Institution: Newcastle University

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

a. Overview

Newcastle University UoA6 delivers world-class research, which uniquely spans the fundamental molecular and biosciences underpinning the primary production of plants and animals, through rural environments, biodiversity of landscapes, the food consumer, and the social and policy drivers of food and farming. Our research is based in the Faculty of Science, Agriculture and Engineering and specifically in the School of Agriculture, Food and Rural Development (AFRD) and the School of Biology (SBiol). Both Schools are major stakeholders in the cross-faculty, interdisciplinary research institutes, the ***Newcastle Institute for Research on Sustainability (NIReS)***, the ***Newcastle Institute for Social Renewal (NISR)*** and the ***Institute for Ageing and Health (IAH)***. We lead the University's ***Centre for Rural Economy (CRE)****, the* ***Centre for Wildlife Management and Conservation,*** and staff are key members of the cross-faculty ***Human Nutrition Research Centre (HNRC)***. We have used these structures to consolidate our RAE2008 research strategy to "*fully integrate research activity within the Unit and across the University and the wider research community*" addressing the key issues of "*farming food and rural development* and *manipulating the ecological footprint of agriculture*". We have strengthened our research in "*consumer choice and attitudes towards production processes and the quality and safety of food*" and "*biosecurity, animal welfare and soil-plant-animal interactions in agricultural systems*". Our objective has been to develop a truly multidisciplinary structure between the two Schools and across the University which not only drives the food and agriculture agendas but also provides flexibility to respond rapidly to the demands of basic, enabling and strategic research. We are organised around six inter-related research themes:

1. ***Integrated Agricultural Production*** – investigating the impact of sustainable, low input farming systems [Leifert, Wilcockson, Butler, Cooper, Chaudhry].
2. ***Integrative Animal Science*** – investigating the impact of animal management systems on animal health, welfare, food security and the environment [Edwards, Kyriazakis, Flecknell, Beard, Butler, Chaudhry, Guy, Frewer, Leach].
3. ***Ecology of Managed Environments*** – investigating and modelling environmental impacts on soil dynamics and biodiversity of landscapes [Rushton, Barnes, Sanderson, Singleton, Cooper, Port].
4. ***Food Quality and Health*** – investigating the impact of the production chain on food quality and safety, functional foods and metabolic response to foods [Seal, Barnes, Brandt, Lietz, Singleton, Hill, Okello].
5. ***Gene Environment Interactions*** – investigating the effects of environmental stresses on plant and animal physiology and productivity at molecular and biochemical levels [Gatehouse, Barnes, Borland, Lietz, Singleton].
6. ***Social Science of Food, Agriculture and Rural Development*** – understanding the rural landscape, emerging research and policy requirements, and the social impacts of food and consumer behaviour [Frewer, Seal, Franks, Kuznesof].

The submission includes 25.4 FTE staff comprising 9.6 Professors, 8 Senior Lecturers, 6.8 Lecturers and 1 Marie Curie International Outgoing Fellow.

b. Research strategy

Our vision is to be a leading research centre for food, agriculture and rural development under the overarching theme of Food Security. This focuses on the development and integration of science and technologies to increase efficiency of resource use applied to the sustainable and ethical provision of food, which is safe, nutritious and acceptable to the consumer.

The Unit is unique in the UK with the combination of research facilities at our disposal to support our research activities. These include two research farms, a new plant and environment field station and glasshouses (2013), state-of-the-art molecular biology equipment and laboratories, access to clinical research facilities, and 'NU-Food', a new food and consumer research suite (2013). These facilities provide an important test-bed for studies expanding the full 'plough to plate' continuum embracing underpinning molecular biosciences, crop production, bioenergy, animal production and welfare, nutrition and consumer behaviour, emerging science and policy needs, and social science aspects of the rural economy. Because of our strategy and structure we are able to influence and respond to key priorities and research challenges identified by individual research councils as well as cross-council initiatives, including those of the BBSRC (*Food security*;

Bioenergy and industrial biotechnology, and *Basic bioscience underpinning health*); ESRC (*Economic performance and sustainable growth*, *Influencing behaviour and informing interventions*, *A vibrant and fair society*), NERC (*The Business of the Environment*) and the MRC (*Living a long and healthy life*). Our research also has a strong industry focus, with direct industry funding (e.g. DSM Nutritional Products Ltd., £276k; Danone £214k), Defra LINK and TSB initiatives (e.g. Turkey Life Cycle Analysis, £280k with 9 industry partners), CASE studentships (e.g. Unilever, Syngenta, KWS UK Ltd., Stockbridge Technology Centre, Aviagen and Merial) and initiatives such as the BBSRC-DRINC programme (BB/G00563X/1; £398k) and BBSRC Crop Science (BB/E006671/1). Our strategy is aligned with the Government's *Vision for Sustainable Development* (Defra, 2011) which highlights the need to maximise wellbeing and protect the environment, without negatively impacting on the ability of future generations to do the same. Because of our multidisciplinary research capacity, reflected in our six research themes, the unit is now in a strong position to lead in the three priority areas highlighted in Defra's 2012-2015 Business Plan: *Support and develop British farming and encourage sustainable food production*, *Enhance the environment and biodiversity to improve quality of life*, and *Support a strong and sustainable green economy, including thriving rural communities, resilient to climate change*.

In the REF period we have made important contributions to the science underpinning all aspects of food security which is a central pillar of Horizon 2020, where the Unit has contributed to programme development (e.g. JPI A Healthy Diet for a Healthy Life; the Technology Platform 'Food for Life'). Our future research strategy is to target opportunities under the Horizon 2020 research themes of prevention research, healthy lifestyles, and healthy environments and economic resilience. These include our key research strengths in environmental change and health, public health and the impact of lifestyle and behaviour, food supply, trade and prices, and sustainable rural communities. Our research achievements are highlighted for each research theme below:

Integrated Agricultural Production: Research carried out in this area is managed through the Nafferton Ecological Farming Group. Research focusses on low-input and organic farm production systems and has been highlighted by the completion of major EU-funded projects, and notable success in securing EU funding. We have strengthened this group by the appointment of two lecturers (Butler and Cooper) since RAE2008. This has enhanced collaborations and brought leadership to EU-funded projects (e.g. LowInputBreeds, EU-FP7-222623; £1.1m; NUE-CROPS, EU-FP7-222645; £1.46m). The Quality Low Input Foods project (QLIF, EU-FP6-506358; £3.07m), completed in 2009, so far has resulted in 120+ peer-reviewed articles, 150+ conference proceedings, and 200+ farmers' guides/workshop reports. Key findings included: identification of beneficial novel soil amendments and biological control agents on prevalence of soil-borne diseases, and effects of production systems on nutritional composition of milk and crops which have influenced profitability of European organic and low-input greenhouse crop (Impact Case Study 3) and dairy production industries. Comparisons between organic and conventional management systems has demonstrated differential effects on the biodiversity of weeds and nitrogen-fixing bacteria in soil and the contaminant metals content of wheat, all of which have significant implications for developing strategies for sustainable crop production and maintaining diversity. Modelling the variety of insect species in field margins and in different agronomic processes links with the *Ecology of Managed Environments* theme. An area recognised as of strategic importance by the group is management of greenhouse gas emissions, and research has identified natural herbs and plant bi-products as potential modifiers of rumen fermentation, reducing methane production (e.g. through Commonwealth Scholarship).

Integrative Animal Science: The theme demonstrates research excellence in integrative animal science focussing on three areas – enhancing the sustainability of livestock systems, including reduction in their environmental impact, improving the quality and safety of animal products, and improving animal health and welfare. Our strength lies in drawing on fundamental research and applying it to areas of societal, industrial and policy importance. Research is on the development and evaluation of livestock systems, and their environmental impact, which interfaces with food safety and food quality, and social and economic drivers. This has been enhanced with the appointment of a Chair in Animal Health and Nutrition (Kyriazakis) and a lecturer in animal welfare (Leach) since RAE2008. The group's work closely links across the Unit with business management, food chain and consumer studies (e.g. EconWelfare EU-FP7-213095; £118k), food science (Q-PorkChains EU-FP6-036245; £209k), and environmental science and organic

agriculture (e.g. PoultryLCA, Defra UNC/003/09; £475k; ERA-Net CORE Organic II OD0220; £104k). Research projects which have had a major impact on the pig industry include PigSAFE (Defra LINK, £375k) which re-designed from first principles and evaluated a new high welfare farrowing system. Our research on the interactive effects of genetics and environment on neonatal pig survival has been used by international breeding companies and is now extended through industry-funded work on sow selection for alternative farrowing systems (Sainbury's, FREESOW, £220k). The team's research has identified the hotspots for mitigation in environmental impact in chicken and turkey systems (Defra LINK , Poultry LCA and TSB Turkey LCA) and produced a Decision Support Tool for reduction of P excretion by pig systems (Defra and BPEX). The group has developed innovative methods for recording and analysing animal behaviour and models, which are expected to become the basis for all future analyses of feeding behaviour. For example, innovative approaches to animal behaviour have been used for the early detection of health and welfare problems (EBLEX and Aviagen BBSRC CASE). Work on the use of natural plant oils in the control of poultry red mite originally funded by Defra (MITEeHEN, AW1136; £251k) has since received industry funding for in-farm evaluation as an environmentally friendly approach to pest control (Kiotechagil Ltd.; Danisco; Elanco Animal Health Products Ltd.). Animal welfare research also includes studies on the scientific basis and behavioural consequences of pain and distress in animals. Techniques developed with laboratory animals analysing behavioural changes for assessing pain and analgesia have had a major impact on veterinary and pharmaceutical practice internationally (Impact Case Study 2) and are now being applied to farm livestock (FAREWELLDOCK, BBSRC/Defra, £661k). The group has consolidated its position in 2013 through new funding from EU FP7 (ProHealth, EU-FP7-613574 £1.2m), BBSRC and TSB.

Ecology of Managed Environments: This research group undertakes interdisciplinary investigations into the processes that affect the many ecosystems that we manage, directly or indirectly. The research encompasses multiple scales, from the soil microbiota through to that of the farm landscape and benefits from research in *Integrated Agricultural Production Systems* and *Social Science of Food Agriculture and Rural Development*. We have shown that important processes such as carbon-sequestration and nutrient flows are affected not only by the above-ground management of the environment but also by the overall biomass. Our research on biodiversity and plant functional types and structure of the microbial soil community also encompasses the bacteria, fungi and invertebrates in the soil rhizosphere and demonstrates that this needs to be managed using appropriate systems to map nutrient uptake (e.g. N-Toolbox EU-FP7-227156, £238k; KWS BBSRC CASE).

The ecology of managed environments includes components of the fauna and flora that can be viewed as both pests or beneficials, or whose status is unclear. The impacts of human management on such species has involved research of contrasting taxa at a range of scales and encompasses the full breadth of the agricultural landscape (e.g. Defra £1.15m 3 projects, Impact Case Study 1), including brownfield and greenfield sites owned by Rio Tinto Alcan (Alcan Aluminium UK Ltd. £186k), underlining the critical importance of sustainable land management in maintaining ecological diversity, coupled with input from Boundary Organisations in successful conservation management (ESRC 240-25-0019, £141k). Insect communities have also been investigated in managed meadows, particularly those under improvement and the behaviour of bumblebees, known to provide pollination ecosystem services, are being investigated at Nafferton Farm**,** building on GIS models of satellite imagery of the farm and the surrounding landscape; this research would not be possible without the unique conventional and organic structures at the farm (BBSRC BB/E002757/1, £136k). Our research in collaboration with Stirling University and Rothamsted Research has indicated that urban gardens have a significant beneficial impact on pollinators in intensively managed agricultural landscapes. Complementary research is being undertaken into the potential and limitations of pest control measures such as the impacts of neonicotinoid pesticides on bumblebee behaviour and the role of trap crops on insect pests of major crops (brassicas) affected by recent withdrawals in conventional control products.

Food Quality and Health: This research dovetails with the Human Nutrition Research Centre portfolio and covers all aspects of the food chain concerned with the provision of healthy, safe and nutritious food from the producer/manufacturer to the consumer, and in the communication of healthy eating public health messages. A particular research strength is the design and use of large-scale dietary intervention studies to investigate the physiological/metabolic response to

changing diet coupled with social science research to investigate attitudes to changing diet. Through its research outputs (publications, Key Note lectures), Newcastle is recognised internationally for its contribution to understanding the health impacts of consuming wholegrain foods and on developing biomarkers of whole grain intake and novel metabolomics approaches to identify diet patterns in free-living people (FSA N05075; £365k). This research is underpinning efforts to set global definitions for whole grain and wholegrain foods, and recommendations for whole grain intake. Our contribution to research on vitamin D intake and its interaction with sunlight exposure has significant public health implications for determining dietary vitamin D requirements. Similarly, the first international publications identifying novel polymorphisms in genes encoding for β-carotene-cleaving enzymes, and interactions between these polymorphisms and other non-coding polymorphisms have attracted attention to the need to re-consider dietary vitamin A requirements (BBSRC BB/G004056/1; £298k; DSM £244). Our research on the effects of cultivation methods and animal production systems on nutrients and bioactive compounds in plants and milk, and their potential health benefits contributes to the debate on the health benefits of organic foods. Evidence that phytochemicals have potential health effects and our research showing that specific medicinal plant extracts interfere with processes involved in progression of Alzheimer's Disease add weight to the evidence supporting the consumption of plant foods. An on-going large-scale dietary intervention study with different types of vegetables will provide further evidence for whether recommendations for fruit and vegetable intake need to be refined (FSA/DOH N02046, £859k).

Gene-Environment Interactions: Our research provides evidence for the underlying molecular processes which affect crop health and productivity, in particular in response to stress from environmental pollutants (abiotics) and insect pests and pathogens (biotics). Understanding of the effects of low-level ozone pollution has contributed to the setting of UNECE-LRTP ozone critical levels/loads for the protection of crops (EU FP7 Marie Curie Fellow) and semi-natural grasslands (DEFRA CPEA33 and AQ3510) across Europe, and work on high productivity grasslands is the only work yet published to combine impacts on productivity and forage quality to provide a picture of impacts on sward 'carrying capacity' (NERC-CEH CASE Studentship). Through a spin-off company, Biofresh now marketed by Freshpallet, research is focussing on use of ozone to control human pathogen contamination of high value fresh produce (ADHB FV386; EUFP7 Marie Curie outgoing Fellowship) and complements research in AFRD allied to *Food Quality and Health*.

The applied research is underpinned by basic research on plant and bacterial antioxidant metabolism and signalling. A BBSRC-funded project (BB/13/D18214) has published the first ever report on the identification of DNA adducts in DNA extracted from soil to determine the presence of mutagenic compounds and is investigating the potential of this method to evaluate effectiveness of soil remediation strategies. We are exploiting our research on seasonal biomass accumulation in plants with crassulacean acid metabolism to support development of novel crops for production of biofuels funded by US DoE (Borland Visiting Professorship, Oakridge National Laboratory, US) and also on sustainable production of economically important species such as pineapple.

We use functional genomics to understand how crops respond to stress from pests and pathogens, to enhance tolerance of these crops through the development of functional molecular markers to produce agricultural commodities with novel/enhanced beneficial traits via marker-assisted breeding. For example, recently funded work under the BBSRC Crop Science Initiative (BB/E006671/1) has identified potential molecular markers in diploid wheat varieties for resistance to aphids. In collaboration with breeding companies (e.g. KWS) research undertaken by the group complements research in *Integrated Agricultural Production* on response of crops to different mineral inputs, which is currently identifying potential molecular markers for both nutrient-use efficiency and pathogen resistance (NUE-Crops EU-FP7, £1.46m). Through collaborative research with Durham University and Fera (TSB; Yorkshire Agriculture Society), we are developing novel biopesticides and also investigating their effects on non-target beneficials, including honeybees.

Social Science of Food, Agriculture and Rural Development: Our interdisciplinary social science research is conducted across a range of scales and draws on a range of disciplines including consumer psychology, consumer science, economics, political science, sociology, and human geography, as well as the inter-linkages across these areas. The contribution of the Centre for Rural Economy to research into sustainable rural economies and societies, which has influenced policy and practice around the world, has been recognised with the award of a Queen's Anniversary

Prize to Newcastle University in 2013. Research strengths in the management and governance of rural land has resulted in some staff in the CRE being returned in UoA16 rather than UoA6. Most research focuses on Europe and other OECD countries, with recent activities expanding into Asia. Research is divided into several key areas. Agriculture, climate change and the environment explores environmental management, with an emphasis on the Common Agricultural Policy (CAP), the climate change policy agenda and the impact of such policies on rural societies. Work on the impact of commodity exports and futures in developing countries has direct relevance to policy makers and institutions such as the World Bank, who are concerned with increasing economic growth and development using agricultural exports as a vehicle.

The social science group has a strong tradition of research in food marketing, with recent work on perceptions of risk and benefit and their influence upon consumer behaviour and consumption around GM food, organic food and other novel products (e.g. QLIF; Food4Me EU-FP7-265494; £100k; Pegasus EU-FP7-226465; £180k). Research on communicating risk is a particular area of strength, and is impacting on policies for how these risks are communicated to the public (e.g. BROWSE EU-FP7-265307; £178k). Other activities focus on research foresight and policy agenda setting (Connect4action, EU-FP7-289023; £76k; Collab4safety EU-FP7-311611; £102k). The social science group interacts closely in *Food Quality and Health* research in interpreting the effects of dietary change on behaviours, and in particular how participation in dietary interventions affects food choice, and how older consumers' knowledge and behaviours in relation to food exposes them to risk of food-borne pathogens (FSA, Studentship).

c. People, including:

i. Staffing strategy and staff development

We provide a research-intense environment, which supports rapid response to new research opportunities and challenges. We also actively support research leave to enable staff to further develop their research expertise and outputs (Borland, US DoE; Singleton, Marie Curie Exchange Fellowship). Building on a research structure from the RAE2008 base, we have identified and addressed the need for expertise in key areas with the recruitment of 2 Chairs (Frewer, Kyriazakis), 1 Senior Lecturer (Hill), 5 lecturers, and 5 moving from Research Associate to lectureships (Butler, Chaudhry, Cooper, Leach, Okello). During the same period there were internal promotions; 3 to Chair (Borland, Rushton, Seal), and 4 to Senior Lecturer (Brennan, Butler, Guy, Lietz). Expanding our research capacity on farm and domestic animal health and welfare was achieved with the appointment of Kyriazakis and Leach, fulfilling the commitment made in RAE2008 to expand our research to identify more reliable welfare indicators across farm species, domestic animals and laboratory species. We firmly believe that integrating the production-consumer continuum is essential for maximising food security and in 2012 Frewer was appointed as the first Chair in Food and Society in the UK. We have recruited proactively to fill appointments in key areas, and our appointment policy is always to appoint on the basis of their international research capability, leadership and quality of research outcomes, consistent with their career stage. As part of forward strategy we have appointed a Senior Lecturer in Precision Crop Agronomy, and a Lecturer in Applied Social Science Statistics, both taking up appointments in January 2014. This strategy has also identified key appointments in Molecular Food Microbiology, Animal Molecular Biology, Plant Metabolic Engineering, Ruminant Science, Consumer Behaviour Science and Agri-Business Management which will be made early in the next REF cycle.

All of our appointments have actively pursued the University's 'Single Equality Scheme' for staff and students, with its commitment to a comprehensive policy of equal opportunities in which individuals are selected and treated on the basis of their relevant merits and abilities and are given equal opportunities within the University. The University became Athena SWAN institutional Bronze Award holders in 2009. We have an appointed 'School Champion' and our objective is to apply for Silver Award status for AFRD in April 2014. Where appropriate new staff are assigned to a more senior mentor within the Unit, who is not their line manager, to facilitate their integration within the research group; we also ensure that newly appointed staff have a reduced teaching-load to enable them to establish their research/groups. The Faculty also operates a mentoring scheme open for all staff at all stages of their career giving academic and research staff access to a mentor from outside their immediate area to use as a sounding board for ideas and to offer a different perspective and encourage interdisciplinary interactions. Additional help available in preparing research applications is a peer review system involving current/former Research Council panel members. All new appointments are made with a probationary period, which is evaluated by the

unit manager during the annual Performance Development Review (PDR) process. We use the PDR process to agree research performance targets, to set new objectives and identify development requirements. Staff may be directed to the University's Staff Development Unit (SDU), which provides a range of research-related training opportunities from managing projects through to protecting results and understanding intellectual property. We recruited a number of ECR staff in the REF period and it is vital for the Unit's continued success that they develop into research leaders in the near future. These staff have been given the opportunity to attend an 8-month intensive research leadership training programme for new and aspiring principal investigators. Participants self-nominate with support from their mentor or PI for the programme which focusses on research team leadership, people and project management, strategic planning, funding and research assessment, all of the skills necessary to bring them to the forefront of their discipline. Our RAs benefit from the University's career development policies and procedures which have been reviewed and renewed to ensure their compatibility with the RCUK Concordat. As a result, the University was one of the first Universities in the UK and Europe to be awarded an HR Excellence in Research Award, which was re-awarded in 2012 for a further two years.

ii. Research students

Postgraduate Research (PG) students are an integral part of our research strategy, with all our staff contributing to their supervision and training; 84 FTE have completed since RAE2008, 39% UK, 20% EU and 41% overseas (from 13 different countries). We are recognised under the University's Code of Practice for Research Degree Programmes as providing a research-oriented environment with appropriate facilities and critical mass of research-active staff. Students are recruited and enrolled in the Faculty Graduate School based on student and project quality, and our policy is that all PG students have a supervisory team with a principal supervisor and at least one other supervisor. An independent progression panel usually comprising the Unit's PG Director and one other, is also appointed. The QAA Codes of Practice for student progression are monitored through the Graduate School *e-progression* system with assessments after 9, 21 and 30 months. Assessment is through oral presentation and/or written report depending on the stage. PG students all contribute to an annual postgraduate conference, organised by the PG students themselves. PGs in the food/nutrition area make similar presentations at the HNRC Annual Research Day. All PG students are required to attend a programme of compulsory and optional skills-training modules, which is fully compliant with the Research Councils' joint statement on skills training for research students. Personal development is recorded through an *e-portfolio* system which is also used to record notes of student/supervisor meetings. PG submission rates are some of the highest in the University with 100%, 100% and 89% of 2006, 2007 and 2008 starters submitting within 4 years, and all completing successfully.

Several of our PG students work closely with Industry and have experience of research that meets stakeholder needs. Currently we have 5 BBSRC CASE studentships, 2 Studentships exclusively funded by the Industry (Nutreco and ASDA) and 8 students funded by AHDB (7 by BPEX and 1 by EBLEX). The unit operates an internal seminar programme and all research and academic staff and PG students are encouraged to attend this and other relevant activities such as the weekly HNRC seminar series. Students are also encouraged to design activities funded by the University. For example, in 2012/13 CRE research student, Hunt, developed a seven seminar series '*Being a Specialist in a Complex World'* for PhD students who will engage with a wider, non-academic public in their professional or research careers. The NIReS-funded programme (which ran again in 2013/4) allows participants to learn about working in interdisciplinary teams with stakeholders, policymakers, media, and researchers. PG students attend conferences to present their work whenever possible (e.g. Gordon Conference, Plant-Herbivore interaction Feb 2013, California) and have won prizes and commendations for their presentations. For example, our students have won the 'best student presentation' award at the British Society of Animal Science for the last 3 years; a student won the 'best student' award at the Agricultural Economics Society Annual Meeting, 2012. The Unit provides funds to facilitate travel and accommodation costs to such meetings if not available from research budgets.

d. Income, infrastructure and facilities

Research during the REF period totalled £12.57m. The largest portion of this (36%, £4.59m) was from EU Agency funding, followed by UK Central Government (30%, £3.83m) with funding from Defra (£2.65m, 21%), the Food Standards Agency and the Department of Health (£0.75m, 6%), reflecting the strongly applied nature of our research base. Research council funding (£1.59m,

13%) has increased during the REF period and with further new grants starting in 2013 (e.g. FAREWELLDOCK, BBSRC/Defra, £661k) this is set to continue to rise as a reflection of our strategies to increase funding from this source. Several major on-going projects with EU funding emphasise our strengths in collaborations across Europe as project leaders and consortia members. These include NUE-crops (EU-FP7 £1.46m); LowInputBreeds (EU-FP7 £1.1m); N-TOOLBOX (EU-FP7 £238k); and ProHealth (EU-FP7 £1.2m).

Our work on food sustainability is encompassed under the interdisciplinary, cross-faculty Newcastle Institute for Research on Sustainability (NIReS). NIReS is a strategic development under the University's Societal Challenge Theme, *Sustainability*, established in 2010. The aim of NIReS is to deliver practical, engaged solutions to real-world issues, under the banner of *Enough, For All, Forever* and the Unit is a key partner in this initiative. We have significant input into the institute, for example, the unit is currently helping to establish a regional Food Policy Council through NIReS to bring together multiple stakeholders interested in food, health, agriculture, the environment and rural issues with the aim of developing consensus-oriented strategies to develop collaborative projects leading to legislation and regulation. NIReS provides an overarching network of activity and support, with collaborators including global organisations, national and local government, and a diverse range of companies and non-governmental organisations.

The provision of healthy, safe and sustainable food is essential in an expanding, ageing population. The *Food Quality and Health* group is one of three research groups in the cross-faculty *Human Nutrition Research Centre* (HNRC) and the Unit group leader is a Co-Director of the HNRC. The HNRC is an internationally renowned University Research Centre with three interlinked multidisciplinary research themes; *Molecular Nutrition, Food Quality and Health and Public Health Nutrition*. There is a strong interaction between this group and the *Social Science of Food* group within CRE in investigating behavioural, sensorial and attitudinal response to foods and dietary change. The University has recognised the strategic relevance of this area of research, industry and public engagement, and has investigated £650k in the refurbishment of facilities resulting in the launch (2013) of 'NU-Food'. This is a high specification food and consumer research facility which includes an industry-standard development kitchen linked to a 10-booth sensory suite, an 8-station (32 person) culinary training facility, and a reception with direct public access into a training suite with consulting rooms, and flexible-sized focus group rooms. For the purposes of this exercise, and reflecting the diversity of our research activity, HNRC staff are returned in two Units, UoA6 and UoA3.

Our pioneering research on the rural and social economy in the CRE was recognised with the award of a Queen's Anniversary Prize to the University in 2013. During the REF period to 2013 the CRE directed the £26m interdisciplinary, BBSRC/ESRC/NERC Rural Economy and Land Use (Relu) programme which brought together approximately 450 researchers from over 50 institutions and organisations. ESRC's evaluation of the programme found that the impacts of Relu have been extensive and transformative in a wide range of areas of food and farming policy and practice, and that the programme has been instrumental in furnishing research funders in the UK with an understanding of the institutional processes and mechanisms needed to enable effective interdisciplinary research and knowledge exchange. As well as its involvement with NIReS, CRE contributes to several key themes within the Newcastle Institute for Social Renewal, established in 2012 under the University's third societal theme 'Social Renewal'. Interdisciplinary research in the *Social science of Food, Agriculture and Rural Development* is driven through CRE, and this was recognised by the University with the strategic appointment of Frewer, an international expert in risk-benefit analysis, in particular communication, associated with food, health, sustainability and safety, to the Chair of Food and Society.

The Centre for Wildlife Management and Conservation is the University's newest Research Centre, established in August 2013. It brings together researches from the Unit and is a collaboration with Defra's executive Food and Environment Research Agency (Fera). The Centre links our academic excellence with Fera's wildlife department, which has the largest concentration of vertebrate ecologists in the UK and provides a platform for informing policy-makers. The Centre is led by Rushton and combines the practical and policy level expertise from Fera Wildlife with that of the academic ecology, biodiversity and conservation research interests at Newcastle.

The Unit manages two research farms and a new plant and environment research field station. **Nafferton Farm** is a unique split-farm mixed conventional and organic beef, dairy and arable farm providing a unique facility for contemporary comparison of matched organic and conventional

systems. A split-parlour system allows for the separate automated feeding and milking of the two dairy herds, giving the opportunity to investigate seasonal and dietary impacts on milk yields and composition used in setting organic standards. Advice for transfer from conventional to certified organic systems and maintaining crop productivity after conversion have been informed by research from the unique Nafferton Factorial Systems Comparison field experiments. These were established in 2003 to quantify the yield and food quality differences between contrasting crop rotations, fertilisation and crop protection practices; this 'split-farm' system is unique within the UK. **Cockle Park Farm** has been managed as an experimental facility since 1896 and is a mixed (pig, sheep, beef, dairy and arable) enterprise with facilities for environmental studies such as fully contained field-scale drainage plots and livestock experimentation in Home Office-licenced facilities. A particular strength is our development of the pig unit as a commercial research centre on pig welfare and production. The *Palace Leas Hay Meadow* trial at the farm is a unique, globally-significant research resource which has been maintained under the same agricultural management systems for 117 years, making this one of the longest-running agricultural field experiment in the UK.

Both farms operate as commercial enterprises so that any research activity can be fully evaluated for its commercial potential. Cockle Park is utilised by NIReS as a demonstration of rural sustainability through the exploitation of research across the university. For example, research on sustainable energy production is centred at Cockle Park Farm promoting the technologies and the wider implications associated with the use of renewable sources of energy from the land via research, education and demonstration. This brings together agriculturalists, natural scientists, environmental engineers and other engineering disciplines, economists, and social scientists to examine issues relating to renewable energy from land in an integrated and holistic manner.

An anaerobic digestion plant (ADP) installed at Cockle Park was jointly funded by NU (£750k) and the Rural Development Programme for England (£540k). The ADP uses slurry from the animal herds at the farm to generate heat, electricity and digestate (an organic fertiliser) and when fully operational will utilise energy crops and food residues from neighbouring businesses. Not only a research facility, the ADP has an important engagement role to help farms become more sustainable through creating energy from waste. With new University funding (£102k) the ADP will be interfaced with the mains system so that when running at full capacity, energy generated can be returned to the grid as well as supply the farm. This will provide an additional facility for NIReS research on electricity supply and is part of our strategy to establish Cockle Park as a test bed for smart-grid and energy storage technologies early in the next REF period.

The University's current £1.2million investment in a new glasshouse complex and trials area at Cockle Park is part of our future strategy to consolidate the activities previously managed by SBiol at the *Close House Experimental Field Station* and *Moorbank Gardens*. Outdoor facilities will include controlled environment chambers for exposure of plants and plant communities to pollutant gases such as ozone. The glasshouses will house an important and diverse collection of tropical plants including agriculturally important species such as coffee, tea and banana. These collections are used to support research in photosynthesis and plant physiology, genetics, medicinal plants, bioremediation, hydrology, agronomy and bee behaviour.

e. Collaboration or contribution to the discipline or research base

The unit has extensive active collaborations (joint publications and/or joint funding) with research organisations and end-users such as the Agriculture and Horticulture Development Board British Pig Executive (£225k) and Fera (through BBSRC funded projects). Links with industry are a strength of the unit, both in terms of joint funding between industry (£1.06m) and government through LINK programmes such as BBSRC-DRINC, TSB, CASE studentships (Syngenta, KWS, Stockbridge Technology Centre, Aviagen, Merial) and direct funding of our research (Danone, Sainsbury's, Cereal Partners Worldwide). Much of our research is informed by the needs of industry and we undertake research and consultancy with companies in the UK and internationally (e.g. Nutreco Inc £35K; Merial £55K). We have conducted the Farm Business Survey for Defra since 1987 identifying and analysing farm profitability in the North of England, and supplying data that contribute to the Farm Accountancy Data Network (FADN) of the EU. We have also established ESRC funded *Landbridge*, which provides a national platform for inter-professional learning for advisers of land managers from the private, public and third sectors and which offers the professions a mechanism for knowledge exchange with major Research Council initiatives such as the Living with Environmental Change Partnership.

Our staff contribute to industry-led initiatives that impact future agendas such as the European BECOTEPS project 'Unlocking the potential of the Bioeconomy' (Brandt), and the European Technology Platform, Food for life (Frewer). Many staff act as consultants to industries in the UK and globally, for example General Mills, Mars Foods, Kraft Foods, Nestlé, Tesco, and are members of Expert Panels for the International Life Sciences Institute Europe and SE Asia.

The international reputation of our research and staff is evident in a number of different ways e.g. in 2012 Singleton was awarded a Marie Curie International Outgoing Fellowship involving collaboration with University of California, Berkeley (Dept of Plant and Microbial Biology), USA, Borland was awarded a Visiting Professorship at Oakridge National Laboratory, USA and Kyriazakis an Adjunct Professorship at the University of Guelph, Canada; Frewer is Emeritus Professor at Wageningen University, The Netherlands; Gatehouse was awarded an Honorary Doctorate from Banat's University of Agricultural Science and Veterinary Medicine, Romania. Over the REF period 95% of our submitted staff have published with international collaborators and our funding has included partnerships with over 75 international industries and research organisations. Eleven of our staff are representatives on science advisory committees for international review panels for research organisations in 16 countries worldwide, and regularly review grant applications for the EU, including Marie Curie awards.

During the current REF period our staff have also received prestigious awards and prizes. For example, the David Black Award from the British Pig Executive was awarded to Edwards for her sustained contribution to the British pig industry. Kyriazakis and Flecknell were awarded as Fellows of the Royal College of Veterinary Surgeons. At an international level, Edwards was also elected as Foreign Academic Correspondent by the Spanish Royal Academy of Veterinary Science for "exceptional professional merit" and Kyriazakis a Fellow of the Greek Agricultural Academy; Flecknell was awarded an Honorary Doctorate from the University of Ghent, and Honorary Diplomate of the American College of Laboratory Animal Medicine.

We place great emphasis on dissemination of our research through contributions to the scientific community through invited attendance at international conferences and in membership of organising committees of international meetings. Examples of conference organising include the US Gordon Research Conference (2008), 'CO2 assimilation in plants: genome to biome' (Borland); The International Conference on Invertebrate Reproduction and Development in the Age of Genetic Modifications, Prague, (2010) (Gatehouse); The 2nd International Conference on Agrochemicals Protecting Crops, Health and Natural Environment – The Role of Chemistry for Sustainable Agriculture (2012) (Gatehouse); The Nutrition Society and American Society for Nutrition joint conference (2011) (Hill); and the 3rd and 4th Whole Grains Global Summits in Newcastle (2009) and Minneapolis (2012) (Seal). During the REF period 70% of our staff were invited speakers at conferences worldwide.

Staff have contributed to a number of UK Research Council and Government Agency Committees such as BBSRC Panel A and Sustainable Agriculture Panel (Rushton); Programme Management Committee, Defra/LINK Sustainable Livestock Production Programme (Edwards); UK Farm Animal Welfare Council (Edwards); FSA Social Science Research Committee (Frewer); Advisory Committee on Novel foods and processes (Ritson) Knowledge Transfer Network Biosciences Food Group (Kuznesof); Fera Science Advisory Panel (Rushton); and International Agency Committees such as Animal Health and Welfare Panel, EFSA (Edwards) and FAO Livestock Environmental Assessment and Performance Partnership (Kyriazakis). During the REF period all of our staff have taken part in the grant review process across all of the relevant UK Government agencies (BBSRC, ESRC, Defra, DOH, etc.), UK Charities and Trusts (Wellcome, Leverhulme, Rank, Diabetes UK etc.).

All staff within the Unit regularly contribute to the review process for highly rated journals in their research field and returned staff currently sit on the editorial boards of 19 international journals, including as senior/section editors (e.g. Section Ed. *J. Agric. Sci. Camb.*, Bilsborrow; Assistant Ed. *Org. Agric.*, Butler; Section Ed. *Animal*, Edwards; Assoc. Ed. *Poultry Sci.*, Kyriazakis; Suppl. Ed. *Br. J. Nutr.*, Seal). Our contribution to the wider academic community also involves contributions as board members of learned societies. For example; Council Member, British Society of Animal Sciences (Chaudhry); Council Member, European Federation of Animal Science (Edwards); Council Member, British Mycological Society (Singleton) and Honorary Scientific Development Officer and Council Member, The Nutrition Society (Seal).