new tomato varieties with improved quality. In a global seeds business worth $2BN, this work has brought benefits to seed producers, food manufacturers and consumers. Work with livestock improved efficiency

of production (e.g. increasing farmers awareness of the causes of seasonal infertility in pigs) contributing to reduction of the environmental impact of raising animals for food.

- *Human and animal health and welfare*: The work of researchers in the cross-cutting Comparative Medicine, Infection and Immunity and Population Health and Welfare themes improved the health and well-being of humans and animals. For example, the development of novel phage based tests for mycobacteria enhanced the speed and efficiency of testing for these pathogens. In addition to reducing risk for food-borne infection to consumers, this provided commercial benefit for the testing company (Rapid Biotec Ltd). The UoN contribution to an enhanced understanding of the cellular mechanisms underlying the treatment of benign and malignant lipoma has been used to improve veterinary treatment with corticosteroids. Population Health and Welfare research has underpinned changes in clinical practice, including greater use of pain-relief for cows and the improvement of health in rescued dogs in shelters. The Centre for Evidence Based Veterinary Medicine (CEBVM, Novartis funded) has a specific remit to conduct and translate research to practice, e.g. the development of a database of critical appraisals to enhance evidence-based clinical decision-making.
- *Economic and commercial*: Links between researchers and business span microbusinesses and entrepreneurs through to global corporations. Research across all themes is associated with new product development, enhanced processes, improved efficiency and greater profitability in the brewing and beverages (SABMiller, Diageo), food and petcare (Mars), meat and livestock (Zoetis), plant breeding (Syngenta), pharmaceutical (Boehringer Ingelheim) and agricultural (BOCMPauls) sectors. Innovative methodologies in food science, developed by UoN, are used by the food industry to meet health targets to reduce the fat, sugar and salt content of foods, whilst maintaining palatability. Work with Dovedale Foods and Moonshine Drinks to develop innovative products secured these companies Food and Drink iNet Innovation Awards (2012; iNet is a contact and partner for businesses, universities and individuals in the food and drink sector in the East Midlands and nationally). Relationships with industry are enhanced by making facilities available for use (>300 SMEs access the facilities and expertise of our Schools) and co-localization with spin-out and subsidiary companies on the SB campus (Flavometrix: flavour and aroma problems in the food, beverage and personal care sector, Eminate; develops and commercialises IP related to food and ingredients). SBS brought New Food Innovation Ltd onto the campus with the intention of building linkages with food companies, resulting in 5 new Technology Strategy Board (TSB) projects (2012-13) that have brought R&D funding to the companies involved. The new Bioenergy and Brewing building on the campus was specifically designed to foster translation of research to product and houses the global research brewery for SABMiller. The building also houses a food processing facility, which has provided business assistance for 94 small and medium enterprises since 2010.
- *Public policy*: UoN expertise has fed into national and international policy-making. Bioenergy researchers gave evidence to the UK Committee for Climate Change, which informed policy at the Dept. for Energy and Climate Change. UoN expertise has also contributed to policy and health education in the areas of assisted reproductive technology (Human Fertility and Embryology Authority) and antenatal nutrition. Improved understanding of influenza informs international vaccination and control policies (World Organization for Animal Health, EFSA). Engagement with networks of expertise increases influence with key stakeholders in the agricultural sector, including DEFRA. UoN leads the DEFRA Farm Business Survey, which continues to inform policy decisions on matters affecting farm businesses in England.

b. Approach to impact

Facilitation of impact: Staff within the unit have always worked closely with the end users of our research and as a consequence 'impact' has always been a feature of our work, although this was an informal part of our research culture rather than a systematic feature. Since 2008, and particularly following EwI, the approach of the Schools to impact has evolved substantially, with the development of more formalised processes for facilitation, measurement and recording of non-academic research outcomes. We have a continuum of engagement with research end users (commercial and public sector) ranging from placement of project students within local SMEs through to strategic partnerships with major international companies. Frequent contact between researchers and end users and good working relationships with business are the basis for impact. Where appropriate these contacts are cemented through high-level negotiation between the UoN

and corporations (e.g. SABMiller, Zoetis, Novartis). This is typified by our long-term relationship with major companies such as Syngenta and Unilever. Syngenta funded much of UoN's early work with genetically modified tomatoes, which laid the foundation for UK participation in the tomato genome sequencing programme, which is now securing economic benefits for plant breeders, growers (£650M UK market) and retailers through improvements in fruit quality traits. Unilever and UoN signed a strategic partnership in March 2013 to explore new opportunities in a range of areas including green processing, energy and sustainability. Unilever has a long association with UoN working with researchers in food and crop science and the partnership allows the company to take an innovative approach to R&D and benefit from research support across several sectors.

Relationships with SMEs are fostered through academics acting as consultants to business (~£220k consultancy fees 2008-13), interactions in EU consortia, provision of access to facilities and infrastructure (training, space and pilot plants) and the hosting of spin-out companies.

Academics are actively encouraged to have an entrepreneurial approach and freely develop interactions with industry. Researchers in SBS and SVMS currently hold 11 patents arising from research and innovation activity. Nottingham has always provided a strong business-friendly environment and has provisions in place for companies to easily access IP. This encourages business to fund research, take concepts and products to market and build a strong portfolio of technology readiness level projects. SBS and SVMS have actively promoted an environment in which researchers develop close working relationships with the agricultural and veterinary sectors (e.g. Biosciences Knowledge Transfer Network). The dissemination of research findings, and the responsiveness of the Schools to the shifting challenges faced in these sectors has enabled UoN to be effective in shaping developments in animal welfare and increase the profitability and competitiveness of the agri-food and livestock industries (e.g. Pepsico, BOCMPauls, Syngenta). National bodies (e.g. DairyCo, HGCA, ADAS) solicit engagement with academics, using UoN expertise to shape and enhance policies and practice. Examples in the dairy industry are close relationships with key veterinary practitioners, the dairy levy board and commercial companies as a means to implement a variety of health initiatives including those on mastitis, lameness and fertility.

Corporate partnerships: Industrial partnerships are a critical basis for research projects across all areas (e.g. Zoetis partnership in BBSRC funded feed efficiency research) and also fund PhD studentships (e.g. 27 RCUK Case awards). At the University level, Business Engagement and Innovation Services (BEIS) play a key role in supporting researchers in delivering non-academic outcomes from their research and managing IP. BEIS delivers the business engagement and knowledge transfer objectives set out in the University's Strategic Plan 2010-15 and contribute expertise and guidance across the full spectrum of the University's innovation activities. This includes Knowledge Exchange (KE), establishment of corporate partnerships with industry and commercialisation of IP. For example within SBS, BEIS provided internal funding to develop novel protein array technology for allergy testing, which is currently proceeding to commercial licensing. BEIS involvement in development of a corporate partnership with Novartis Animal Health increased the potential global impact of the CEBVM.

As the Schools are increasingly involved in large scale, multi-centre programmes of research, putting in place processes to ensure that impact is effectively managed is of growing importance. A key approach to this has been embedding industrial advisory boards into the project management (e.g. Lignocellulosic Conversion to Ethanol Bioenergy project, ERDF Lipid and Starch Centre). The BBSRC Advanced Training Partnership in Agri-Food (AATP; UoN in conjunction with Harper Adams University, Cranfield University, Rothamsted Research and industrial partners) is a further route for dissemination of research through training programmes specifically designed and delivered for the agri-food industry. The partnership offers a range of training from one day CPD through to MSc and PhD. The management structures of the AATP include members from industry, providing a forum for liaison and the partnership has reached out to business ranging from small farms to global companies.

Developing an impact culture: Since 2008 we have stimulated a culture where individuals at all levels are engaged with impact. This has, in part, involved answering questions such as what 'impact' is, how impact can be identified and how the Schools can promote and support academics in achieving impact. In SBS the EwI competition refocused the understanding of impact among the academic community. This was achieved through workshops that explored ways in which impact had been derived from past research, ways that impact might be measured and processes for generating research income in partnership with industry. In SVMS, local dissemination of the

processes leading to successful translation of research to clinical outcomes (e.g. DairyCo bovine mastitis control scheme) has promoted awareness of potential for research to have broad impact.

In 2009 SBS appointed a business development executive (BDE) with promotion of impact as a key role and this evolved into a business manager role with a particular emphasis on SME interaction. A Knowledge Transfer and Outreach group (KTOG) was also established to formulate and implement policies relating to impact. Early activities were focused on monitoring and promoting outreach and public engagement with our science. The BDE worked with external agencies to develop collaborative partnerships, promoting those partnerships to policy makers, including development work on the BBSRC AATP, where normally competing organisations needed to collaborate on the training programmes. KTOG has championed the development of impact training for all researchers and provision of services to researchers that support their efforts to embed impact in their research including: seminars run by the BEIS Technology Transfer Office to guide staff on how best to identify, record, protect and develop IP; workshops that guide researchers on building impact into research proposals; and workshops for research students. Since 2011 students have been required to provide impact statements in progress reports.

The Schools have embedded strategies for public engagement within their research strategies, with the aim of being innovative in communicating research to a wide audience. KTOG promoted knowledge outreach talks to internal (non-academic) staff and the local community and UoN research in Plant and Crop Science was highlighted with a Gold medal winning display at Chelsea Flower Show (2013), which was visited by ~150000 people. Researchers provide bespoke KE presentations to, and visits from, farmer groups. The agricultural levy boards circulate the KE materials arising from UoN research to levy payers (e.g. HGCA distributes materials based upon UoN research on lodging and eyespot in winter wheat and BPEX disseminates UoN pig research).

c. Strategy and plans

Strategic aims: The five-year strategy for impact in the area of Agriculture, Veterinary and Food Science is encompassed by the following overarching aims:

- *Responsive management of impact*: We will implement processes that enable and incentivise the translation of science into outcomes that have potential for impact. The Schools will both utilize and shape the development of UoN support for KE activity and industrial engagement, with increased emphasis on high-growth, innovative SMEs in addition to national and multinational corporations.
- *Strategic engagement with end-users and policy-makers*: We will proactively engage with business, government, policy-makers and funding bodies to identify and influence development of research initiatives that respond to and deliver the research needs of end-users.
- *Embedding an impact culture*: We will build on the changes initiated by EwI to firmly establish an environment that supports innovative and entrepreneurial outcomes from excellent curiosity-driven research.

UoN has established a KE Framework for 2013-18 which recognises KE as a core activity underpinning research. The Framework is governed by Faculty and School Directors of Research and supported by BEIS and is underpinned by four main objectives:

- *Enabling*. Creating and embedding KE culture and a cohesive UoN-wide approach.
- *Engaging*. Expanding the UoN relationship with business and other key stakeholders.
- *Delivering.* Support for translation of research, consultancy and commercialising IP.
- *Global reach*. Exploiting international KE opportunities, particularly in Asia.

Plan for delivery of aims:

Short-term: The Schools have formally embedded impact into research strategies and identified champions to drive impact strategy and the delivery of major external opportunities at School management team-level. SBS will employ a new research development executive for this role by the end of 2013 to supplement the work of the existing business manager. Key priorities are: a) the development of training and processes to incentivise researchers to incorporate impact into research plans and deliverables; b) to develop simplified, transparent access and contracting for external partners to access UoN research facilities and expertise; c) to access and make effective use of funds (e.g. internal supporting funds, Higher Education Innovation funding, BBSRC Sparking Impact awards; funding for pathways to impact from RCUK responsive mode grants) to secure the pipeline between researchers and the non-academic beneficiaries of research and d) to embed processes for recording, monitoring progress and publicising the successful impact of

research in the unit. Research staff will be encouraged to engage with impact activity through evaluation of their contribution at annual performance review. UoN now requires evidence of research impact activity for academic promotion.

Medium-term: Greater engagement with BEIS expertise will provide a resource for business engagement, facilitate improved contacts with research end-users and promote diversification of the UoN funding profile to include greater industrial focus (e.g. Innovation and Knowledge Centres, TSB). Increased use will be made of UoN Strategic Partnership agreements with corporations (e.g. Unilever) and research funders (e.g. BBSRC), in addition to the roles played by UoN researchers in RCUK strategy panels, in order to influence national research and impact agendas. External partners will be brought into research strategy groups as special advisors (e.g. from industry or clinical practice). Working with trade associations and other bodies representing large groups of end-users will widen the capacity of research to benefit a broader industry base.

Long-term: SBS and SVMS researchers will continue to be involved with high-level, international trade and partnership delegations (UoN and UK government led) to expand involvement in new markets (China, India and Brazil). Bidirectional secondments between UoN and partners in industry and clinical areas will contribute to improved understanding of how important economic and societal contributions are achieved. The Schools will establish research showcase platforms that host impact events that bring together researchers with international thought-leaders, policy-makers and commercial partners.

d. Relationship to case studies

Since 2008 our key approaches to impact have been based upon formation of high-level partnerships with large businesses; engagement with SMEs; relationships with national bodies and engagement with the agricultural and livestock sectors. The case studies presented provide examples of research impact in these areas.

Partnerships with large businesses: Our partnerships with large businesses are generally developed over a long period and enable impact of research through our partners providing funding in addition to exploiting the IP that we generate. This is exemplified by UoN work on "*Optimising the production and processing of animal feeds"*, "*Transferring biopolymer technology to the food industry*" and, "*Advancing analgesic use in cattle*". These cases show how UoN research has developed and transformed commercial markets. UoN expertise provides a basis for technical training that enhances the skill-base of both large companies and SMEs. Research-based technical knowledge is disseminated to industry through postgraduate training courses that are accessed by major national and international manufacturers (e.g. "*Improving sensory science capability through industry training*").

Engagement with SMEs: The interactions between individual academics, research groups and SMEs represent a major pipeline for knowledge transfer and the development of commercial impacts. Building on an international research reputation ERDF funded Starch Processing and Lipid and Starch Processing Centres serve SMEs (over 300 are involved) and link to the East Midlands Food and Drink iNET to serve local companies. "*Development of diagnostic systems for plant diseases*", "*Transferring biopolymer technology to the food industry*" and "*Creation of new ingredients for the food industry"* demonstrate some elements of our SME interactions.

Engagement with national and international bodies: National bodies and umbrella organisations are often crucial in providing wider dissemination of research to end-users. "*British dairy herd national mastitis control scheme",* provides a good example of such involvement. DairyCo are a levy-funded, not-for-profit organisation working on behalf of Britain's dairy farmers. The collaboration of UoN with DairyCo led to the DairyCo National Bovine Mastitis Control Scheme, which is a model for the development of similar interventions on an international scale. "*Influencing national and international health policies on early life nutrition*", describes how UoN has contributed to a body of evidence that now shapes global health policies and public health initiatives.

Engagement with agricultural and livestock sectors: Strong partnerships in these sectors have facilitated broad dissemination of UoN research findings, with resulting benefits for farmers and the agricultural economy. Analyses of individual farm performance ("*Improving farm business performance using FBS on-line benchmarking*"), recommendations on wheat sowing ("*Improving wheat yield and quality by optimising crop management strategies*") and guidance on the management of cattle ("*Developing tools to restore fertility in dairy cows'*; "*Prevention of dry period infections in dairy cows*") optimise productivity and provide significant profit gains.