

Unit-level environment template (REF5b)

Institution: University of Edinburgh and Scotland's Rural College
Unit of Assessment: 6 (Agriculture, Food and Veterinary Sciences)
<p>1. Unit context and structure, research and impact strategy</p> <p>1.1 Overview</p> <p>This joint UoA6 submission from the University of Edinburgh (UoE) and Scotland's Rural College (SRUC) reflects a collaboration of over a century, aligned to critical challenges in agriculture, food and veterinary sciences. With the human population predicted to exceed 9 billion by 2050, our vision is to improve the health and wellbeing of humans, animals, plants and the environment, safeguarding local and global food chains and rural communities, and driving transformative improvements in productivity and efficiency. This vision aligns with the UN Sustainable Development Goals and the strategic priorities of regional, national and international industry, policy stakeholders, funding agencies and investors.</p> <p>We form a research community of 271 (257.23 FTE) researchers returned to this UoA. Approaching three-quarters of these staff are co-located at our exceptional Easter Bush campus (>£275m investment since opening in 2011), representing the largest concentration of animal science expertise in Europe. The campus is home to UoE's Royal (Dick) School of Veterinary Studies (R(D)SVS), including the BBSRC Roslin Institute and the Global Academy of Agriculture and Food Security, and is part of SRUC's Science Society and Business Faculty. SRUC has 5 further campuses across Scotland, 8 research farms/stations, 8 disease surveillance centres and hubs, and a regional network of 26 offices across Scotland and the north of England. Our extensive international research networks extend our reach from 'lab to land' and 'local to global' and exemplify our ethos of ensuring our research benefits stakeholders and rural communities globally (Fig. 1).</p> <div data-bbox="161 1144 999 1984"> </div> <div data-bbox="1023 1160 1445 1330"> <p>Figure 1. Our themes and initiatives align under One Health to develop research-led solutions at regional- national- and global-scales.</p> </div> <div data-bbox="1023 1361 1326 1966"> <ul style="list-style-type: none"> Genetics & genomics Animal development, biology, behaviour & welfare Infection & immunity Clinical veterinary sciences Environmental, economic & social sciences Future food systems </div>

1.1.1 Key highlights and developments

Research growth

We have grown by 42% since REF2014, from 179.99 to 257.23 FTE, strategically attracting research leaders to build critical mass and breadth aligned to our vision. Our competitive research income of £359.9m over the REF2021 period includes the BBSRC strategic funding (a total of £52.0m during REF period) to the Roslin Institute, and £34.8m (2016 onwards) to SRUC from the Scottish Government Rural & Environment Science & Analytical Services (RESAS) strategic research programme. Our average annual income of £51.4m p.a. includes a **leverage of an additional ~£3.2m of competitively awarded research grants for every £1m of BBSRC and RESAS core investment**. Our average annual **research student degree awards have increased 23%** from 29.3 (REF2014) to 36.0 (REF2021). This has been driven by new PhD programmes, for example in Agriculture and Food Security, a Wellcome-funded Doctoral Training Partnership (DTP) on One Health Models of Diseases (first intake 2020), and renewal of UKRI-funded DTPs (EASTBIO, E4, SGSSS) and the Wellcome 2016 ECAT DTP (£10.2m); the UK's first clinical academic PhD training programme for medical (ECAT) and veterinary (ECAT-V) graduates combining PhD and clinical specialist training, and an international exemplar.

New partnerships

Our challenge focus is underpinned by new and strengthened existing partnerships at regional, national and global levels, supported by funding from the Scottish and UK Governments, UKRI, industry and philanthropy, in addition to our Institutional investments. Examples of new partnerships include:

- The Centre for Tropical Livestock Genetics & Health (CTLGH) in partnership with the International Livestock Research Institute (ILRI) to drive genetic gain in African farm animals and build capacity for technology-led breeding (\$21.3m USD; Bill & Melinda Gates Foundation and the Foreign, Commonwealth and Development Office).
- Supporting Evidence-Based Interventions (SEBI) to collate and apply data to guide investment in livestock systems that benefit smallholders in low- and middle-income countries (\$10.9m USD since 2016, Bill & Melinda Gates Foundation).
- Partnership in Innovate UK funded Agri-Tech Centres, including the Centre for Innovation Excellence in Livestock (CIEL), the Agricultural Engineering Precision Innovation Centre (Agri-Epi) and Agrimetrics (£11.2m, Agri-Tech centres plus match funding) connecting our researchers with stakeholders across the food supply chain.
- Establishment of the Global Academy to support decision making to transform agri-food systems and food security (£38m, UoE and UK Government capital from UoE's £237m data-driven innovation component of the Edinburgh and South-East Scotland City Region Deal).

Infrastructure investments

Since REF2014 we have **invested £152m in world-class buildings, estate and research facilities** (section 3). Key research investments include the:

- Charnock Bradley Building (£31m), including the Easter Bush Science Outreach Centre (EBSOC), Roslin Innovation Centre and Roslin Technologies Ltd to support our engagement with the sector and the public.
- Large Animal Research & Imaging Facility (LARIF) at Easter Bush (£25m).
- Rural Veterinary Hub in Inverness (£7m).
- Allermuir Avian Innovation and Skills Centre for improving avian nutrition, health and welfare (£5.4m).
- Equine diagnostic, surgical and critical care unit (£3.7m).
- Advanced mobile phenotyping facilities for livestock research (£2.7m).
- Veterinary and Analytical Laboratory (£1.2m).
- Edinburgh Genetic Evaluation Services (£1.4m).

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In addition, we have invested heavily in improving the operational running of the Easter Bush campus including an energy centre (£12.9m, City Deal), a solar farm (£3.2m, SFC RELCO Fund), a nursery (£2.8m, UoE), high-voltage power, paths, roads etc (£8.8m, UoE) and advanced computing networks (£28.7m, City Deal).

Delivering impact

Our industry-linked capability in data-driven innovation for agriculture has been substantially boosted by major investments, including the £1.3bn **Edinburgh and South-East Scotland City Region Deal**, the £290m **Aberdeen City Region Deal** and the £390m **Borderlands Region Deal**, including £237m capital from UK and Scottish Governments for data-driven innovation, leveraged to £661m with revenue investments (section 4). With this investment in our data-creating capabilities, and infrastructure to support industry collaborations and commercialisation, we are ideally placed to deliver knowledge at scale and the technologies to transform global agriculture. Such investments have helped us increase the reach and impact of our research, as exemplified in our impact case studies (ICS) and section 4. Indeed, between 2014/15 and 2018/19 UoE spin-out companies had the second highest turnover value in the UK (£672.2m), accounting for 74.7% of Scotland's total spin-out turnover. In addition, our research expertise has ensured our policy advice to government (e.g. Scottish Government's Centres of Expertise in Animal Disease Outbreaks (EPIC), Climate Change (CXC), Plant Health, and Brexit Hub) has been fundamental to informing strategic decision-making and policy in Scotland and more widely.

1.2 Research and impact strategy

Our research comprises 6 themes that interface to develop interdisciplinary research-led solutions to address many of the critical regional-, national- and global-scale multifaceted challenges within One Health (Fig 1). Our community takes world-class underpinning basic and applied bioscience, agricultural science and technology, and economics and social science, through to translation to the end-user, addressing, redefining and developing solutions to these key challenges. These themes span complementary expertise in diverse disciplines and are underpinned by exceptional infrastructure to deliver our shared Unit strategy and instil training in vulnerable skills and capacities identified in UKRI cross-Council reviews. They nurture talented postgraduate students and early career researchers, to deliver impact within Scotland, the UK and globally.

1.2.1 Research themes

(1): Genetics and genomics (50 PIs)



Critical challenge

More accurate prediction of phenotype from genotype to improve animal health and welfare and the sustainability and efficiency of food production through selection.

Research focus

This theme works from nucleotide sequences to in-field genetic improvement in farmed terrestrial and aquatic animals, selected companion animal species, and agricultural crops, often collaboratively with industry and end users. We use massive datasets of pedigree and nucleotide polymorphism data linked to phenotype records to make genetic associations and develop tools to estimate the genetic value of individuals. These data often come from individual and industry stakeholders driving genetic gain in practice, thereby directly impacting their breeding programmes through genetic and genomic selection. Where there are no tools for genotyping (e.g. SNP arrays), we co-create them, and where there is no genetic and genomic selection, we identify the route to introduce it. As functional variants frequently occur in regulatory and coding regions, we produce better reference genomes and are applying high quality functional annotation, for example by mapping all transcripts across species, relevant cells and tissues at key development stages. The causal variants identified by such research can be integrated into breeding programmes or edited into the species directly.

Research highlights

- Production of large functional datasets (e.g. high-resolution sheep transcriptome atlas by **Clark, M Watson, Whitelaw, Archibald**; PLoS Genet 2017), and improved reference genomes (e.g. for domestic pigs by **Archibald** and others; Gigascience 2020). This has made significant contributions to the global Functional Annotation of Animal Genomes project, co-initiated by the Roslin Institute (<https://www.faang.org>). **Prendergast, Djikeng, Archibald** and **Wall** have devised novel strategies to visualise genome variation and identify signatures across breeds (e.g. Nat Commun 2020).
- Production of tools to enable dissection of genotype/phenotype, including both software and lab-based tools (e.g. SNP arrays; ICS E). Among heritable traits dissected are resistance to key endemic and exotic diseases of terrestrial animals (e.g. **Denholm, Wall, Banos, Coffey**; J Dairy Sci 2017), aquatic diseases (e.g. **R Houston, Robledo**; G3 2018, Fig 2), early life prediction of fitness (e.g. **Banos, Coffey** Front Genet 2019) and quality and processing attributes in grain crops (e.g. **Hoad, Topp**; Front Plant Sci 2019). Recognition includes the 2017 Queen's Anniversary Prize for the Langhill dairy cattle genetic selection experiment.
- Development of genome-wide strategies for silencing of genes using siRNA libraries (e.g. **Grey** mBio 2018) and mutagenesis using sgRNA libraries and CRISPR/Cas9 to assign roles to genes in cattle, pig, chicken and salmon cells, building on BBSRC strategic and capital investment at the Roslin Institute and capability of the Edinburgh Phenotypic Assay Centre.
- Pioneering analyses of microbiomes and metagenomes, for example **M Watson, Roehe** and **Dewhurst** providing the most comprehensive atlas of rumen microbes and proteins (Nat Commun 2018) and linking these to heritable differences in greenhouse gas emissions (PLoS Genet 2016). They have shown that microbiome markers improve genomic prediction of key traits (e.g. feed conversion efficiency; Front Microbiol 2020) and are working with a breeding company to integrate microbiome data into their selection process. Recognitions include the 2017 PLoS Genetics research prize, and the Times Higher 2018 research project of the year shortlist.

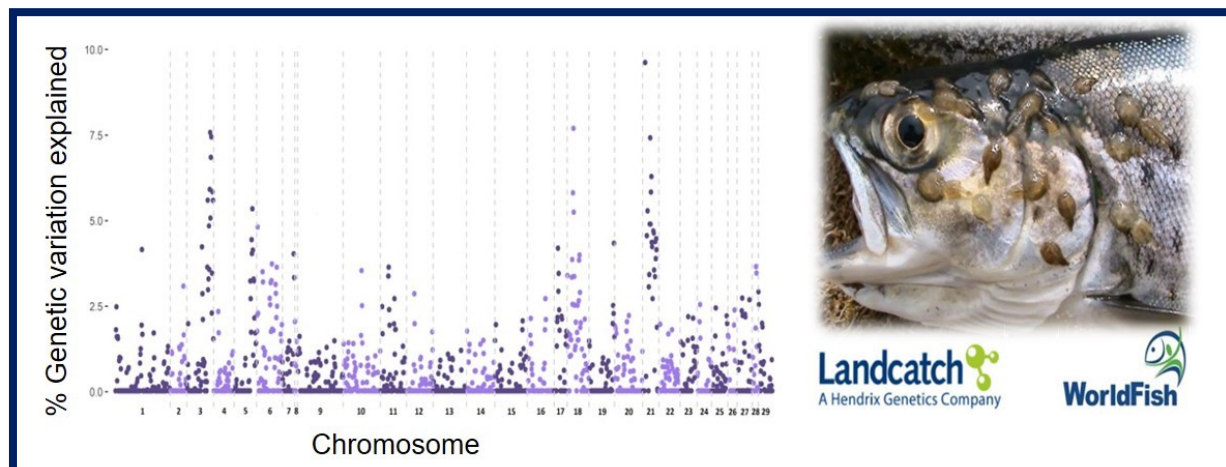


Figure 2. We design genotyping tools for terrestrial and aquatic farmed animals and apply these to dissect the genomic architecture of key traits, including here resistance to sea lice

(2): Animal development, biology, behaviour and welfare (33 PIs)



Critical challenge

Improve the health and welfare of animals through understanding of their development, physiology and behaviour.

Research focus

This theme investigates the fundamental biology of farmed and companion animals from the molecular level, through cellular interactions and embryonic development, to the physiology of animals through life. We develop novel tools and technologies to support this theme, other research themes and external collaborations. Our research outcomes underpin One Health as species-specific understanding of development and physiology inform advances in husbandry and

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breeding of farmed animal species, while technical innovations are at the forefront of introducing new technologies in animal health and breeding. Understanding of animal function and behaviour also allows us to create solutions to welfare problems of managed animals, and to derive objective measures of animal welfare.

Research highlights

- Research by **McGrew** has led to the development of a fully defined culture medium for chicken primordial germ cells (PGCs) and efficient gene-editing, enabling gene deletion, single-base mutations and gene-targeting (Stem Cell Reports 2015). The invention of GA-embryos in which the host embryo PGCs can be ablated and replaced by edited PGCs allows production of adult birds with 100% gene-edited offspring (Fig. 3). This reduces the time to generate gene-edited birds by a generation, and forms the basis of a unique system for cryopreservation of genetic lines of chickens (PNAS 2020).

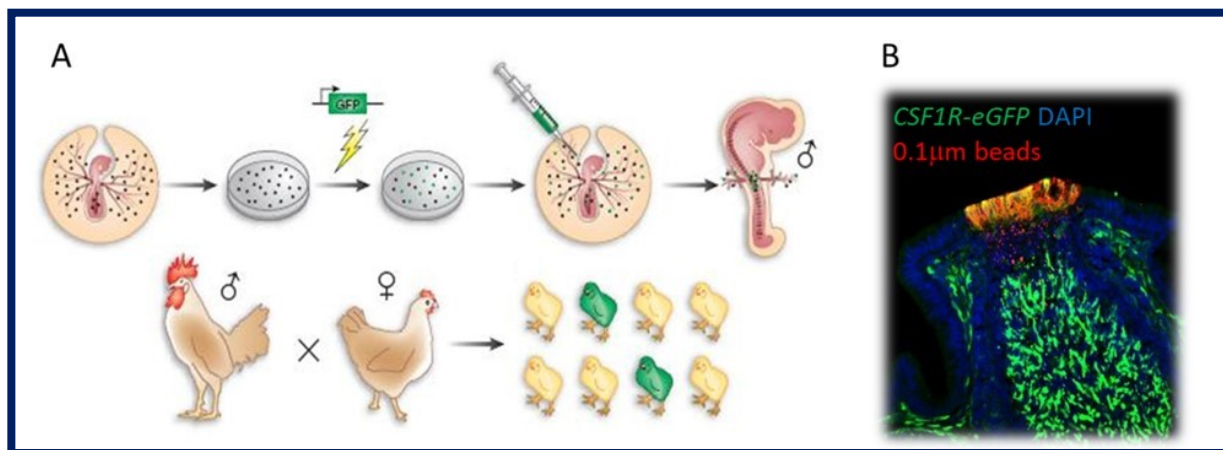


Figure 3. Generation of transgenic reporter chickens to visualise the avian immune system; (A) strategies to culture and genetically alter PGCs and inject during embryo development; (B) revealing novel M-cell subpopulations as portals of entry for antigens and pathogens.

- Imaging of chicken embryos of fluorescent reporter lines by **Rainger** and **Prendergast** has established a tractable model of optic fissure closure (eLife 2019), opening new avenues to explore the genetic basis of human ocular coloboma and sight loss. **Whitelaw, Lillico** and **Wishart** demonstrated that genome-edited sheep with mutation of *CLN1* provide a valuable model of infantile neuronal ceroid lipofuscinosis (Sci Rep 2019), priming collaborative research to evaluate gene and protein therapies.
- Our research has advanced knowledge of pre- and post-natal influences on behavioural development and how farm measures and management actions relate to animal welfare. For example, **Sandercock** has shown that tail-docking in pigs is associated with neuropathic-like pain sensitivities, linked to sustained changes in inflammatory and pain-associated gene expression (Front Vet Sci, 2019). In pigs, **Turner, Baxter, D'Eath** and others have established that play (Sci Reports 2020), aggression (Animal, 2016) and tail posture (Anim Behav Sci, 2018) are sensitive welfare indicators, some of which can be measured through analysis of video images by machine learning. They have pioneered the biological validation and modelling of sensor and camera systems in real-world applications, leading to an early warning system (TailTech) for tail biting outbreaks.
- We have advanced knowledge of the pre- and post-natal influences on behavioural development, environmental impact on brain health and temperament and the impact of pain induced by farm management actions on motivation, cognition and neurology. For example, **Lawrence** has established that play is a sensitive welfare indicator (Appl Anim Behav Sci 2018), and has quantified positive impacts of environmental enrichment and associated neurophysiological responses (Physiol Behav 2017; Behav Brain Res. 2018).

(3): Infection and immunity (36 PIs)



Critical challenge

Detect, prevent and treat animal and zoonotic diseases to enhance health and welfare.

Research focus

The focus of this theme is to mitigate the threat of infectious disease to farmed animals and crops to enhance welfare and resilience/productivity, as well as reducing the threat of zoonoses to humans. Our research covers a broad variety of host species, pathogens and experimental approaches, with focus on both key pathogens and their hosts, including the underlying genetics that dictate the response to infection. We study the genetics, epidemiology, replication, pathogenesis and host response to infection with endemic bacteria, parasites and viruses, in temperate and tropical climates, and are at the forefront of developing and applying new tools and technologies for discovery of pathogen virulence determinants, and host susceptibility and resistance traits. We also develop novel approaches to predict and control crop and livestock diseases and to reduce antimicrobial resistance. Through close collaboration with industry, we inform, develop and deliver best-applied practice.

Research highlights

- We have provided valuable insights into host-tropism, cross-species transmission and virulence of pathogens. For example, work of: **Fitzgerald** and others on *Staphylococcus aureus* (Sci Adv 2019; Nat Ecol. Evol. 2018; Nat Genet 2015; Science 2018; PLoS Pathog 2017); **Lycett** on the role of migratory wild birds in global spread of avian influenza H5N8 (Science 2016; PNAS 2020); **Kao** and **Lycett** on transmission routes and spread of bovine tuberculosis (Mol. Ecol 2019; eLife 2019); and **Del-Pozo** and **Shaw** on the role of *Mycobacterium leprae* and *M. lepramatosis* in causing leprosy in red squirrels, with implications for conservation of the species and public health (Science 2016). **Gally** and **Dallman** have also used machine learning to predict zoonotic risk of *E. coli* and *Salmonella* found in farm animals and for source attribution during outbreaks (PNAS 2016; Microb Genom 2017).
- Using knowledge of molecular mechanisms in host-pathogen interactions, we have used genome editing to produce animals resistant to diseases, for example pigs refractory to porcine reproductive and respiratory syndrome owing to modification of the viral receptor CD163 (**Archibald, Lillico, Opriessnig, Tait-Burkard** and **Whitelaw**; PLoS Pathog 2017, J Virol 2018). This interdisciplinary work interfaces with themes 1 and 2, combining high-quality reference genome and transcriptional organisation data for pigs, editing and reproductive technology for implantation of modified pig zygotes, and expert input from virologists with macrophage and pig models of infection. Similar work is ongoing for avian influenza following identification of a key host restriction factor (**McGrew** and **Sang**; eLife 2019).

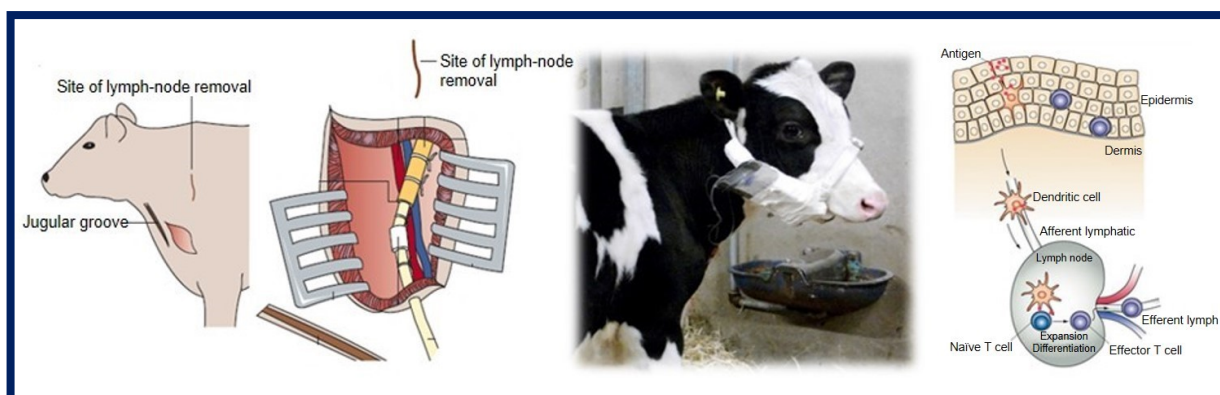


Figure 4. A surgical model to access migratory antigen-presenting cells draining the skin of cattle in real-time following infection or vaccination.

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- **Hope's** development of a pseudoafferent lymph duct cannulation model in cattle has enabled the real-time analysis of immune responses (Immunology 2017; Fig 4), and **Morrison** was awarded the Plowright Prize for research on the role of diversity in determining protective immunity in cattle against *T. parva*. Work by **Sang, Balic** and others on novel transgenic chicken lines has allowed characterisation of the origins and function of macrophages and microfold cells (BMC Biol 2015; Front Immunol 2019). **Mabbott** and **M Stevens** have also shown how gut microbiota promote M-cell development and function, with potential to reverse age-related decline in mucosal immunity (iScience 2020).
- Research by **Hoebe** on *Ramularia collo-cygni*, the agent responsible for Ramularia leaf spot disease of barley, has identified mechanisms for avoiding detection by the host, enabling it to survive as an endophyte for much of the plant's life cycle before eventually turning pathogenic (Mol Plant Microbe Interact 2018). **Havis, Burnett** and others have shown routes of spread of this fungus and its ability to rapidly evolve resistance to fungicides (BMC Genomics 2016).

(4): Clinical veterinary sciences (81 Pls)



Critical challenge

Improve the diagnosis, treatment and prevention of societally important non-infectious diseases in veterinary species.

Research focus

Our clinical and translational veterinary research on non-infectious diseases encompasses diagnosis, prevention and therapy, and primarily focuses on companion animals (cats, dogs and horses). This represents an important route for translation and application of our more fundamental animal bioscience. Research into novel diagnostic approaches includes: the identification, validation and application of biomarkers of disease; development and evaluation of new diagnostic platforms; and improving the real-time monitoring of disease and repair. Our work to prevent non-infectious diseases benefits from large-scale longitudinal cohort studies and interfaces with work on the genetic basis of heritable disorders in theme 1 to guide breeding decisions. Research on therapeutics includes clinical trials of new drugs, devices and clinical protocols. Our work on developing novel prevention strategies ranges from the rollout of novel, large-scale preventive health vaccination campaigns through to basic research which advances understanding of the pathobiology of important diseases. We also use animals as a biomedical model (e.g. CFTR1 edited sheep to test gene therapy, and natural ovine model of lung cancer, Fig 5).



Figure 5. The Wellcome-funded Critical Care Laboratory for Large Animals offers unique capabilities priming development of novel biomedical models at the interface with other UoAs.

Research highlights:

- We have developed mass spectrometry-based assays, many of which are now commercially available, to dissect vitamin D-associated disorders in dogs (**A Gow, Ryan, Milne, Philbey, Mellanby**; J Vet Intern Med 2020; PLoS ONE 2015), sheep (**A Macrae, Clements, Mellanby**; Sci Rep 2016), obesity-associated glucocorticoid metabolism in horses (**Morgan, Keen**; Sci Rep 2017), and biomarkers of important diseases (**Clements, Mellanby, Ryan, A Gow**; Vet J

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2020). **Mellanby, A Gow, and Milne** have developed novel microRNA-based diagnostics (J Vet Intern Med 2018) for high throughput platforms (Anal Chem 2020), resulting in spin-out of Vetsina Animal Diagnostics Ltd. **Donadeu** and **Banos** are working with DESTINA Genomics to commercialise miRNA diagnostics for mastitis, fertility and other functional traits in cattle (Sci Rep 2018).

- We have devised diagnostic protocols to diagnose important disorders faster and more accurately. Examples include development of improved diagnostics for diseases in cats by **Gunn-Moore and Hope** (Transbound Emerg Dis 2020), and in horses by **Dixon** (Equine Vet J 2018). **Argyle** has developed novel monoclonal antibody therapies for companion animals (PLoS ONE 2016) and **Clements** has developed novel approaches to assess gait in ducks and chickens (Biol Open 2016).
- **Rainger, Prendergast and Schoenebeck** have identified a variant of *OLFML3* associated with glaucoma, priming the development of a genetic test to eliminate blindness (G3 2019). **Clements** and **Bronsvoort** have defined risk factors for limber tail (Vet Rec 2016), aided by our DogsLife longitudinal cohort (www.dogslife.ac.uk), and **Wiener, Haskell** and others have identified the genetics underpinning dog behaviour (Heredity 2019). Our work on the pathophysiology of important diseases of companion animals (e.g. by **Argyle, Pang, Corcoran** and **McGorum**) has revealed novel molecular understanding of infectious diseases (J Gen Virol 2014), metastatic spread (Sci Rep 2020) and defined insights into novel treatment strategies (PLoS ONE 2014).

(5): Environmental, economic and social sciences (30 PIs)



Critical challenge

Responsible consumption and production, that brings benefits and resilience for rural farming and urban environments, communities and economy.

Research focus

This theme focuses on how agriculture affects, and is affected by, environment, people, society, and ecology. This includes addressing key issues around reducing the negative impacts of food production while understanding how this is impacted by food choices and governance systems. Central to this is understanding attitudes, perceptions and behaviours to a range of stimuli (e.g. climate change, animal welfare/health, water quality, food waste) and other policy instruments (e.g. agricultural policies, food taxation), with the aim of enhancing benefits and resilience for farming rural and urban environments, communities and the economy. Much of the research in this theme is co-developed and delivered in partnership, engaging national and international end users.

Research highlights

- Research by **Moran, Glenk, Barnes, Baggs, A Duncan** and **Revoredo-Giha** has led to the development, adoption and uptake of sustainable agricultural technologies within food supply chains, including in low- and middle-income countries (e.g. **Revoredo-Giha**, Sustainability 2020). For example, development and adoption of the *Legume Choice* decision support tool in sub-Saharan Africa to help inform decisions on the right crop, the right place and the right time. **Barnes** has identified attitudinal and behavioural differences in European crop growers with regard to the economic return of precision technology, which leads to a greater probability of uptake (Land Use Policy 2019).

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- Research by **Rees, V Eory, Topp, Cloy, MacLeod** and **Moran** has underpinned the quantification of greenhouse gas emissions from UK agriculture leading to improved UK emission inventory reporting (ICS F), including from previously ignored sectors such as fisheries (**MacLeod**, Sci Rep 2020; Fig 6), and the development of integrated assessment tools for cost-effective greenhouse gas mitigation in agriculture. These tools include AgRECalc®, an on-farm greenhouse gas calculator tool, that has been used to footprint >4,000 farms (ICS F), and the Cool Farm Tool (**Hillier**; J Clean Prod 2019; section 4).

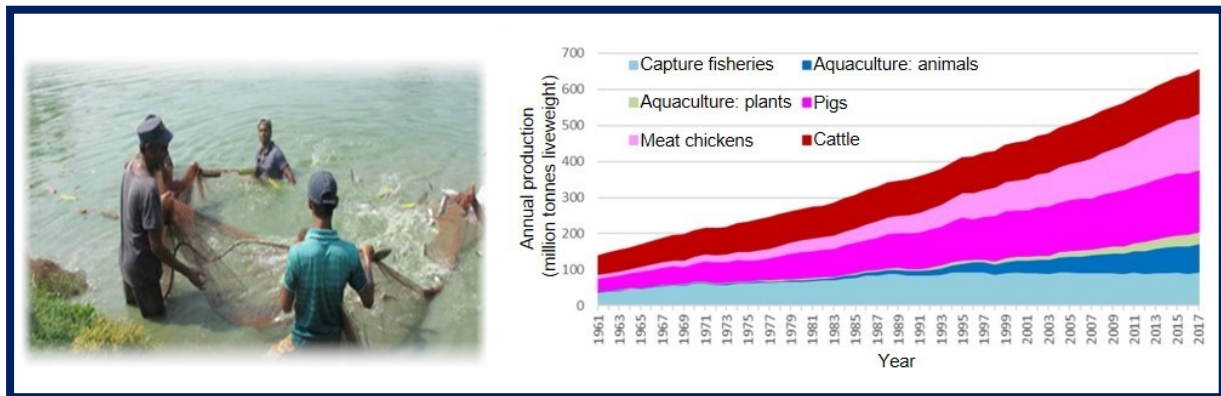


Figure 6. Quantifying greenhouse gas emissions from different sectors.

- Alexander, Barnes, McCracken, McVittie** and **Moran** have developed frameworks for assessing food system resilience to global shocks. For example, viability indicators of British extensive hill systems post-Brexit showed the influence of physical criteria, attitudes and farm structural decision-making on viability status (Scott Geograph J 2017). For supply chains less protected by EU regulations (e.g. pig meat) collaborative multi stakeholder action has been shown to increase the overall resilience of the supply chain post Brexit. Also with **Thomson**, and **McMorran** they have predicted farm households within less favoured areas of the UK to be more disadvantaged post-Brexit with the removal of the CAP free trade with the EU (Land Use Policy 2020).
- Our research on stakeholders' perceptions of ethical issues relating to food production has increased understanding of how perceptions of production systems can effectively change consumer behaviour. For example, **Akaichi** and **Revoredo-Giha** (Brit Food J 2016) found a high level of price elasticity regarding animal welfare labelling of livestock products with consumers substituting between different types of animal friendly labels. They also showed that demand for livestock products with enhanced labelling attributes increased if a product related to multiple attributes such as sustainability (e.g. organic), enhanced animal welfare and nutritional profile (J Clean Prod, 2019).

(6): Future food systems (41 Pls)



Critical challenge

Achieve security, equity and sustainability of the global food system, for safe, nutritious and sustainable diets.

Research focus

This theme investigates and promotes innovation in complex food systems, including appropriate new technologies, to deliver sustainable, healthy diets, to drive the transformation towards resilient, fair, ethical and sustainable food systems, and to support growth in the wider bioeconomy. This includes novel farming systems, optimizing use of animal genetic resources and feed resources to develop sustainable livestock systems, management of soil, crops and livestock for sustainable intensification and precision agriculture. Working with industry stakeholders, we explore how digital and data innovations and tools can be utilised to develop sustainability indicators and improve food production systems. We take 'whole chain' or 'network' approaches, which embrace the marketing environment within which agri-food supply chains and networks operate.

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Research highlights

- Our research in optimising the use of plant and animal genetic resources and feed resources, including exploring trait-function and genotype-management-environment relationships has led to blueprints that underpin climate-smart breeding initiatives. Findings by **Baggs** and **Hopkins** on plant-soil interactions (Glob Change Biol 2019) and soil microbial communities (Nature 2014) in response to drought and temperature changes are being applied to inform soil and crop management under a future climate. For livestock, **Coffey** and **Conington** have reported genetic correlations in relation to production efficiency in goats (J Dairy Sci 2017), and **Wall**, **Banos** and **Conington** have identified differences in potential resilience to future climate (J Dairy Sci 2017; BMC Genet 2019).
- **Rees**, **Wall**, **Hillier**, **Moran** and **De Oliveira Silva** have identified a number of sustainable transition paths for different farming systems to deliver net-zero carbon agriculture. These include local land sparing actions to achieve greenhouse gas reductions (Nat Clim Change 2016a), global transition paths such as in Brazilian beef production (Nat Clim Change 2016b; ICS B) and for Chinese (Glob Change Biol 2018) and Indian (Sci Total Environ 2019) agriculture making the links to nutritional diets (Agric Ecosyst Environ 2017).

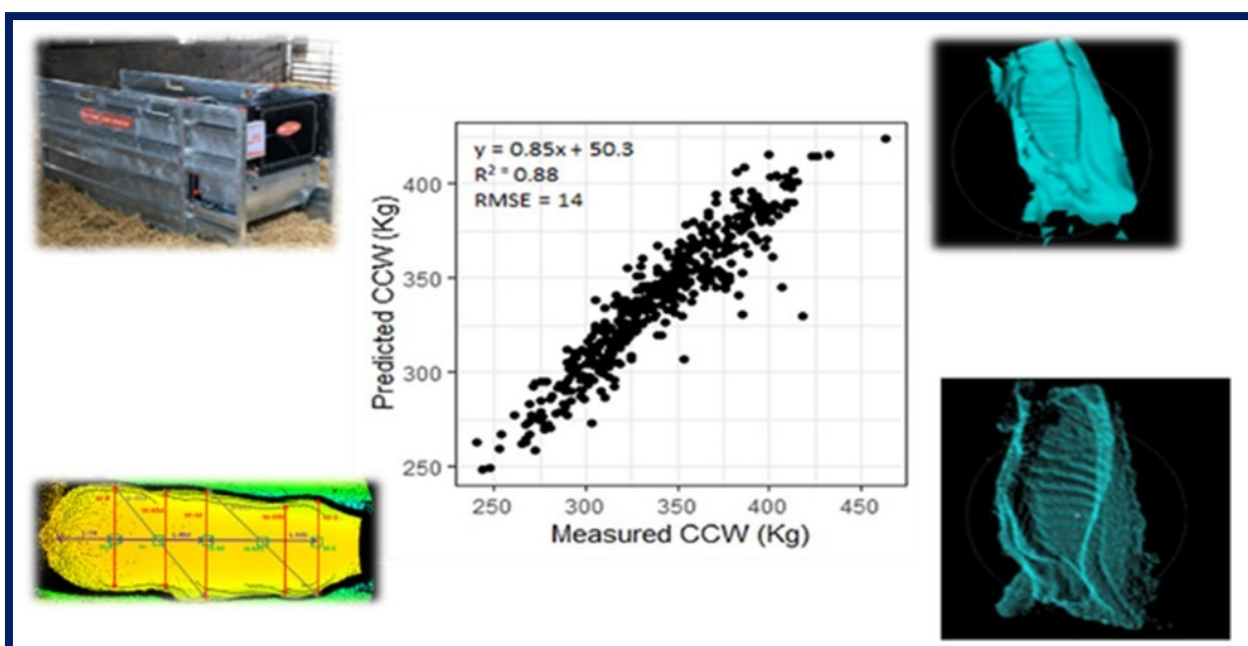


Figure 7. Pen mounted cameras enable remote 3D images of live animals. Using artificial neural nets these images are used to predict characteristics including cold carcass weights (CCW) and saleable meat yields.

- **Coffey**, **Denholm** and **Wall** have shown how machine learning and other data-driven approaches can be used to predict high value traits from routine milk samples including bovine TB (J Dairy Sci 2020) and animal energy status (J Dairy Sci 2019a). This has potential to inform animal management (J Dairy Sci 2019b), and remote and animal mounted measures can be used to predict final carcass value of beef animals (Front Sustain Food Syst 2019; Fig. 7; ICS C).

1.2.2 COVID-19 research



COVID-19 provides a vivid example of how the research capabilities in our Unit can be pulled together rapidly and effectively to address global challenges. More than 70 of our research staff have supported research tackling COVID-19, from the practical repurposing of our analytical laboratories to deliver >3,000 COVID tests a week (**Caldow**), to fundamental molecular virology, modelling/epidemiology and translational research. **Tait-Burkard** is a UK partner on a €78m initiative to find therapeutics for COVID-19, building on research into drugs used to treat other viruses. Immediate impact has come from **Tait-Burkard**'s input into the development of a highly sensitive, multiplexed RT-qPCR assay at a vastly reduced price compared to commercially

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available products, which has been used by a local NHS hub testing facility for diagnosis. **Grey** has leveraged expertise in animal transgenics to generate a pig model for COVID-19 disease and treatment.

Our diverse epidemiological modelling teams play central roles in providing the Scottish and UK Governments with data-informed predictions to underpin COVID-19 policy decisions. For example, **Kao** has developed an individual-based computer model of COVID-19 transmission in Scotland to help Health Protection Scotland better understand regional differences in risks and to plan for changes in control. Expertise of **Corbishley** and **Gally** in wastewater sampling has helped develop detection of the SARS-CoV-2 genome in sewage as a surveillance technique. Translational research has focused on using expertise developed during the 2009 influenza pandemic, **Digard** has been involved in testing/validating a variety of virus disinfection processes for SARS-CoV-2, ranging from banknotes, facemasks to whole rooms, as well as testing facemask efficacy. **Reeves** and **Gunn** have worked with NHS Scotland to understand the differences in transmission across Scotland and the potential implications of differing local management scenarios. Food chain analyses by **Revoredo-Giha** has focused on potential short- and long-term effects of COVID-19 on food production and supply.

1.3 Approach to Impact

Our knowledge exchange and commercialisation strategy aims to mobilise the knowledge generated from our research and deliver impact from it, translating evidence, expertise and experience into continuous innovation and uplift in the natural economy. We tailor our approach to impact for each of our key target audiences:

- **Animal health/biosciences/agri-food/veterinary companies and professionals.** Engagement via collaborative research. We have established strategic partnerships worth £9.4m with >30 companies across this sector, including Zoetis, Hill's Pet Nutrition, Genus PIC, Cobb Vantress, Hendrix Genetics and Worldfish.
- **Farm and land-based industries.** Engagement via co-funded participatory research, training and consulting including our network of 8 veterinary surveillance centres and farm and rural business support services in SAC Consulting Solutions.
- **Policy makers.** Engagement via membership of key government committees and dedicated policy-relevant communications. The Rural Policy Centre issues regular reports and briefings and provides the secretariat for the Scottish Government Cross-Party Group on Rural Affairs.
- **The public.** Engagement via website and media strategies, Massive Open On-line Courses (MOOCS), open days, public events (e.g. Edinburgh International Science Festival), and displays at UK agricultural shows. Our new Charnock Bradley building provides a home to the EBSOC, which provides a resource for teaching high school teachers and students.
- **Other scientific users.** Publication of high-quality research studies in appropriate journals and presentation of findings at key international conferences. For genomic resources we generate databases, and develop improved analytical tools to enable their access and utility.

In addition to our eleven Impact Case Studies (ICS), notable examples that demonstrate how we achieve impact through our strategy include:

Control of bovine tuberculosis (bTB) using genetic approaches



(animal health

companies, farm industries, scientific users, policy makers)

Woolliams and **Coffey** have shown that heritable resistance of Holstein dairy cattle to *Mycobacterium bovis* involves multiple loci of small effect (BMC Genomics 2017). Further they demonstrated genomic selection for bTB resistance based on SNP markers to be feasible and unlikely to affect the specificity or sensitivity of the skin test for bTB detection (Genet Sel Evol 2016). This led to the development of genetic evaluations for bTB risk, commercialised as the TB Advantage genetic index by the Agriculture & Horticulture Development Board.

Improving egg quality (bioscience companies)

Dunn has defined the origin and deposition of the cuticle in eggs (Biol Reprod 2017). Working closely with poultry breeders (Lohmann Tierzucht and Aviagen), **Dunn** has demonstrated that cuticle deposition improves egg biosecurity throughout the laying cycle and can be measured on hatching eggs without compromising embryonic development (Poult Sci 2019), with feasibility of genetic selection to improve egg quality and reduce losses in poultry production (Genet Sel Evol 2019). Ongoing industry-linked research is quantifying this impact and dissecting the underlying genomic architecture of the trait (BMC Genomics 2020).

BVD eradication (farm industries, veterinary professionals)

The Bovine Viral Diarrhoea (Scotland) Order 2019, monitoring inspections, and improved test regimes have been informed from research by **Humphrey, Reeves** and **Gunn** (e.g. Sci Rep 2018, 2019). This has decreased disease exposure from ~40% in 2010 to ~10% in 2019, and an estimated increase in farm business income of £2k-£14k, or ~£20-£70 per cow, depending on farm type. When aggregated across the industry, we estimate that the total benefits are ~£2.4m if all farms with a BVD 'not-negative' status completely eradicated the disease from their farms.

Longitudinal cohort study of companion animals (veterinary professionals, public)

We have developed the world's largest and longest running single breed dog cohort study. The health of >8,000 Labradors has been monitored for >10 years using a citizen science, owner-led web interfaced study design (Prev Vet Med 2015). This work by **Clements, Bronsvort** and **Schoenebeck** has defined novel ways to manage and clean large cohort datasets (PLoS One 2020; J Med Internet Res 2015), the incidence and risk factors of important diseases (Vet Rec 2016) and has highlighted that the incidence of important disorders is much higher than was previously reported (Prev Vet Med 2017).

Rural Brexit Hub (policy makers, farm and land-based industries)

Our close engagement with industry and policy stakeholders has led to a wide range of rapid research and policy analysis to inform alternative policy scenarios for food production in Scotland and the UK post Brexit (<https://www.ruralbrexit.scot>). **Barnes, S Thomson, Revoredo-Giha**, and **Costa-Font** studied the effect of Brexit on rural incomes, with households in less favoured areas predicted to be most disadvantaged (Land Use Policy, 2016 & 2020) and food supply, with demand for items such as fresh fruit sensitive to changes in prices and likely to drop post Brexit (J Int Food Agribusiness Mark, 2017).

1.4 Open ethical research

Open research

Our commitment to an open approach for all our research is underpinned with a suite of tools and support, including the Edinburgh International Data Facility and the Digital Research Services, to help researchers be effective with their data before, during and after completion of a research project. In addition to both partners' Institutional policies on open access (OA) (REF5a) our OA requirements are tracked monthly and tabled at our Unit's management meetings, reporting 96.3% OA compliance between 2016 and 2020. We use pre-print servers such as bioRxiv for rapid dissemination of findings prior to (or during) submission to journals for peer-review. We also promote our open research agenda across our stakeholders with the new research findings from our research portal feeding into weekly communications.

Unit-level environment template (REF5b)

Open data

Our SEBI programme hosts the Livestock Data for Decisions (LD4D) open resource (<https://www.livestockdata.org/>) for cataloguing and organising livestock data to make it more discoverable and digestible, priming interactions between data providers and users. In addition to the UoE DataShare archive (REF5a) and SRUC data repository (REF5a), we generate vast genome and transcriptome datasets that are shared via the EMBL-EBI European Nucleotide Archive or NCBI Sequence Read Archive with associated metadata, and via community-specific resources. We deposit proteome data via the PRIDE archive and software, and underlying code is openly shared on GitHub for use by others and to permit interrogation.

Where projects involve collaboration with industry, bespoke legally-binding collaboration agreements are negotiated that protect (wherever feasible) our ability to publish and share primary data. This is not always possible in relation to commercially sensitive data contributed by partners; however, publication is almost always permitted subject to scrutiny by the external party and protection of Intellectual Property (IP) where applicable. We avoid such restrictions on research students by protecting their IP position and need for academic freedom as projects are agreed. Annual assurance and mid-term evaluation of the Roslin Institute Strategic Programmes (ISPs) requires us to report our data management activities to the BBSRC. The RESAS programme in SRUC is supported by a live progress reporting system as well as annual reporting and metrics, and external mid programme review.

Research ethics and integrity

Our Institutional policies and codes of conduct (REF5a) are augmented at Unit level. Since REF2014 we have implemented more in-depth earlier stage scrutiny of research proposals with regard to: (i) required ethical approval (e.g. for licensed procedures under the Animals (Scientific Procedures) Act 1986, use of human tissues or studies involving veterinary patients, social science ethics of research engaging stakeholders) and associated licences; (ii) risk assessments (e.g. HSE or local consent); (iii) use or release of sensitive data; and (iv) details of resources required including animals and related facilities. This allows us to identify any concerns regarding research integrity, in particular the ethical use of animals in research, appropriate uses of human or veterinary samples and data, conflicts of interest, compliance with relevant regulations, potential misconduct, and the opportunity to decline proposals to funders on ethical grounds if appropriate.

Our premises are regularly inspected to maintain their Home Office Certificate of Designation and all work covered by the Animals (Scientific Procedures) Act 1986 is conducted under Home Office project and personal licence authority. Licensee training and competencies are regularly updated. All requests for animal use and study plans are scrutinised by the local Ethical Review Committee. This includes overseas research which is expected to comply with UK standards. For clinical research studies undertaken under the auspices of the Veterinary Surgeons Act, all activities are scrutinised by the Veterinary Ethics Research Committee. Our client consent forms and information sheets are regularly reviewed and updated so that there is high client engagement in our research.

Since REF2014 we have made significant advances in the 3Rs, notably stem cell and organoid models, strategies for screening libraries of strains or mutants in pools, welfare gains via environmental enrichment, and humane protocols for euthanasia. We have introduced annual 3Rs events to promote awareness and share good practice. We promote adherence to ARRIVE guidelines for reporting animal research and have signed the Concordat on Openness in Animal Research.

Our researchers operate under a Quality Assurance scheme compliant with the Joint Funders Code of Practice for Research and receive training at induction. Laboratory-based research is documented in indexed hard-bound notebooks counter-signed weekly, scanned on completion and retained for at least ten years. Electronic data are retained for the same period on Institution-owned, secure and resilient storage. Data are critically reviewed by the investigators via weekly

Unit-level environment template (REF5b)

meetings and are subject to appropriate statistical tests to ensure that studies are adequately powered to justify conclusions, supported by Biomathematics & Statistics Scotland. Electronic data (e.g. nucleotide sequences, transcriptome or proteome datasets) are submitted to curated databases with associated meta-data in compliance with funder expectations and data sharing policies.

1.5 Future aims

Our research delivers high quality challenge-focussed findings to help understand and transform the world around us, locally and globally. Working in partnership with industry, policy and society our staff and students will collaborate to design, develop and deliver our underpinning strategy of driving real world solutions to the challenges we face. We seek to address major challenges based around these UN sustainable development goals:



We have identified specific areas of new opportunities for joint activity and co-location, with the purpose of leveraging future investment and funding opportunities, maximising the impact of our research, and providing a world-leading research environment for our students and staff. We anticipate these areas may coalesce into centres once they achieve critical mass and sustainable income over the next 5-10 years.

Epidemiology and One Health Centre

Building on our contributions to EPIC for Scottish Government and SEBI to the benefit of low and middle income countries, this disease outbreak science and policy unit will provide rapid data-driven intelligence enabling robust and rapid disease control decision-making within the UK and globally.

Centre for Aquaculture Genetics and Health

Existing investments in research aquarium facilities, development of genotyping tools and genome editing technology for key aquatic species, and strategic partnerships with Worldfish and Hendrix Genetics, will be further enhanced to improve aquaculture breeding programmes.

Centre for Data Driven Breeding

In partnership with breeding companies, we will develop advanced approaches to genetic improvement of crops and livestock, integrating the latest genomic and data science methods.

Centre of Dairy Innovation

Based at our Barony Campus, this centre will support dairy industry-led research, encourage knowledge exchange and create innovation across the sector.

Challenge Driven Research to drive innovation and change in the natural economy

We will establish a virtual Challenge Driven Research Centre that breaks down traditional 'boundaries' between disciplines, academia with industry and society, and geographies. We will promote interdisciplinary challenge focused research and impact, in collaboration with industry and policy stakeholders to address the needs of the natural economy responding to the global climate emergency whilst producing safe and improved food and maintaining a thriving natural capital, and future food systems through the use of data and digital innovation.

2. People

2.1 Staffing strategy

Our strategy for enhancing strength in our themes and our future aims is centred on: (i) appointments of scientists who are world leading in their fields, or early career researchers (ECRs) on upward trajectories to be future leaders, (ii) developing careers through mentoring and continuous professional development within (iii) a framework of opportunity which is founded on the principles of equality, diversity and inclusivity (EDI), support, development, health and wellbeing. Our strategy ensures that we have a healthy research base with the breadth, depth and long-term stability of skills, expertise and experience, in order to deliver our research vision, develop solutions to critical challenges and ensure global impact. In this way, our strategy makes major contributions to addressing vulnerable skills and capacities identified in cross-Council reviews by UKRI (e.g. <https://mrc.ukri.org/documents/pdf/review-of-vulnerable-skills-and-capabilities/>).

Recruitment policy

Key to our strategy is regularly reviewing our skills base, mapping this to our current and emerging needs, and integrating this with succession planning and recruitment. As part of this process, we hold regular 'away days' to reflect on and refresh our research strategy, assess and refine our short-to-medium term strategic objectives and identify gaps or vulnerabilities to inform our succession planning. Our strategy is to combine external recruitment of established researchers with development of ECRs to group leader status through competitive fellowships, and to address any imbalances in gender.

Our research staff numbers have increased since REF2014 to 257.23 FTE (Fig 8), through recruitment of 66.6 FTE new research leaders (48% female). This includes 15 new professorial staff to our Unit (**Djikeng, Baggs, Raybould, A Duncan, Kao, Opriessnig, Hopkins, Argo, J Newbold, C Newbold, Foster, Powell, Thakur, Mackay, Holden**), and new appointments to the Global Academy (**Simm, Baggs, A Duncan, Moran, Boden,**

Raybould, Hillier, Jarvis, Alexander, Gathorne-Hardy, Shields, Jaacks, De Oliveira Silva). This enhances our disciplinary breadth and interdisciplinary approaches, for example in soil biogeochemistry, environmental modelling, epidemiology, biorefining and processing, precision ruminant nutrition, food safety, food policy, rural entrepreneurship and quantitative crop breeding. We have invested in joint appointments with other UoAs: 2 x 0.4 FTE joint academic appointments with UoE's School of Geosciences, 0.7 FTE with UoE's School of Social and Political Science, and 5 joint posts in One Health with UoE's Medical School (returned to UoA1).

2.2 Training and development

Recognising and rewarding excellence

We provide a positive work culture where staff are nurtured, supported, recognised and rewarded. Since REF2014 we have established training budgets (averaging £44k p.a.), and have introduced and implemented universal and simplified personal development reviews (PDR, UoE; 'Making Performance Matter', SRUC), with 100% compliance. During these, staff discuss with their line manager progress against agreed objectives for the previous year, target setting for the next year,

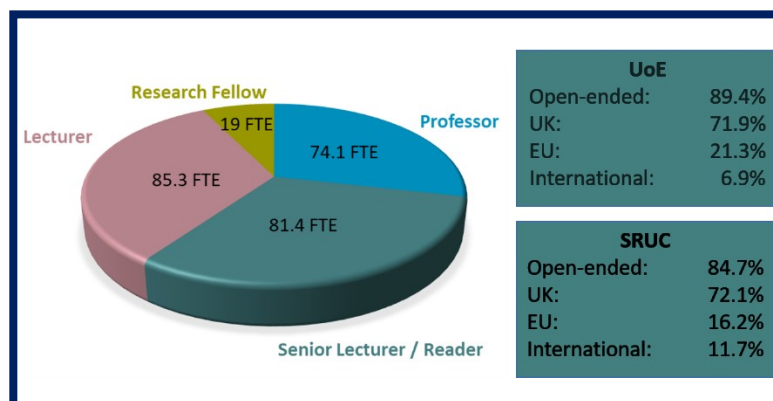


Figure 8. REF1a staff profile at census date.

Unit-level environment template (REF5b)

opportunities for their career development, and workload and balance of responsibilities. Within this framework, all new staff prepare objectives with their line manager as part of their probation period, are given up to 50% lighter administration and teaching responsibilities during the first year and are provided dedicated research space.

Since REF2014 we have transformed our approach to promotions, resulting in 12 successful promotions to Professor, 17 to Reader, 26 to Senior Lecturer, and 8 to Senior Researcher at UoE, and 13 to Professor, 3 to Reader and 3 to Senior Lecturer at SRUC. We now consider all staff each year for their readiness for promotion and performance related pay awards, rather than relying on self-nomination. An annual presentation to all staff on the academic promotions and contribution awards processes, contains key factors for each staffing grade and information on special circumstances, feedback and appeals. We explain the different pathways to promotion, including clinical, teaching and research, provide exemplars for each, and explain the paperwork and timescales required for application. For academic staff this is an annual process. For support staff a review of grades, incremental and lump sum awards occurs biannually.

Research leave, links and secondments

Researchers with 3 or more years' service can request leave to engage in study or research to accrue strategic and/or financial benefits to our Unit that align with our strategic aims. For example, a sabbatical year for **Wemelsfelder** at the University of Aberdeen helped in the development of interdisciplinary understanding of animal welfare (ICS H). We also offer the opportunity to undertake secondments to industry and policy bodies. We foster innovation and entrepreneurship through enterprise fellowships, industry and policy placements and secondments, partnership awards and impact accelerator/pump-priming funds, making full use of devolved funding schemes such as BBSRC Impact Accelerator Awards, Flexible Talent Mobility Awards, ISCF seeding awards, Wellcome ISSF and MRC Confidence in Concept awards. Several of our staff (e.g. **Woolhouse, Mellanby, Farquharson, MacRae, Digard, McLachlan, Fitzgerald, Tait-Burkhard, Gally, Vazquez-Boland, Dallman, Wishart, Rainger, Vernimmen**) benefit from One Health links with the Edinburgh Medical School and Biological Sciences (UoAs 1, 4 and 5), enabling access to facilities and related expertise.

Career and personal development mechanisms

A range of development opportunities are available to our staff, from Institutional level support for all staff, bespoke support for specific career stages, through to bespoke Unit provision. Supporting people and rewarding excellence is core to the SRUC People Strategy (launched 2019). As part of a workforce transformation plan the progression pathway in SRUC is being harmonised across academic job types. Our Above & Beyond Awards recognises all people working for SRUC and the impact they make.

We have implemented additional support measures to help our researchers through the COVID-19 pandemic, including specific peer groups for staff and students on-campus and online. Since REF2014 we have established a **Careers Development Committee** for the Easter Bush campus, which aims to support career development through the provision of local support with representatives from all career stages. The group organise training events and activities, including a 'grant writing course' and an annual 'coaching for success' programme. We also benefit from training provided to UoE through the **Institute for Academic Development** (IAD) and participate in the Mentoring Connections scheme coordinated by IAD and Human Resources. We have introduced a range of handbooks to bring together useful information, policies and sources of advice for different groups on-campus, including 'support for parents', a 'postgraduate student handbook', and a 'postdoc handbook'.

2.2.1 Support for principal investigators

In addition to the above, we offer bespoke support and development opportunities for our more established researchers. During the REF2021 period 12 of our staff were supported in senior

Unit-level environment template (REF5b)

leadership training, 18 on 'first steps into leadership and management', 2 on our 'aspiring manager programme', and 4 on 'introduction to management'. The opportunity for selection for our 'strategic leadership in research' programme is available to staff able to demonstrate evidence of big grant readiness. In addition to pitching research ideas, this programme also offers wraparound support such as coaching, mentoring and action-based learning sets. Our Leadership Academy (established 2018) is a bespoke development programme designed to develop capability and capacity for the future. The programme based around the Insights Leading Transformational Change model has trained 16 new leaders. For PIs within our Unit we also provide:

- A research-mentoring scheme for clinical academics.
- An open plan physical research environment that promotes interaction amongst staff members.
- Joint weekly Easter Bush Research Consortium seminar series and multi-site virtual seminar series with invited external speakers.
- Regular 'retreats' to develop research strategy and ideas.
- Allocation of some of the Roslin Institute ISP funding to catalyse inter-disciplinary work across PIs to prime grant proposals and future ISP objectives.
- Investment of BBSRC strategic funding to protect and develop vulnerable skills and capacities at the Roslin Institute, including through core-funded staff supporting investigators, animal facilities and technology platforms. At the time of submission ~75 are jointly funded by BBSRC and UoE via ISPs and a Core Capability Grant totalling £32m for 2017-2022.
- SRUC has adopted the use of the Vitae Research Development Framework within the annual Making Performance Matter meetings. This allows individual development actions to be evaluated and tailored programmes for researchers to be developed at all stages of their job progression. More general researcher skills events are run throughout the year, including skills sessions on grant development, postgraduate supervision, and data skills.
- SRUC holds a monthly meeting of research active professors to which key governmental, industrial and international representatives are invited to discuss current trends and opportunities.

2.2.2 Support for early career researchers (ECRs)

Initiatives to promote career development and opportunity for all ECRs in our Unit include:

- Continued recruitment of ECRs under the University of Edinburgh Scientific Academic Track (ESAT) scheme, underpinned by ~£2m (since REF2014) for start-up funding, facilities and mentoring to help individuals transition to fully independent research leaders.
- Internal funding to support staff to enrol for part-time postgraduate programmes, including PhD research.
- Strong formal mentoring programmes to support new members of academic staff and early career scientists.
- All postdoctoral fellows and early career researchers are eligible to apply for tenure track roles and are encouraged to develop their independent research through applying for minor grants, being named as co-investigators on major research projects, and supervising Masters and PhD students.
- A number of opportunities to support ECRs develop their early-stage translational projects and skills. These include funding (e.g. Wellcome Trust iTPA Springboard) and training opportunities (e.g. Science Entrepreneur Experience, SPARK and IGNITION).
- Publication of a clinical academic roadmap (**Mellanby, Argyle**; Vet Rec 2015) to help the veterinary profession become more successful in producing the next generation of clinician scientists.
- Development of a pan vet school research mentoring scheme connecting mentees with experienced mentors (<https://www.vetschoolscouncil.ac.uk/research/vsc-research-mentoring-scheme/>).

ECR recruitment

The strategic recruitment of ECRs provides a strong cohort to take our Unit forward over the next 10-15 years and ensure effective succession. As such, ECRs are an integral part of our research community and culture. The recruitment of independent research fellows (salary supported by their grant income) is a key component of our strategy (Table1).

Table 1. Independent research fellows appointed across our Unit during the REF2021 period.

Fellowship scheme	Fellows
Chancellor's fellows (SFC International Excellence Initiative)	Clark, De Oliveira Silva, Gorjanc, Hassan, Jaacks, Schoenebeck, Vernimmen, Lycett
Roslin Institute	Bean, Connelley, [Rainger], Robledo, Robert, Balic, Tait-Burkard, Diack, J Smith, Lynskey
UoE Career Track	Grey, Prendergast, J Stevens, Davey, Wiener, Wishart
SRUC Challenge Fellows	Rudman, Fuentes-Montemayor, Burns, L Novo, Li, van Munster, Gupta, Bergero
Wellcome Trust	Gaunt (Sir Henry Dale), Hoyle (career re-entry), Morgan (clinical research career development)
SRUC Academic Research Fellows	Ramos-Morales, P Morrison, Sharma
Wellcome Trust for ECAT-V	Paris, C Davidson, Madden
UKRI Future Leaders	Rainger
BBSRC Discovery	Muwonge

Since REF2014 we have established formal tenure track schemes. The **Edinburgh Scientific Academic Track** (ESAT) provides bespoke career development training, mentoring and a transparent, milestone-driven pathway to achieving an open-ended UoE staff contract within 5-7 years. This can include further fellowships such as UoE Chancellor's fellowship, Roslin Institute fellowship, MRC Career Development Award, Wellcome Trust Sir Henry Dale Fellowship or equivalent, with open-ended employment with UoE at an appropriate level, subject to a successful review in the final year of the fellowship. Similarly, SRUC have made strategic investments in **Academic Research Fellows** and **Challenge Fellowships** to support development of the future Challenge Driven Research Centre.

These initiatives have helped us to appoint 42 Fellows to our Unit since REF2014 capitalising on our vibrant research environment to fast-track their careers. These appointments embed capability in bone physiology, skeletal development, avian transgenics, livestock genomics, genetics and epigenetics, and pathogens and inflammation, climate change, food production, food security, digital innovation and growing the natural economy. In addition, **Wellcome Trust support for ECAT-V** has allowed us to offer prestigious 6-8 year awards to 12 high performing, early career veterinary academics across a wide range of clinical specialism. During their PhD the vet clinicians spend time away from speciality in world-leading research groups before returning to either complete postgraduate clinical training or work as a senior clinical academic. Post completion of clinical training and PhD, the ECAT-V lecturers receive bespoke mentoring and management of their clinical load to ensure that they are highly competitive for subsequent postdoctoral fellowships.

2.2.3 Support for postdoctoral research fellows

Postdoctoral research fellows are the life-blood of our Unit, and we are committed to ensuring their time with us is both productive and enjoyable and sets them up for a successful career. In addition to the above support for ECRs, we offer bespoke support for postdoctoral researchers (whether core- or grant-funded) to support them develop their early-stage translational projects and skills. These include:

- A postdoctoral committee to support and develop the postdoctoral community by organising activities to facilitate career development and by promoting social interaction. This committee is represented on our Careers Development Committee.
- Working closely with the IAD, we provide bespoke training courses on campus, for example 'making the most of your postdoc - strategies for independence'. We also provide a budget for attending external courses.
- A postdoctoral handbook providing a welcome message, guidance on living in Edinburgh, working at our campuses, career development and support, knowledge exchange, and social life.
- An early career grants scheme for PhD students and ECRs to apply for up to £3k to develop their own research ideas in preparation for external grant and fellowship applications.
- A weekly post-doctoral-led seminar programme for PhD students and post-doctoral scientists to share their research, including weekly seminars by video across our campuses.
- Our clinical community have monthly Grand Rounds where internal and external speakers present novel research findings.
- Our Challenge Fellows hold a regular weekly seminar series to discuss shared research interests and funding opportunities.

2.2.4 Support for technical and support staff

We offer dedicated support for our 585 technical and 411 academic support staff, including career development and professional registration. Both Institutions have signed the Technician Commitment in 2017 recognising the key role technicians play in research, teaching and supporting students (<https://www.ed.ac.uk/technicians/technician-commitment>). This Commitment aims to support technicians to gain skills and recognition through registration with professional bodies, accreditation and training courses, enhance the visibility of technicians and to offer documented career pathways with clear processes for grading and progression. We encourage working across themes and groups to enhance the repertoire of skills that technicians acquire and their profile. Where technicians have contributed to the design, execution and analysis of research our expectation, in accordance with our Fair Publication Policy, is that they are co-authors of resulting publications.

2.3 Research students

Our high-quality research training environment is home to a vibrant postgraduate student community. Since REF2014, our Unit has registered 318 postgraduate research students (Fig. 9), of whom 53 were co-supervised between UoE (this Unit) and SRUC staff. The international draw of our programmes is evidenced by 35.8% of our registered postgraduate students being from outside the UK, from 54 countries, and 25.2% from outside Europe.

Funding and recruitment initiatives

Since REF2014 we have initiated 7 new funding streams and have enhanced the training and support available. External funding is mainly through doctoral training programmes (DTPs) from UKRI (UoE led BBSRC EASTBIO, MRC Precision Medicine, ESRC SGSSS and NERC E4), five Wellcome Trust programmes (Hosts, Pathogens and Global Health; Integrative Cell Mechanisms; One Health Models of Disease: Science, Ethics and Society; Translational Neuroscience; and for clinicians ECAT-V) and charities and other bodies (e.g. the Dogs Trust, Darwin Trust, BPEX, Pfizer, HBLB, ScotBeef and the Horse Trust). We have joint PhD programmes with the Pirbright Institute and with the Universities of Glasgow, Stirling, Aberdeen and Leiden, and co-supervision with other Institutes (e.g. the James Hutton Institute). Studentships are often match-funded by UoE or SRUC. We are also successful in attracting industry funding, and typically ~10% of our students are supported by industry partnerships.

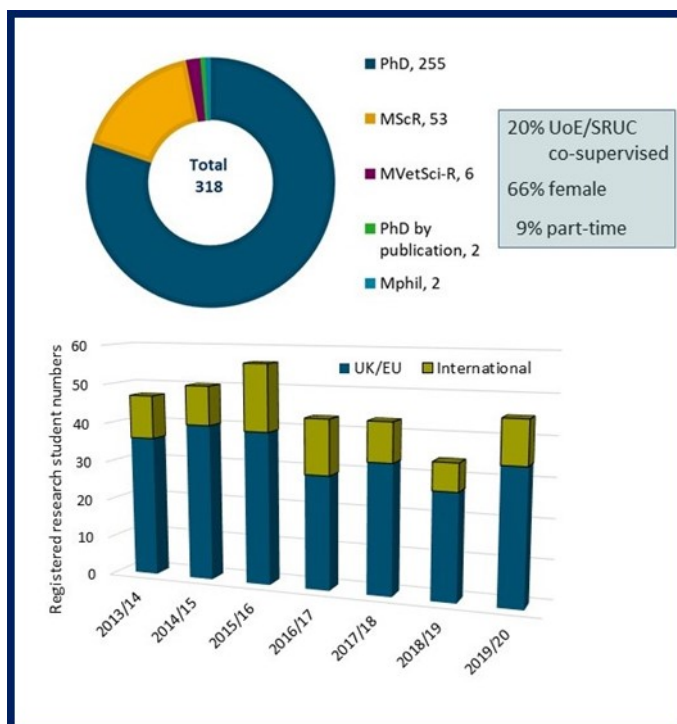


Figure 9. Registered postgraduate research students, new intake per year.

International students are mostly funded on competitive scholarships from their country of origin. We also capitalise on our engagement with international partners, for example the National Institute for Animal Biotechnology in India. Across the REF2021 period we have offered additional support to 20 international students through UoE's Global Research Scholarships, the Principal's Career Development Scholarships that are focused on career development opportunities (undergraduate teaching, entrepreneurship, public engagement), as well as initiatives such as the BBSRC Newton Fund partnership scheme. This diversity of funding enables us to ensure that all PhD students have a research budget of at least £18k for the duration of their studentship.

Our recruitment activities are founded on our EDI policies. All PhD projects are advertised on our Institution websites, FindaPhD.com, DTP-specific websites and through Learned Societies communications. We advertise more projects than we have places to fund, making all calls competitive. All projects and student selections are reviewed by the Postgraduate Committee. We also ensure that projects will provide appropriate training, sufficient funds are available, and that supervisors receive EDI training and attend a supervisor training event every 5 years. We ensure that all shortlisting and interview panels have male and female representation, and include at least one PhD Division convener. It is mandatory for all involved in selection and recruitment to have up to date training in recruitment and selection, and in unconscious bias.

Support and monitoring

Each student is affiliated to a research Division/Department with its own postgraduate research convener, who assists the Postgraduate Director (**Farquharson**), and who are the primary contact for students requiring advice or guidance. Each postgraduate student has a minimum of two supervisors and a thesis committee, comprising supervisors, an external advisor and an independent chair. Formal reports are presented to the thesis committee at 10 weeks, 9 months, and then annually until completion. We offer flexibility in our programmes, for example, part-time

Unit-level environment template (REF5b)

MReS and PhD programmes for those unable to study full-time, the opportunity for staff to undertake PhD study, and PhD by publication. All SRUC students within our Unit are registered with UoE, and in 2020 SRUC Doctoral Colleges were established to bring together postgraduate communities (students and supervisors) across different campuses.

Our Postgraduate Support and Advisory Committee, chaired by the Deputy Postgraduate Director (**J Stevens**), gives consideration to individual student and supervisor needs and circumstances. New initiatives arising from this committee include guidance on mental health and wellbeing. The success and vibrancy of our postgraduate programmes and student support is evident from the latest Postgraduate Research Experience Survey (PRES 2019) in which 85.7% of our students reported overall satisfaction. We host numerous community-building activities, for example a residential induction event held at UoE's Firbush Outdoor Activities Centre in Perthshire. In addition, the Easter Bush Society organises social events, external speakers and provides opportunities for students to practice presentations and discuss their research in an informal environment.

Skills development and career preparation

Our aim is to equip students with the funding, resources, training, supervision and career guidance to complete innovative, high quality research, to submit their thesis within four years and assist them into the next stage of their careers within the veterinary and food system sectors. Career choices are varied, with many pursuing careers outside academia that require bioscience and computational skills, and we aim to develop and train highly skilled, adaptable, resilient and employable postgraduates. Initiatives include:

- Experience and bespoke training in teaching, data science, entrepreneurship and public engagement activities, alongside our research staff, with dedicated time (180 hrs p.a.) for this allocated within the UoE's Principal's Career Development Scholarships.
- Experience of supervision and project management through our talent pipeline to postgraduate research, for example a summer research student programme for ~30 3rd year veterinary students, and 15-20 honours project students p.a.
- Research project embedded as part of the clinical speciality training of our clinical residents. These students can also undertake a Masters degree by research (MRes).
- Students with SRUC are eligible to receive dedicated training in statistical and bioinformatics techniques from **Biomathematics and Statistics Scotland** as part of SRUC's engagements with the RESAS programme.

Each student has a training needs assessment at the start of their study, which is refreshed at each thesis committee reporting stage. Our student induction includes guidance about internal training events and courses offered free by the IAD, which integrates transferrable and scientific skills as outlined in the Vitae Researcher Development framework. Within the suite of courses offered by IAD are courses aimed at postgraduate research students.

Our students have many opportunities to present their work to internal and external audiences, and a fund of £500 for conference attendance is available to each student. Our annual postgraduate research days are devoted to posters and oral presentations for all postgraduate students, including clinical residents. These conclude with the Charnock Bradley Lecture, given by an eminent researcher, and there are cash prizes of more than £1,500 in total awarded to the three best talks and posters. In addition, our students have also presented at meetings of BBSRC Institutes, and SRUC-based students take part in an inter-Institute competition among the Scottish Government Main Research Providers, culminating in the Science for Life Lecture.

2.4 Equality, diversity and inclusion

We are committed to EDI and eliminating discrimination and prejudice in all our business to foster a more diverse and inclusive Unit. This has resulted in measurable positive change since REF2014. Most notably, since 2014 we have:

- Achieved **Athena SWAN Gold status** for the Roslin Institute (2017), and **Athena SWAN Silver status** for the R(D)SVS (2018). Our EDI team received the UoE Principal's Medal for Exceptional Service in 2018. In 2019 the Easter Bush Campus was awarded silver for **Investors in Young People** demonstrating our commitment to providing opportunities and experience to local youth within our community. SRUC is working towards recognition of its efforts in promoting EDI across the organisation and with stakeholders, including membership of the Athena SWAN charter with imminent application for bronze status. These activities are helping us address gender balance (female staff currently comprise 40.2% of our Unit), and increase the proportion of black and ethnic minority (BME) staff (Staff surveys 2020: UoE 6.9% of staff, 85% responders; SRUC 17.1% of staff, 95% responders). Since REF2014 13 of our female staff have participated in Aurora leadership development.
- Established an Easter Bush Equality, Diversity and Inclusion Group (EB-EDI) with convenors from across the campus and representing academic, professional services staff and postgraduate students. EB-EDI organise a range of events and training, for example LGBT-STEM Day, monthly Rainbow Cake Socials, mental health first aid training, mental health awareness training, and "Where do you draw the line" training aimed at highlighting and addressing bullying and harassment.
- Joined **Stonewall Diversity Champions**, a leading employer's programme, and community of >750 employers, that ensure all LGBTQI+ staff are accepted without exception in the workplace, and help to create inclusive, accepting environments. UoE has increased its ranking by 200 places in the Stonewall Workplace Equality Index in the past 4 years (ranked 121st in 2019, up from 321st in 2015).
- Established the Easter Bush **Careers Development Committee** to support and develop good practice, particularly with regard to recruitment and development of academic and postdoctoral research staff.
- Opened an on-site nursery (section 3), a gym (2018), and facilities for cyclists, walkers and runners on our campuses.
- Embedded policies to promote EDI, including expectations for representation of women and minority groups on committees, interview panels, panels reviewing applications for devolved research funds, and amongst our seminar speakers and at academic events. For example, we ensure that 50% of our seminar programme speakers are women.
- Introduced mandatory training for all staff in equality and diversity, unconscious bias, and bullying and harassment.
- Developed a **Coaching for Success** programme in collaboration with EQUATE Scotland, a Scottish Government organisation that supports women in STEM careers. Since it started in 2017 we have supported an average of 12 staff each year for 12 sessions each, with 3 coaches assigned to the programme.
- Established a **Rainbow Staff Network** (2020) with the aim of providing mutual support, encouragement and mentoring to LGBTQI+ staff and raise the visibility of LGBTQI+ issues. This is part of our staff engagement and working with senior management to create a diverse and inclusive working environment.
- Hosted a reception at the Scottish Parliament to celebrate and extend engagement with our international work on advancing gender equality in science.

Our approach toward flexible working has helped enable 11.9% (UoE) and 33.0% (SRUC) of staff and 9% of research students in our Unit to work part-time or flexibly across the REF2021 period. Since REF2014 we have embedded a suite of equality, diversity and family-friendly policies, flexible and part-time working, and carer's grants (up to £400) that are linked to our training programme and to facilitate travel and conference attendance. Remote working is encouraged, where helpful, and facilitated by seamless access to University computer servers via the Virtual Private Network. We take a sympathetic approach to requests for extended periods of paid carers leave, bereavement leave and leave for other exceptional circumstances, with provision well in excess of statutory entitlements, working with staff to reallocate their work, negotiate extensions to research grants and enable phased returns to work.

Unit-level environment template (REF5b)

We are committed to removing barriers to employment for disabled people and provide services to support the needs of disabled staff and students, to develop and perform to their full potential. In addition to provision of reasonable adjustments where required, we provide: assistive technology (software and hardware); disabled parking on all our campuses; and office and lab space suitable for any individual needs. The UoE disabled staff network provides a confidential environment to share experiences, best practice, gather ideas on disability issues, inform the UoE approach to creating an inclusive and supportive culture, and raise the profile of disabled people and disability within UoE and beyond.

We have also established the **Easter Bush Youth Forum**; an initiative in partnership with Investors in People and the Scottish Government, representing all campus staff aged 16-28, including apprentices, PhD students and veterinary nurses, with the aim of easing the transition from school or University to a career at Easter Bush. This ensures every new start has a 'buddy', improves awareness of avenues for help and training, and creates a platform for younger staff to express their views.

Supporting staff in their career pathways

We provide support and career development opportunities for researchers at every stage of their careers (see above), but placing special emphasis on important transitional stages, promotions, new appointees and ECRs. Since REF2014 we have implemented a range of focus groups and communication forums, for example the postdoctoral society and committee, and facilitate access to wider resources such as the UoE Athena SWAN network and EQUATE Scotland. To embed EDI in career pathways we have introduced new initiatives since REF2014, including:

- Financial support for additional childcare expenses (e.g. care provider costs, travel expenses of care provider) enabling a researcher to attend work-related conferences and training events. This is a biannual call for applications of max value £400 per applicant.
- We advertise opportunities such as vacant/new roles or committee membership to all staff, and we adhere to our EDI policy in all our internal and external recruitment processes, actively encouraging underrepresented groups to apply.
- We self-monitor all our committees to ensure they are gender diverse.
- We review recommendations for promotion or pay awards for evidence of gender or ethnic imbalance, or bias against part-time staff, at each stage of the process.

REF submission and codes of practice

We adopted the respective REF2021 **Codes of Practice** of the UoE and SRUC (REF5a), underpinned by six guiding principles: transparency, consistency, accountability, inclusivity, quality and application for the purposes of REF2021. Both Institutions shared their respective Codes of Practice, supported with a Memorandum of Understanding and Data Sharing Agreement. We agreed a common set of criteria and selection process that adhered to both. Information about any staff circumstances was not shared.

In line with our Codes of Practice, we adopted an inclusive approach to defining 'independent researcher', and embraced the decision to return 100% of eligible academic staff, which builds on our inclusive submission to REF2014 (90% of eligible staff). We adopted a rigorous, fair and transparent approach to selecting outputs, fully accounting for staff special circumstances which have affected their research activity. The process took full account of EDI considerations, building in unconscious bias and EDI training. We also set up an independent EDI group to review the distribution of outputs across staff by gender and career stage (noting that we were unable to access accurate data on other protected characteristics because of the voluntary nature of the information and constraints to updating personal details). The result of this review demonstrates that 29% of outputs submitted are authored/co-authored by female staff (who comprise 40.2% of our staff); 24.2% by ECR/Lecturer staff/Senior Research Fellow (36.9% of our staff). Overall, 70.1% of staff contributed 2 or more outputs. Output nomination was

Unit-level environment template (REF5b)

undertaken as part of our commitment to the San Francisco Declaration for improving how research is assessed (DORA), and our published principles on use of quantitative data and metrics on research activity.

3. Income, infrastructure and facilities

3.1 Income

Strategic investments from the BBSRC and Scottish Government

Our research benefits from BBSRC strategic investment in the Roslin Institute and Scottish Government investment in SRUC via RESAS. These investments include five-year funding cycles for specific research programmes and for underpinning infrastructure and expertise.

UKRI strategic investment at the Roslin Institute of £52.0m spanned 2012-2017 (five Institute Strategic Programmes and 2 National Capability Grants) and 2017-2022 (three Institute Strategic Programmes, a Core Capability Grant and transitional funds) to sustain:

(i) The running costs (staff, utilities, consumables) of our large animal research facilities (mammalian, avian and aquaculture species) and other research infrastructure (bio imaging, genome sequencing, proteomics and metabolomics; research administration).

(ii) Institute Strategic Programmes (ISPs) that underpin specific research activities by contributing to academic and research staff salaries, and providing modest support for research consumables and pump-priming new research activities.

Scottish Government supports SRUC through income of £34.8m (since REF2014) for: delivery of the Environment, Agriculture and Food strategy research programme; maintenance of key underpinning capacity, including the Langhill Dairy Herd; and participation in centres of expertise in Animal Disease Outbreaks (EPIC; also with UoE), Plant Health and ClimateXChange (section 4).

Strategy for generating income

During the REF2021 period, we have purposely shifted our focus from discipline-based research towards solutions that align to more immediate challenges in society and for policy agenda for the next two decades. Our joint strategy to achieve this was to:

- Foster a vibrant, collaborative research community, equipped with the time, resources and scientific query to strengthen individual and collective interdisciplinary research portfolios.
- Actively support diversification in our funding portfolio, enabling a range of income from individual fellowships to large multidisciplinary awards.
- Adopt flexibility to align with the changing nature of critical challenges, and in response to the funding environment shift towards challenge-led research and impact.
- Evolve and enhance our strategic partnerships and investment in world-leading infrastructure and facilities.

Underpinning this strategy are mechanisms to promote research excellence. For example, we host core events, including workshops (e.g. BBSRC Cross Institute workshop on predictive breeding in 2018) and research think tanks and retreats (typically focused on imminent funding initiatives), host seminars and symposia (formal and informal) and journal clubs, inviting internationally renowned scientific leads to meet with our researchers and discuss current and future collaborations. Edinburgh Innovations Ltd (section 4) has embedded business development and legal executives at Easter Bush to facilitate our relationships with commercial partners and

Unit-level environment template (REF5b)

external collaborators. SAC Commercial Ltd enhance SRUC's commercially related activities in linking research to end user practices.

Current income and examples of success

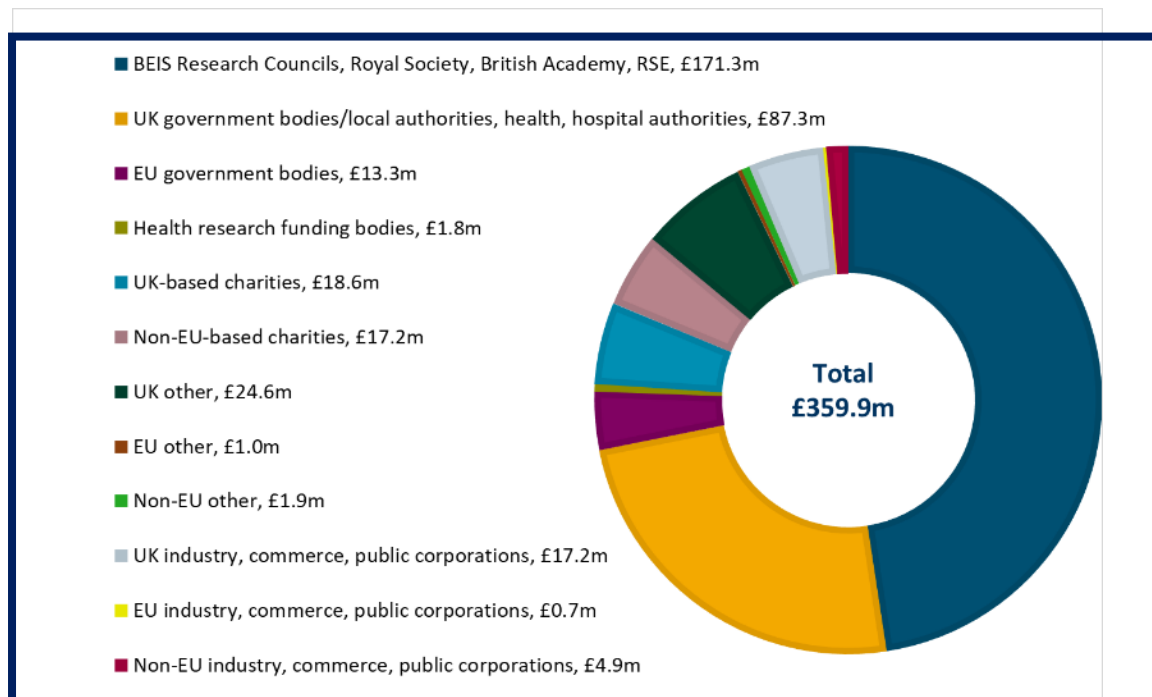


















Figure 10. Total research income by HESA category, 2013/14 to 2019/20.



The success of our strategy is evidenced by the magnitude and diversity of our funding sources, reflecting the multidisciplinary and complex nature of the critical challenges we seek to address. Our combined Unit income (excluding internal investment or infrastructure) has seen a 42.8% increase since REF2014 from £38.8m in 2013/2014 to an average of £51.4m p.a. (total £359.9m during the REF2021 period; Fig 10). This is mainly due to successes in (i) competitively awarded grants from UKRI, UK governments, the EU, and UK (Table 2), (ii) research contracts and partnerships with commercial entities, and (iii) the above strategic funds, competitively awarded on a five year cycle, from the BBSRC to the Roslin Institute and from the Scottish Government to SRUC. This has been supplemented with capital awards from UKRI and UK and Scottish Governments. The increase in competitive funding is also a reflection of SRUC's eligibility for UKRI funding since 2011 and throughout this REF period. Unit-wide funding successes since REF2014 also include our Doctoral Training Partnerships: renewal of the BBSRC EASTBIO and NERC E3/E4 DTPs; award of the ESRC SGSSS DTP; two cycles of the Wellcome Hosts, Pathogens and Global Health DTP; and a £4.5m Wellcome One Health Models of Disease DTP.

Table 2: Examples of personal funding successes >£0.5m, from across our Unit.

Unit-level environment template (REF5b)


Funded Research >£0.5m		
BBSRC	<p>Hickey £1.2m, precision breeding of broilers. Archibald, £1.9m, functional annotation of animal genomes. Hickey £746k pig muscle causal variation. Hume £685k transcriptome atlas for Indian buffalo. Roehe, M Watson £644k genetic architecture of rumen microbiome. Banos £563k biomarkers of dairy cow fitness and longevity. Wall, Hickey £613k future strategies for dairy cattle breeding.</p> <p>Sang £628k, transgenic reporters for avian development. Turner, £558k, aggression in pigs.</p> <p>Stevens £1.1m (sLoLa), glycoconjugate veterinary vaccines. Digard £1.1m, avian influenza viruses. Tait-Burkard, £787k porcine reproductive & respiratory syndrome.</p>	  
UKRI GCRF, Newton & Future Leaders	<p>Rainger £1.5m, <i>Future Leaders Fellowship</i>, eye development in avian models</p> <p>Connelley £2.0m, coordination of International Veterinary Vaccinology Network.</p> <p>Hillier, Rees £1.3m, south Asian nitrogen hub. Baggs £780k, sustainability indicators for maize breeding. Baggs, A Duncan, Barnes £1.7m decision support for legume selection in Sub-Saharan Africa. Baggs, Rees, Topp £736k N-CIRCLE virtual joint centre.</p>	   
Innovate UK	<p>Hickey £1.2m, next-generation pig breeding. Conington £682k genomic improvement for novel traits in goats. Coffey £509k genomics for beef carcass traits. Lambe, Conington, Coffey £568k breeding for more taste, less waste in lamb.</p> <p>Wall £860k, data-driven approaches for product quality in beef production chains.</p>	  
EU	<p>Series of EU-funded projects on the functional annotation of animal genomes, including AQUA-FAANG (€835k, R Houston, Macqueen), and GENE-SWitCH (€905, Clark, M Watson, Archibald). Conington, D Wilson €951k, small ruminants breeding for efficiency and resilience.</p> <p>Morgan-Davies, €964k, TECHCARE precision technology for welfare in small ruminant farming.</p>	 
Wellcome Trust	<p>Gaunt £1.0m <i>Sir Henry Dale fellowship</i>, role of dinucleotide bias in viral replication and pathogenesis. Fitzgerald £1.3m, Bacterial host adaptation to combat infectious disease.</p>	
Department of Health	<p>Diack £1.1m, sub-clinical vCJD infection; £888k pre-clinical vCJD infectivity.</p>	
DEFRA	<p>Wall £1.1m, beef genetic improvement platform for feed efficiency.</p> <p>Kao £773k, epidemiology of <i>Mycobacterium bovis</i> transmission.</p>	 

Unit-level environment template (REF5b)

Food Standards Scotland	Gally £2.1m, <i>E. coli</i> O157 in cattle and prediction of zoonotic risk. Tongue £597k, <i>E. coli</i> O157 super shedding in cattle.	
Charities	>£500k from Dogs Trust e.g. Clements , Bronsvort Dogslife – factors associated with health and longevity.	

Industry and commercial income

We have benefited from a series of partnerships with major companies, including Genus PIC (£1.7m), Cobb-Vantress (£2.2m), Hendrix-Genetics (£277k), Zoetis (£1.0m), Monsanto (£622k), Hill's Pet Nutrition (£598k), Bayer Crop Science and KWS (£89k), encompassing research on crops, pigs, poultry, beef cattle, aquatic species and companion animals, and including animal health companies (vaccines, diagnostics, biologicals). Such collaborative research with industry has made extensive use of leveraging schemes including £470k in industrial studentships, £466k industry contribution to BBSRC funding (e.g. LINK, IPA), and £23.8m from Innovate UK, providing clear paths to implement our findings and to promote understanding of end-user needs among researchers. Edinburgh Genomics has contributed to the award of £78.9m research income, including IPAs, CASE and Innovate UK, as well as direct income from industry.

Since 2014 this income stream has been bolstered by the establishment of the Roslin Innovation Centre (section 4) which has provided us with numerous opportunities to interact with Agri-Tech SMEs, with early success in winning partnering awards via the Industrial Strategy Challenge Fund. In its first 3 years of operation Roslin Technologies Ltd has provided both direct award of £270k to our researchers, leverage of an additional £213k from BBSRC IAA and EASTBIO DTP studentships, and facilitated 10 consultancies (totalling £70k). For example, they have directly invested £198k in vaccines for African trypanomiasis in cattle, catalysed further by BBSRC IAA support (**Grey, L Morisson**), and are progressing the commercial development phase of a cattle *E. coli* 0137:H7 vaccine to prevent food-borne illness in humans (**Gally**). 

We have also secured substantial funds to catalyse research with potential for impact, for example via a BBSRC Impact Accelerator Award (£600k), Flexible Talent Mobility Awards (£320k), Agri-Tech Catalyst seeding awards (£272k), Wellcome Institute Strategic Support Fund and Institutional Translational Partnership Awards (shared across other UoE UoAs), and internal pump-priming schemes via BBSRC strategic funding. Such schemes foster enthusiasm among researchers to achieve impact and an entrepreneurial culture. For example, we recently launched a £400k Food & Agriculture Science Transformer (FAST) in partnership between Deep Science Ventures to invest in innovative ideas and people toward new spin-out companies and products.

3.2 Infrastructure and Facilities

Since REF2014 we have invested £152m in our world-class infrastructure and research facilities (Fig 11) to realise our objective to create a centre of excellence of global relevance to veterinary and agricultural research, which consolidated and expanded our resources and synergies within our Unit and with our local partners within the Easter Bush Research Consortium and at our sites across Scotland.

Operational infrastructure: buildings and estates

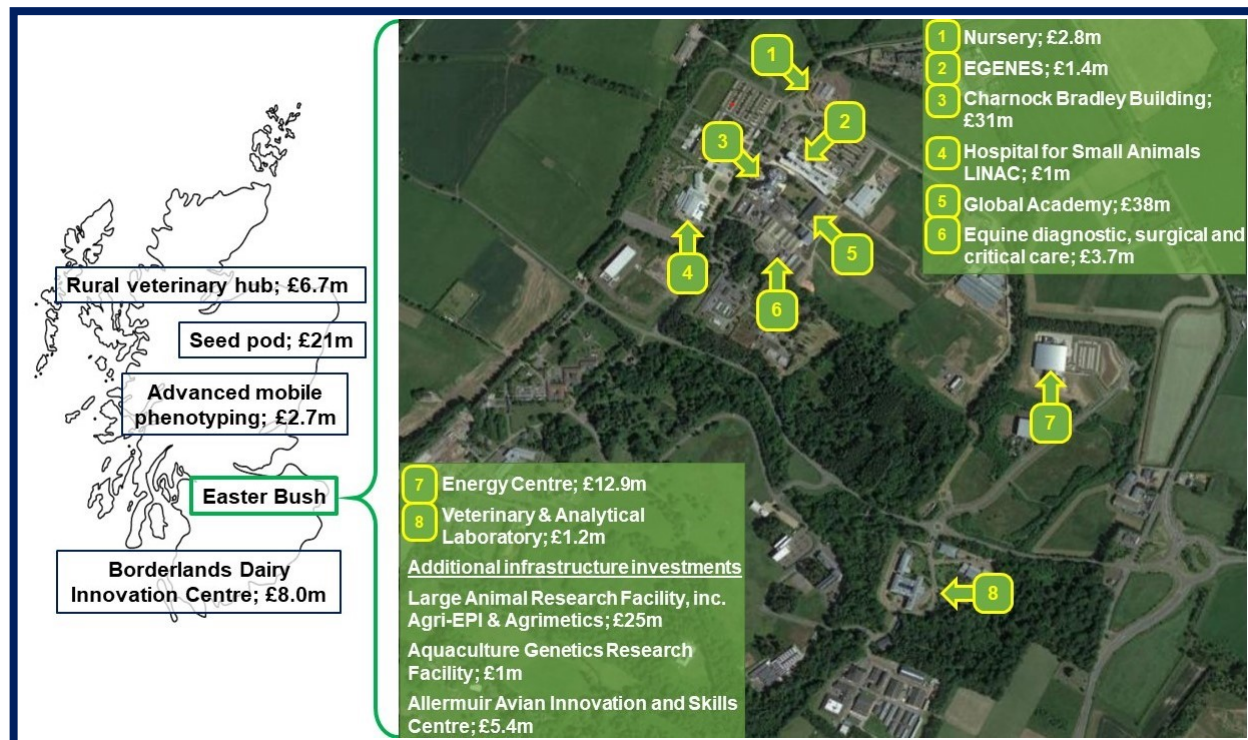


Figure 11. Locations of key investments during the REF2021 period.

Veterinary teaching, research and clinical services are centred in the **Veterinary Teaching Building** at the heart of the Easter Bush campus. Animal bioscience on the Easter Bush campus is focused in the UoE/SRUC shared **Roslin Institute Building**, with clinical research supported by the **Hospital for Small Animals**, the **Riddell-Swan Veterinary Cancer Centre** and **Farm Animal Services** (including practice and hospital), the **Biological Research Facility** for small laboratory animals and the **National Avian Research Facility**.

Key operational investments since REF2014

- The **Charnock Bradley Building** opened in 2018 (£31m; £5m BBSRC, £10m Scottish Government, £16m UoE) that houses the **Roslin Innovation Centre**, the **Easter Bush Science Outreach Centre**, the campus gym and facilities for cyclists.
- The **Easter Bush Energy Centre** opened in 2017 (£12.9m, City Deal) enabling the campus to produce its own low-carbon energy (additional 2,000 tonnes p.a.) to meet the demands of the campus and advanced computing facility.
- The **Easter Bush Solar Farm** (£3.2m, SFC Renewal Energy and Low Carbon Options) to supplement power to the Energy Centre, and make the Easter Bush campus carbon neutral.
- A **nursery** at Easter Bush opened in 2018 (£2.8m from UoE) for children of staff and students, opened in 2018 and operated by Arcadia, provides an example of our continuing investment in improving facilities for staff/student parents.
- Infrastructure to support the campus** (£8.8m, UoE), including the HV ring required to connect the energy centre to all the campus, SUDS pond extension, and essential supporting infrastructure (paths and campus ring road).
- Advanced Computing Facility extension** (£28.7m, City Deal) for UoE, totalling a £43m investment when including equipment and software.
- Langhill Farm Silage Complex** (£0.9m UoE) essential replacement to maintain the dairy farm at Langhill, used for both teaching and research.

In addition, our research benefits from our Unit's nine **commercial farms** in the Easter Bush vicinity, and >4,000 hectares of farm estates in the UK. This includes: dairy herds near Edinburgh (Langhill) and Dumfries (Crichton and Barony); sheep flocks near Easter Bush (Dryden, Easter

Unit-level environment template (REF5b)

Bush, Woodhouselee, Castlelaw), the West Highlands (Kirkton) and Dumfries (Barony); pig and beef research facilities at Easter Howgate, adjacent to the Bush Estate; commercial pig facility for industry related research in West Lothian (Oatridge); and agronomy and crop rotation trial sites in Edinburgh and Aberdeen. Over half of our farm estate is devoted to farming systems research platforms. These include extensive time series databases covering animal and land based activities dating back up to 50 years. We also have significant facilities for poultry research, including the BBSRC-sponsored National Avian Research Facility at Easter Bush with separate conventional and specified pathogen-free buildings and the Allermuir Avian Innovation and Skills Centre the UK's largest facility dedicated to improving avian nutrition, health and welfare capable of innovative studies under near-commercial conditions with the intention of helping to bridge the gap between research and poultry businesses.

Key research investments

Since REF2014, we have resourced our research activities with £52m for infrastructure, facilities and organisation of our research to foster and build our synergies that increase the quality and quantity of our research. Most notably we have established:

- The **Equine Diagnostic, Surgical and Critical Care Unit** opened in 2018 (£3.7m; £3.5m UoE, £0.2m donations). This unit extends our clinical and research strengths in equine medicine, and houses examination spaces, general and orthopaedic surgical theatres with adjacent induction and recovery boxes, a standing surgery suite, and a critical care unit, with 24-hour video monitoring and an adjacent laboratory.
- The **Allermuir Avian Innovation and Skills Centre** opened in 2019 on the Easter Bush campus (£5.4m, SRUC and the **Centre for Innovation Excellence in Livestock, CIEL**). This is the UK's largest facility working to improve avian nutrition, health and welfare. By trialling innovative ideas under near-commercial conditions, the Centre is helping to bridge the gap between research and business. The facilities, supported by Innovate UK through CIEL, include space for up to 5,800 broiler chickens, a multi-purpose poultry house for more than 1,300 laying hens, and four smaller rooms for up to 960 broilers.
- The **Large Animal Research and Imaging Facility (LARIF)** opened in 2020 (£25m; £11m CIEL, £12m UoE, £2m Agri-Epi). This provides exceptional imaging, surgical, gene editing and isolation facilities, supporting scientific research into the health and wellbeing of animals such as sheep, pig, cattle and horses. This includes advanced imaging technologies such as a large bore MRI scanner (additional £4.6m) suitable for large animal research, two full-sized operating and recovery suites, critical care, facilities for production of genetically modified and genome edited animals, and a containment suite for work with pathogens. LARIF houses the **Wellcome Critical Care Laboratory for Large Animals**, an experimental intensive care facility for large animals established in 2014 (£0.6m capital, Wellcome Trust), containing CT (£468k Wellcome Trust) and C-ARM (UoE supported) scanners. The local node of Agri-EPI, the Innovate UK **Agricultural Engineering Precision Innovation Centre**, occupies purpose built space immediately adjacent to LARIF.
- An **Aquaculture Genetics Research Facility** (freshwater aquaculture) at Easter Bush (£1m BBSRC and Agri-EPI). This is equipped with a hatchery and grow out room, and a disease challenge room, allowing us to conduct research on priority infectious diseases of aquaculture species (cold and warm water fish), including facilities for genome modification and experimental pathogen challenge.
- An **advanced mobile phenotyping facility** for livestock research (£2.7m, SRUC and CIEL funded), which includes a mobile CT scanner, based at Easter Bush, for high-resolution assessment of sheep and pig carcass or live animal body composition, and the **Taste and Sensory Testing Environment** - a portable facility equipped with imaging and product quality testing technologies.
- The **Veterinary and Analytical Laboratory** at Pentland Science Park, near the Easter Bush campus (£1.2m SFC Financial Transaction Programme), housing molecular biology, serology, parasitology, histopathology, bacteriology and biochemistry laboratories.
- **Edinburgh Genetic Evaluation Services (EGENES)** (£1.4m, co-funded by SRUC and CIEL), a complete genomic evaluation and delivery system for livestock species based at Easter Bush.

Unit-level environment template (REF5b)

This investment in hardware and software helps EGENES deliver premium products from profitable, sustainable farming systems for commercial customers.

- A **Biorefining and Bioprocessing Facility** (£130k, SRUC) to explore new products from biomass, co-located with our **Dairy Innovation Centre**.
- A **Rural Veterinary Hub** in Inverness (£4m from the European Regional Development Fund Scotland Programme, £2.7m SRUC). The project is led by Highlands and Islands Enterprise and SRUC to support cutting-edge facilities for disease surveillance.
- £750k for facilities to record sheep feed intake, with a mobile facility to allow for precision assessment of individual sheep, and a £500k redevelopment of the **High Welfare Sow Unit** for studying sow and piglet behaviour and performance.
- New infrastructure and facilities for the **Hospital for Small Animals** amounting to >£1m improvement in capacity to undertake research, including 1.5T MRI and 64 slice computed tomography (CT) scanners, a linear accelerator, an endoscopy suite, a physiotherapy centre, a radiotherapy unit, consulting rooms and a revamped ICU facility.

In addition, we have continued to invest in our research lines and datasets, for example:

- Maintenance of the **Langhill selection lines** of dairy cattle (£159k p.a. Scottish Government). This is a unique international resource for dairy cattle genetics, providing data related to milk yields, health, fertility, welfare standards and dairy farming's impact on climate change. The associated database has supported >£1.8m (2019/20) research in (i) biomarkers and phenotype predictors (ii) systems analysis/economics. (iii) genetic and genomic research and tools development and (iv) grassland and forage management.
- Development of novel edited and transgenic avian lines, and provision of other research lines (e.g. inbred specified pathogen-free chickens) via the **National Avian Research Facility** (BBSRC National Capability £1.2m, 2012-2017; and continued within BBSRC Core Capability £1.2m 2017-2022).
- Novel transgenic mice expressing human, bovine and ovine PrP used for the strain typing of prions and assessment of their zoonotic risk, supported with investment from BBSRC ISP (£2.9m 2012-2017), and Department of Health (£3.5m).
- Datasets on the sequence, expression, regulation and functional annotation of farm animal genomes, with £0.9m investment from BBSRC (2012-2017) for the **ARK Genomics Centre for Comparative & Functional Genomics** and a further £1.9m from BBSRC for computing infrastructure to act as the data coordination centre for the Functional Annotation of Animal Genomes (FAANG) consortium, and sustained by EU funding >€2m (e.g. GENE-SWitCH, Ovine FAANG, AQUA-FAANG).

4. Collaboration and contribution to the research base, economy and society

4.1 Collaborations

Support for interdisciplinary research and partnerships

Our challenge focus and theme structure are underpinned with strengthened existing, and new, strategic partnerships at regional, national and global levels, supported with funding from Scottish and UK Governments, industry and philanthropy, in addition to our Institutional investments. Our most notable new partnerships since 2014 include:

- The **Centre for Tropical Livestock Genetics & Health** (CTLGH; **Djikeng**, director); a partnership with the International Livestock Research Institute (ILRI; Nairobi and Addis Ababa) established in 2015 (\$16m USD from the Bill & Melinda Gates Foundation, \$5.3m USD from the Foreign, Commonwealth and Development Office). CTLGH seeks to mobilise advances in animal genetics, genomics, breeding and reproductive technology to drive genetic gain in farmed animals indigenous to low- and middle-income countries, mostly in sub-Saharan Africa. CTLGH has since leveraged significant further funding, including £3.8m from DfID, which is managed through the Bill & Melinda Gates Foundation.

Unit-level environment template (REF5b)

- **Supporting Evidence-Based Interventions** (SEBI; **Peters**, director) funded by the Bill & Melinda Gates Foundation (\$10.9m USD since 2016), harnesses data on livestock productivity, diseases and interventions to inform evidence-based decisions for animal farmers in low- and middle-income countries. SEBI work with a range of partners including CSIRO, ILRI, the Nelson Mandela African Institution of Science and Technology, LTS International and the Universities of Glasgow, Addis Ababa, Penn State, Peradeniya Sri Lanka and Ilorin Nigeria.
- The **Global Academy of Agriculture & Food Security** (**Simm**, director), launched in 2018 with £38m investment, provides an interdisciplinary hub of research, education and consulting expertise. It brings together researchers and educators from across our Unit, UoE (an additional 32 associate members), and national and international partnerships. Activity is aligned around agri-food systems innovation, One Health and data driven innovation.
- The **Centre for Innovation Excellence in Livestock** (CIEL) brings our Unit together with 10 other academic institutions and >50 industry partners spanning all aspects of livestock production and supply with an associated infrastructural investment (section 3).
- The **Agricultural Engineering Precision Innovation Centre** (Agri-EPI) focuses on research, development and demonstration of precision agriculture and engineering solutions for the livestock, arable, horticulture and aquaculture sectors, with investments supporting enhanced phenotyping in many of our farm animal and aquaculture facilities.
- **Agrimetrics**, an Agri-Tech Centre helping to provide access to linked-data, infrastructure and expert organisations and researchers to solve global food and environmental challenges. This is a partnership with NIAB, Rothamsted Research, the University of Reading, Airbus and Microsoft, and is part of Microsoft's prestigious AI for Earth programme. Helping to link industry partners to share and use data is a key activity, for example we founded **Vetnomics**, to update vets on the latest developments in data driven breeding.
- **Shanghai Jiao Tong University – UoE One Health Centre** (**Simm**, co-director) launched in 2020 with the shared vision of creating an internationally-leading research, education and design centre and think tank on One Health policy and practice to enhance human, animal and environmental health, and wellbeing, in support of sustainable development. This includes financial support from Shanghai Jiao Tong University for research projects, and targeted intended support from Chinese national and regional governments.
- Collaboration between **Teagasc** and SRUC focussed around environmental, consumer and economic challenges facing pasture-based livestock systems. Together we work with academic and commercial partners to identify routes to the development of sustainable and resilient pasture-based livestock production systems that can help mitigate greenhouse gas emissions and adapt to a changing climate, while continuing to provide food and nutrition security.
- SRUC partners in the **Global Challenges University Alliance (GCUA 2030)**, with a dozen international Universities including from Chile, China, New Zealand, Rwanda, Sweden and the USA. A key objective is to equip the next generation of researchers, teachers and academic leaders with knowledge, tools and networks that will strengthen their capacity to work across disciplines and to conduct translational research.
- **One Health partnerships**, for example the Wellcome DTP on One Health Models of Disease: Science, Society and Ethics, and bi-lateral PhD training schemes with the Universities of Glasgow and Leiden.

These partnerships have been supported by interdisciplinary joint appointments:

- Across our Unit (e.g. **Djikeng**, **Lawrence**, **Dwyer** and **Banos**) and with other Schools across UoE (e.g. **Alexander** and **Gathorne-Hardy** with the School of Geosciences; **Raybould** with the School of Social and Political Science; **Shields**, **Moran** and **Simm** with Edinburgh Futures Institute).
- With external Institutions (e.g. **A Duncan** and **Mrode** with ILRI; **Mwacharo** with ICARDA; **Djikeng** honorary positions at University of Queensland, University of South Africa, and Washington State University; **C Watson** Royal Swedish Academy of Agriculture and Forestry (KSLA) Wallenberg Professorship; **Ogden** special Professor at Kyoto University).

Unit-level environment template (REF5b)

Since REF2014, the Roslin Institute has extended its collaborations with other BBSRC-sponsored Institutes, notably with the Quadram Institute on foodborne pathogens and microbiomes, the Earlham Institute on functional annotation of animal genomes and the Pirbright Institute on control of viral diseases. For example, a joint studentship scheme with the Pirbright Institute supporting two new PGR students each year; one student at each Institute, with supervisors from both, and the students spending time in the co-supervisors' laboratories. SRUC is part of the Scottish Environment, Food and Agriculture Research Institutes (SEFARI), a consortium of 6 Institutes addressing key mid- to longer-term challenges for Scotland's environment, agriculture, land use, food and rural communities. Our veterinary practices and surveillance centres across Scotland provide access to expertise and opportunities to develop projects in companion animal, equine and livestock medicine and to influence the provision of care. The SRUC Carbon Management Centre (**Rees**, head) creates strong links to UoE School of Geosciences and the ClimateXChange Centre of Expertise. We also share facilities across different UoAs (for example, the Vitamin D Animal Laboratory with the Queen's Medical Research Institute (UoA1), and Plant-Soil Systems facilities within the School of Geosciences (UoA7)), and share access with external partners. For example, through Edinburgh Infectious Diseases (**Fitzgerald**, director), a network of researchers and clinicians, we are able to access infrastructure and expertise across UoE, the Moredun Research Institute, and Edinburgh Napier and Heriot Watt Universities.

City Region Deals

Our collaborative partnerships with public sector and businesses in these packages of funding agreed between Scottish and UK governments and local partners, support transformative change and interventions to improve regional economies and create jobs.

Edinburgh City and Region Deal

The Edinburgh and South East Scotland (ESES) City Deal, a £1.3bn investment (£661m for research development and innovation), aims to establish the region as the data capital of Europe, attracting investment, fuelling entrepreneurship and delivering inclusive growth.

The Easter Bush campus is one of five data driven innovation 'hubs' designed to integrate different areas across the UoE to enable multidisciplinary approaches to tackling data-orientated issues. For our Unit the **Agri-Tech Data Driven Innovation Hub** helps leverage existing world-class research Institutes and commercialisation facilities, and works with commercial partners, enabling us to become a global location of agri-tech and veterinary excellence to maximise productivity through generation and collation of a multitude of local and global data. This creates the opportunity for more research partnering with public, private and third sector organisations, delivering benefits around Talent, Research, Adoption, Data and Entrepreneurship (TRADE). This is underpinned with numerous enabling initiatives, for example, funding for ECRs to collaborate with industry under the Train@Ed pre-tenure track fellowship scheme. This also facilitates establishment of partnerships with the Agri-Tech Centres (e.g. Agri-Epi and CIEL), and other City Deal investment areas such as the City Deal Food and Drink Innovation Park at Queen Margaret University.

Aberdeen City Region Deal

We are partners with Opportunity North East (ONE) in the development of SeedPod a new £21m centre of excellence for nurturing and growing food and drink businesses in north east Scotland. Based on our Craibstone campus, SeedPod will provide the tools, knowledge and training to help fledgling and established companies to identify new markets, drive growth and adopt cutting edge production technologies, increasing profitability and capitalising upon the region's assets and collaborative links. For example, with Opportunity North East investment **C Watson** is investigating creating new foods, related products and by-products from alternative crops such as gorse.

Borderlands Growth Deal

As part of this deal we are developing a Borderlands Dairy Innovation Centre (£8.0m) at our Barony campus. The centre will work with industry and academics to reduce the time it takes for research and technology to be applied within commercial dairies and the supply chain. There will be a focus on testing new products, technologies and production systems, as well as carbon neutral farming solutions.

4.2 Contributions to economy and society

Translation and development of impact

We work closely with end-users of our research through co-funded research, training and consulting, including via our network of veterinary surveillance centres and support services for farms and rural businesses. Research is often carried out on-farm with significant knowledge exchange to farmers and veterinary surgeons. Achieving impact from our R&D into understanding the genetic control in plant and animal species is enhanced through **Edinburgh Genetic Evaluation Services (EGENES)** which provide data services and routine genetic and genomic evaluations for all dairy cows in the UK, commercial recorded pedigree sheep and beef, international aquaculture, pig and goat breeding companies. Associated unique infrastructure allows for the co-delivery of new approaches to genetic evaluations including hard to measure traits such as meat together with feed and environmental efficiency. Our engagement with stakeholders across the food supply chain has been significantly extended via our roles in the CIEL, Agri-EPI and Agrimetrics Agri-Tech Centres. In addition, we share software and materials, for example our AlphaGenes suite of software for analysis of genetic associations and breeding programme design was previously licensed for use by several global breeding companies, and is now open access (<https://alphagenes.roslin.ed.ac.uk/wp/>).

Industry collaboration

Much of our interdisciplinary research is in collaboration with industry with the aim of co-creation of innovations. Such collaborations involve major strategic partnership agreements with a total value of >£24.5m p.a., whereby recurrent income is received for joint projects (e.g. with Zoetis, Hill's Pet Nutrition, Genus PIC, Cobb Vantress, Hendrix Genetics and Worldfish). Such close engagement with industry and policy stakeholders has also led to a wide range of rapid research and policy analysis to inform alternative policy scenarios for food production.



Figure 12. The Charnock Bradley Building houses the Roslin Innovation Centre, Roslin Technologies Ltd and EBSOC.

Commercialisation of our research is supported by **Edinburgh Innovations Ltd** who provide support for translation of our research with business development, legal and contracts teams embedded at Easter Bush to identify, protect and mature IP and facilitate collaborative research with external partners. This was further augmented in 2017 by establishment of **Roslin Technologies Ltd**, a biotech company that transforms science innovations to provide solutions to global challenges in AgTech and animal health. Roslin Technologies together with DESTINA Genomics formed a new company, **Vetsina Animal Diagnostics Ltd**, to develop innovative diagnostics of illness and infection in companion animals and livestock. Other commercial partnerships include: **Aquaponics Garden**, a company based at our

Unit-level environment template (REF5b)

Elmwood campus that is developing a closed-loop farming method where trout waste is used to fertilise food and non-food crops; **MI:RNA** which, based on our veterinary diagnostics work, provides a unique, cost-effective diagnostic assay to identify heart disease in animals; and **ID MAPPS**, based in Inverness, that uses our Unit's epidemiological expertise to develop and commercialise new approaches to monitoring levels of Lyme Borreliosis in the environment. Additional examples of commercialisation include a diverse array of viable products including candidate vaccines for influenza and infectious bronchitis in chickens, phage therapy for persistent *E. coli* infections, small RNA diagnostics for African trypanosomiasis and novel diagnostics for PRRSV.

At the heart of the Easter Bush Campus is the **Roslin Innovation Centre**, a £31m investment by UoE, Scottish Government and the BBSRC, with >41,000 sq. ft. of flexible laboratory and office space (Fig 12). At time of submission it is occupied by 18 industry partner tenants (e.g. Roslin Technologies Ltd, Vetsina Animal Diagnostics Ltd, Ingenza Ltd), with hot-desking for a further 5 partners. This provides our researchers opportunities to collaborate with co-located industry partners. For example, with Deep Science Ventures (DSV) to deliver Scotland's first agricultural venture builder 'FAST', combining expertise and facilities across themes 1-6, with DSV's expertise in launching science companies.

SAC Consulting Solutions

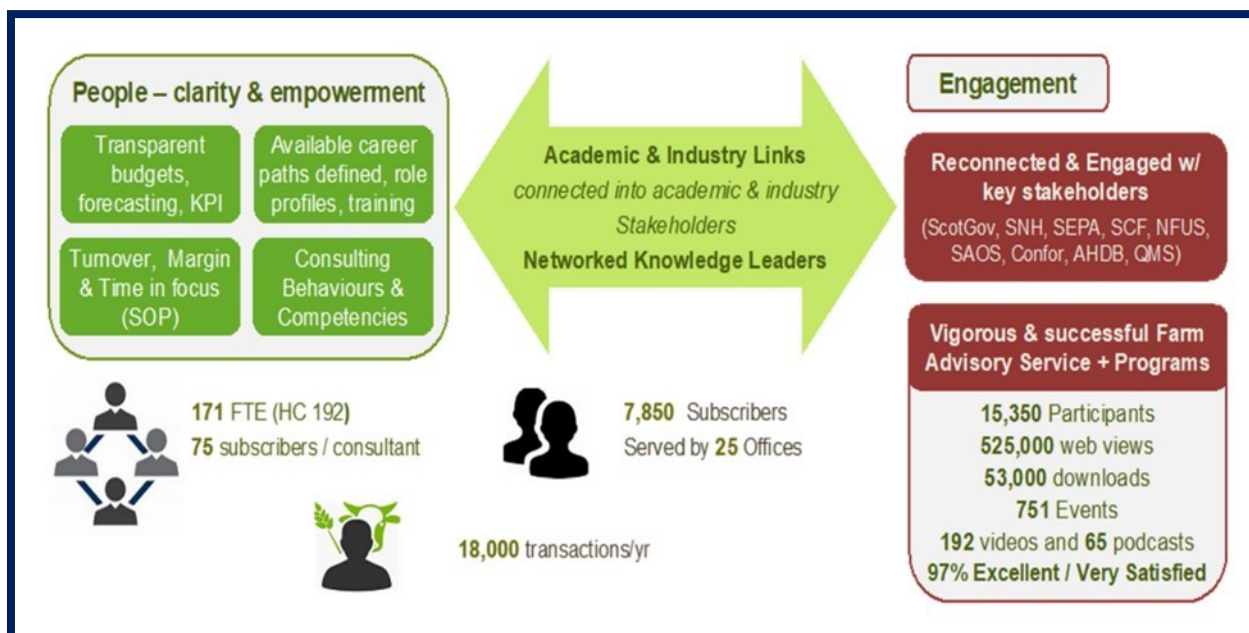


Figure 13: SAC Consulting Solutions – a link from research to end users.

SRUC supplies >£14.5m p.a. in consultancy services to UK SME's. The approach is guided through a strategy for commercialisation and innovation through SAC Commercial Ltd (SACC). Our researchers (e.g. **Wall, Rees, J Newbold, Coffey**) work closely with SAC Consulting Solutions, a key activity of SACC with the purpose of supporting the growth and prosperity of rural communities and being the leading agri-food consultancy linking producers with their environment (Fig. 13). With a team of >375 consultants, veterinarians and specialists across 26 offices, SAC Consulting Solutions offers local knowledge and expertise to farmers, rural businesses, food processing firms and supplier markets. Services range from analytical to bespoke individual consultancies, covering all aspects of rural enterprise from agronomy, livestock and dairy services to disease surveillance, farm animal diagnostics and environmental consultancy. It also offers a dedicated UKAS-accredited analytical facility, which provides a seamless service from field to laboratory. A recent survey carried out by SAC Consulting Solutions showed that it has achieved 67% penetration in the farming industry.

The Cool Farm Alliance

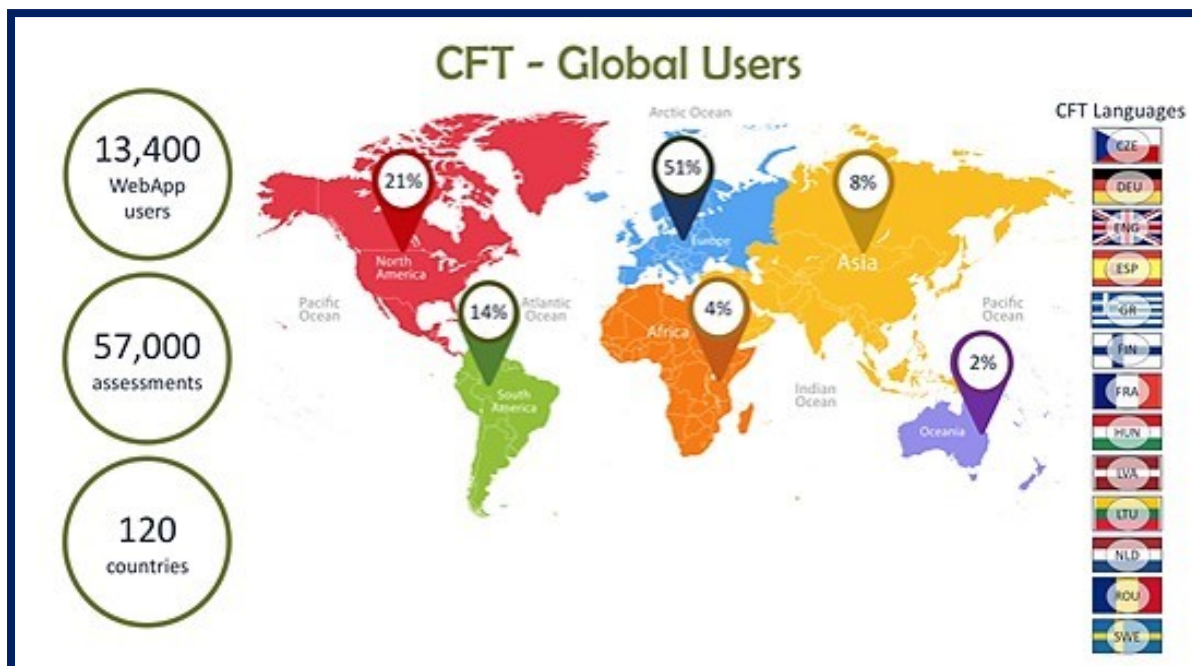



Figure 14. The global reach of the Cool Farm Tool.

The Cool Farm Tool is a multi-metric decision support tool for farmers to assess and improve environmental performance. It is co-funded by industry and deployed in the supply chains of many major global food and drink and retail brands (e.g. Unilever, Danone, PepsiCo, Mars, Kellogg's) in ~120 countries (Fig 14). **Hillier** was the original developer of the tool and is a Director of the Community Interest Company founded to manage the tool; the Cool Farm Alliance. Since REF2014 **Hillier** has co-led the strategic planning delivery of new science into the Cool Farm Tool.

Influencing government policy

We have substantial interactions with the Scottish and UK Governments and EU, notably in relation to control of animal diseases (e.g. via EPIC and advice to the Animal and Plant Health Agency), food safety (e.g. with Public Health Scotland and Food Standards Scotland and their equivalents in England), and the risk of zoonotic and iatrogenic prion diseases (with the Department of Health and Social Care). SRUC's Rural Policy Centre produces regular reports and briefings and we coordinate the Scottish Consortium for Rural Research to promote research and dialogue with policy-makers. We have contributed to Royal Society, Nuffield Council and OECD reviews on the role of genetically-altered animals in the future of food and farming (**Sang, Whitelaw**). Many of our researchers are members of expert advisory panels for government, learned societies and major non-governmental organisations (Tables 3 & 4). Through such interaction with policymakers, our research has informed new legislation, for example, new EU legislation in relation to low atmosphere pressure stunning for culling of pigs and poultry (**Martin**). 

We have regular contact with government and industry facilitated by our Rural Policy centre. This includes providing the Secretariat for the Cross-Party Group in the Scottish Parliament on Rural Policy, hosting the Edinburgh Agricultural Economics Discussion Circle that meets monthly and running a series of webinars to inform implementation of the Islands (Scotland) Act 2018, in particular the development of the National Islands Plan. Through our research and advisory roles (Table 3), we provide written, hearing and presented evidence to UK and Scottish Governments. Notable examples include:

Unit-level environment template (REF5b)

Written evidence: UK Government Joint Committee on Human Rights and COVID-19 - COVID and the right to food (**Shields**). Scottish Parliament Consultation on Good Food Nation Bill - evidence focused on Accountability and Responsibility for Food Systems in Scotland (**Shields**).

Committee hearing evidence: Scottish Parliament Rural Affairs and Climate Change Environment Committee 2015-16, Human Rights and Land Reform (2015, **Shields**).

Presented evidence: to Westminster Parliament Science and Technology Committee inquiry into GM and application of the precautionary principle in Europe, representing the Royal Society of Biology (2014, **Sang**); to the House of Lords on TB in foxhounds (2017, **Gunn-Moore**).

Presentation: Harnessing the opportunities of new breeding techniques All Party Parliamentary Group on Science and Technology in Agriculture (Westminster) (2016, **Sang**).

Consultations: Our Rural Policy Centre (**S Thomson, Barnes, McCracken, Wall** and others) has responded to and provided evidence to a wide range of Scottish and UK Government consultations (Box A).

Box A: Scottish and UK government consultations

2015

- Public Health Review Engagement Paper
- RACCE Committee evidence for Land Reform (Scotland) Bill
- Review of Croft House Grant Scheme
- The Future of Land Reform in Scotland

2016

- Future of Forestry in Scotland consultation
- Scottish Agriculture Discussion Document
- Land Use Strategy 2016-2021 Consultation
- UK Gov Soil Health Inquiry

2017

- Draft Climate Change Plan (RPP3) call for evidence to the Rural Economy and Connectivity Committee
- Draft Climate Change Plan (RPP3) call for evidence to the Environment, Climate Change, and Land Reform Committee

2018

- National Council of Rural Advisers "A Rural Conservation: Together We can, Together we will"

2019

- Scottish Government's National Islands Plan and Island Communities Impact Assessments
- Scottish Affairs Committee Inquiry on "The Future of Scottish Agriculture post-Brexit"

Scottish Government's Centres of Expertise

Animal Disease Outbreaks (EPIC): We are long-standing and significant contributors to EPIC (**Boden**, deputy director), which provides evidence-based guidance to prepare the livestock sector for incursion of exotic or emerging diseases and aid their control. For example, **Porphyre, Woolhouse** and **Gunn** played a key role in devising government policy for the emergency response for an outbreak of Foot-and-Mouth Disease in Scotland (ICS D).

Plant Health: The aim is to improve resilience to plant health threats in Scotland by connecting science to application to inform policy, planning, responses and solutions. **Burnett** and **Evans** lead on agriculture plant health, providing expertise on the use/withdrawal of chemical pest control in a range of crop plants and disease/pest threats. This links to our Crop Clinic services for growers, giving detailed, up-to-date information on pests, weeds and diseases and integrated crop management solutions.

ClimateXChange (CXC): A collaboration between 16 research and HE Institutions providing responsive research to Scottish Government policy teams and other public agencies on climate change and the transition to a low carbon economy. **Dewhurst, Barnes, V Eory, Macleod, Moran, Wall, Rees, McVittie** and **Glenk** work with CXC to translate policy and industry findings. This includes rapid evidence reviews, policy briefings and recommendations for policy and practice, particularly those related to land use in the Scottish Climate Change Plan, understanding greenhouse gas accounting, system-wide emissions and mitigation options from different land uses and scenarios.

Unit-level environment template (REF5b)

Public engagement

Strategy

Our public engagement with research (PER) ranges from outreach to involvement in research projects. PER is fundamental to our aim to address critical challenges and reaches >8,000 people p.a. supported by >300 days of researcher time. Our strategy is for a programme of research relevance, promoting collaboration with the public, inspiring trust in scientific research and raising aspirations around STEM careers. This is resourced with a team of 4 dedicated support staff, an academic lead (**Davey**) and external funding. Within the REF2021 period we have secured >£200k for activities from UKRI, BBSRC, Wellcome Trust, learned societies and charities. A Community Engagement prize at the 2016 Scottish Enterprise Life Sciences Awards recognised our commitment to local community engagement.

Partnership working is key to reaching the Easter Bush Science Outreach Centre's (EBSOC) priority audiences. We work closely with the UoE Widening Participation team, charities (e.g. the Nuffield Foundation; the Social Mobility Foundation) and local external organisations (e.g. the Royal Highland Education Trust; National Museums Scotland) to reach new audiences. We also work with teachers via the Great Science Share for Schools, SSERC and Education Scotland's Raising Aspirations in Science Education programme.

Activities and events

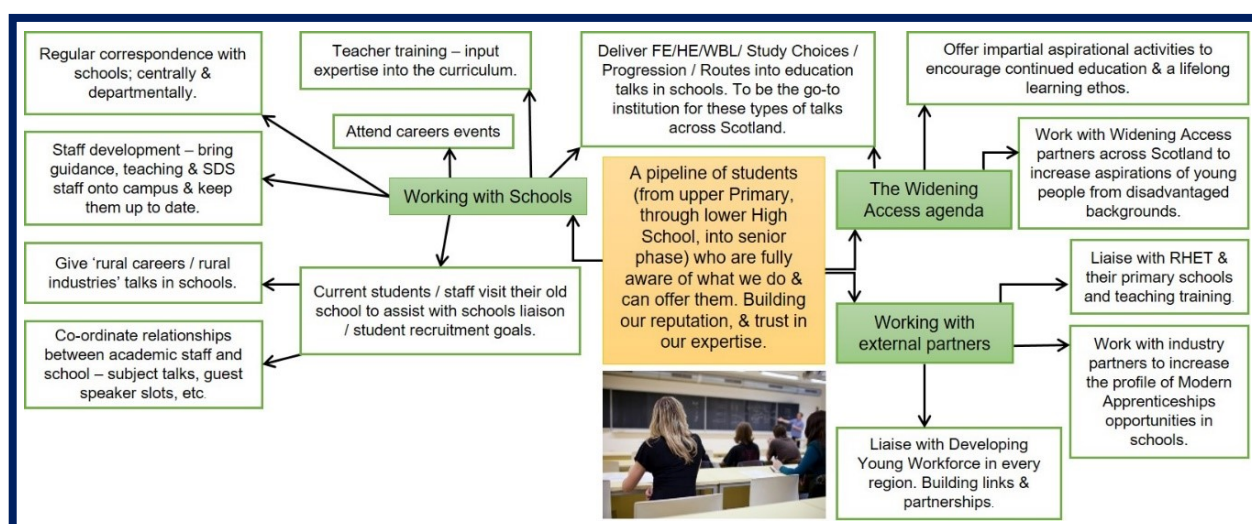


Figure 15. Mapping SRUC school engagement activities.

Unit-level environment template (REF5b)

We have significant interaction with primary and secondary schools (e.g. SRUC engaged with >1,700 students in 2018/2019; Fig 15). Our on-campus PER programme is delivered through EBSOC, within a wider programme of outreach activities and online engagement. The purpose-built engagement laboratory within EBSOC has greatly enhanced our PER programme by providing hands-on, research-linked experiences (Fig 16). We prioritise activities for individuals with low science capital, for example people who live rurally or in areas of socio-economic deprivation, and communities less likely to engage with scientific events, and priority given to schools in the most-deprived 20% of Scotland (SIMD20).



Figure 16: EBSOC; a fully equipped laboratory for school and public use.

Events range from drop-in events where members of the public explore our research and have a conversation with a scientist, to longer-term participatory research and citizen science projects. Examples include:

- The Dogslife project (**Clements**), a longitudinal cohort study of Labrador health with participation by >8,200 UK dog owners, and the All4Paws project, which provides free veterinary services to homeless pet owners.
- Massive Open Online Courses (MOOCs), including 'How do we feed 11 billion people?' and 'The Truth about Cats and Dogs'.
- High-profile events including the Royal Society Summer Science Exhibition (**Digard**), BBSRC's Great British Bioscience Festival (**Digard**), the Cheltenham Science Festival (**Whitelaw**), New Scientist Live (**Simm, Whitelaw, Lillico, R Houston, Tait-Burkard**) and the British Science Festival (**Schoenebeck, Djikeng**).
- Presence at agricultural sector events. For example, in 2019 to celebrate 100 Years of Animal Genetics in Edinburgh, we attended 10 agricultural shows across Scotland and Northern England (**Archibald, Davey, F Houston, A Wilson, Collie, McLachlan, Sargison, Clark**).
- Work experience provision for high school pupils via Nuffield Research Placements (**Collie, Corbishley, Davey, Grey, J Smith**) and Science Insights, a programme co-founded by the Roslin Institute with a focus on widening access to higher education, which has supported 236 pupils and involved 174 staff and students since REF2014.
- Scottish Marine Animal Stranding Scheme (SMASS), a multiple organisational collaboration, led by SRUC (**Brownlow**), to raise awareness of marine animal entanglements amongst fishermen and other marine users including the general public.
- Public engagement series with internal and external speakers (e.g. 'Plate to Planet' and 'Give us today our daily bread – but how?' in 2019), typically attended by 70-100 members of the public.
- International engagements include: stakeholder and farmer workshops in Malawi, Kenya, Ethiopia, Uganda and Zimbabwe (**Baggs, A Duncan, Muwonge**, e.g. Fig 17); large-scale public health education (Mission Rabies; **Mellanby**); PER training for African women scientists via the GCRF-funded IVVN African Schools Outreach Programme (**Connelley**);

Unit-level environment template (REF5b)

and development of international engagement resources including 'More Milk Zuri?!' (**L Morrison**) funded by a BBSRC Impact Accelerator grant.



Figure 17. Smallholder participatory scoring for legume functions within the *Legume Choice* discussion tool.

COVID-19 related public engagement

We moved PER training and many activities online including Science Insights, COVID-19 talks (**Digard, Lycett**), and webinars about climate change. We have contributed to wider UoE programmes including the Research Insights public events programme 'COVID-19: Behind the numbers' (**Kao**). Science@Home activities include an educational toolkit about animal behaviour (**Lawrence, Meddle**), downloaded by ~12,600 participants and winner of an Openness Award from Understanding Animal Research.

We have been providing advice and commentaries on COVID-19 issues, that have helped inform the public and frame the Scottish and UK Governments' responses. This includes from our work on: the virology (e.g. **Digard, Tait-Burkard**: BBC1, ITV, STV, Radio 5 Live), infection biology (e.g. **Vazquez-Boland**: several newspapers), and epidemiology (e.g. **Kao**: newspapers, radio, BBC One, Sky News). Research by **Lycett** has underpinned a web tool showing results of sequencing analysis including movies of spread: <http://129.215.193.110:3838/RiseFallScotCOVID/>.

4.3 Contributions to the research base

Advisory roles

These include contributions to UK and Scottish Governments, funders and other advisory roles both national and international (Table 3).

Table 3. Selection of our key advisory roles, during REF2021 period.

Contributions to Governmental and International Advisory Bodies	
International Advisory roles	<p><u>Europe:</u> >16 roles e.g. International Advisory Board of CRB-anim (Sang). Advisor to European Food Safety Authority (R Houston). ELIXIR Scientific Advisory Board (Archibald). ARRIGE Scientific Advisory Committee (Whitelaw). Czech Institute of Animal Physiology and Genetics (C Newbold).</p> <p><u>Other international:</u> Including, Steering Group for LD4D (A Duncan). Lead, establishment of African Animal Breeding Academy (Djikeng). Independent Scientific Advisory Board, the Southern African Centre for Infectious Disease Surveillance (Djikeng).</p> <p><u>PhD examining:</u> ~57% of our research staff have acted as PhD external examiners, across 25 countries.</p>
Leadership in UK Science	<p><u>UK & Scottish Governments:</u> Deputy Director EPIC (Boden). SNH Scientific Advisory Committee (Ogden). Advisory Committee, Releases to the Environment (Defra) (Raybould). Agri-Food Technology Council (Simm). Defra Science Advisory Council (Kao, Powell). DfID Science Advisory Group (Powell). Scottish Science Advisory Council (Powell). Landscape Alliance Working Groups (Shields). Scottish Animal Welfare Commission (Dwyer, chair; Haskell). Sector Lead Agriculture Plant Health CoE (Burnett).</p> <p><u>RCVS and Veterinary School's Council (VSC):</u> Fellowship Credentials Panel (Boden). Science Advisory Panel (Nuttall). Chair, Veterinary Schools Council Education Committee (Rhind). Chair, VSC Research Committee (Argyle).</p> <p><u>Other roles:</u> Including: Scientific Advisory Board, Pirbright Institute. Food Standards Agency Register of Specialists. Scottish Human Rights Commission Steering Group. Scottish Universities Legal Network on Europe Trustee, The Sainsbury Laboratory. Worldwide Veterinary Services. Food and Drink Sector Council, Innovation. Scottish Aquaculture Innovation Centre Board. Food and Farming Futures Board. Research and Knowledge Exchange Committee of Universities Scotland.</p>
Contributions to Science Funding	
Funding Committees and Organisations - UK	<p><u>Advisory roles:</u> (i) <u>BBSRC Council</u> (2014-2018, Sang). GCRF Strategy Advisory Group (2016-2019, Sang). Appointments Board (2018-, Sang). Agriculture and Food Security Strategy Advisory Panel (Sang, Baggs, Deputy Chair). COVID panel of experts (Kao). Animal Health Research Club (Archibald). SARIC steering group (Hillier). Working groups (Whitelaw, Wall, Baggs, Simm). (ii) <u>NERC</u>, Science Board, TAB, NAN (Baggs). (iii) <u>Nuffield Council</u>, bioethics working group (Whitelaw).</p> <p><u>Committee/panel chairs:</u> BBSRC Committee A (Meddle, Wall), Committee B (Baggs), BBSRC-FAPESP (Holden), Agri-food Training Partnership (Wall), GCRF and Newton calls (Baggs), Wellcome Trust (Fitzgerald), private sector funders e.g. Dogs Trust Canine Welfare (Argyle), Horserace Betting Levy Board (Farquharson).</p> <p><u>Committee/panel members:</u> >40 staff for a range of funders including BBSRC, NERC, EPSRC, MRC, UKRI Future Leaders, MRC, GCRF & Newton, Innovate UK, NC3Rs, Wellcome Trust, PetSavers, Arthritis Research UK, Houghton Trust UK, Carnegie Trust, Horse Trust, Bloomsbury SET, British Heart Foundation.</p>
Funding committees-international	<p>>22 staff for FWO, NIH, ANR, SNSF, RCN, CSC, DFG, ESF, NWO, DFF, IFS, FORMAS, AAS, IWT, ETAg, Irish EPA, DAFM, AMS, NSF, USDA, L'OREAL-UNESCO Women in Science, Vienna Science & technology Fund.</p>

Unit-level environment template (REF5b)

Indicators of wider influence

These include contributions to science communication, learned societies and other organisations, and awards (personal, research and impact) to our researchers (Table 4).

Table 4. Selection of our indicators of esteem, during REF2021 period.

Unit-level environment template (REF5b)

Contributions to Science Communication	
Industry-facing roles	<p><u>Leadership positions:</u> Vice President Animal Biotechnology NewVectys SAS (Whitelaw). Chairman TAG-UK (Whitelaw). Director TRACE Wildlife Forensics Network (Ogden). Director, the Cool Farm Alliance (Hillier).</p> <p><u>Consultancies:</u> For >18 companies, e.g. Edimer Pharmaceuticals (Headon). Zenoaq (Argyle). Boehringer Ingelheim (Pirie). Xelect Ltd (Macqueen, R Houston). Biotangents (Hope). RTL (Hope). Hill's Pet Nutrition (Mellanby). Syngenta (Davey).</p> <p><u>Advisory boards:</u> Roslin Technologies (Argyle, Whitelaw). Manzanita Pharmaceuticals (Dalziel). Recombinetics Inc (Whitelaw). ImmunoGenes Ag (Whitelaw). Food and Drink Sector Council Innovation Working Group (Simm). DSM Maestro (M Watson). Stratified Medicine Scotland Innovation Centre (M Watson).</p>
Journal Editorial roles	<p><u>Editor- or co-Editor -in-Chief:</u> e.g. Microbiol (M Stevens). Pathogens (Opriessnig). J Endocrinol (Farquharson). Vet Comp Oncol (Argyle). Vet Res Commun (Dalziel). Transgenic Res (Lillico). Domest Anim Endocrinol (Donadeu). Agriculture (Baggs). Front Sustain Food Syst (Rees).</p> <p><u>Editorial Boards:</u> Leading roles in >85 peer review journals.</p>
Conference hosting, organising and keynotes	<p><u>Scientific advisory and organising committees:</u> For ~97 international conferences across the UK, Europe, USA, Canada, Australia, Ghana, Uganda South Africa and Japan.</p> <p><u>Conference hosting:</u> 24 conferences at Edinburgh and hosting elsewhere, including London, Italy, Kenya, Ghana, Uganda, Japan.</p> <p><u>Keynote addresses:</u> >415 at conferences and other scientific meetings in 38 countries, including across Europe, Asia, the Americas, Australasia, Africa.</p>
Other Measures of Distinction	
Elections to Learned Societies	FRSE (Argyle, Powell). FRSA for contributions to social progress and development (Argyle). FRVCS McGorum, Argyle, Clements, A Macrae, Clutton, Pollock, Mellanby, Gow . FRSB Stevens, Baggs, Whitelaw, Gunn-Moore, Hope, Simm, Shaw, Fitzgerald, J Newbold, C Watson . Senior Fellowships HEA Mackay, Simm; Rhind, Pollock . Sallie Rosen Kaplan Fellowship for Women Scientists, NIH Buishand . Fellow AAM Vazquez-Boland . Fellow Royal College of Pathologists Piccinelli . Fellow Anatomical Society Wishart . Young Academy of Scotland, RSE Wall .
Contribution to Societies & Organisations	Office bearing positions in >36 societies, including: RSE (Archibald, Argyle). RSB (Raybould). BSAS (Wall, Dewhurst , president). BSSS (Baggs , president; Hopkins, Buckingham). AAB (C Watson President). ECVPH (Boden , president). ECVP (Malbon , president). ECVCP (Milne). RCVS (Argyle , Junior Vice-President; Sargison). Houghton Trust (M Stevens). SVS (Jennings). SBN (Meddle). BSDB (Davey). BSGCT (McLachlan). SWFS (Ogden , president). AAB & ESA (C Watson , president). WPSA (Sandilands UK president). ISAE (Turner, Haskell). IAM (Roberts). >40 staff and students are STEM ambassadors.
Notable Awards/Prizes	<p><u>Personal:</u> OBE for contributions to Food Security and Bioscience for Health (Sang, 2020). OBE for services to Veterinary Education (Rhind, 2017). International Nelson Mandela Justice Award for making a difference to others in agricultural development (Djikeng, 2020). Princess Royal Award for Services to the Dairy Industry (Coffey, 2020).</p> <p><u>Research:</u> > 16 awards, e.g. The Queens Anniversary Prize for the Langhill Dairy Genetic Selection Study, 2017 (SRUC). The Sir John Hammond Award, BSAS (Wall, 2014). Petplan Scientific Achievement Award (Mellanby, 2016; Clements 2019). BSAVA</p>

Unit-level environment template (REF5b)

	<p>Blaine Award (Mellanby, 2020). Kennel Club International Prize (Argyle, 2015). BSAVA Simon Award (Clements, 2018). BSAVA Woodrow Award (Gow, 2020). <u>Impact:</u> Openness Awards 2018 (Tait-Burkard). New Product of the Year 2020, Poultry Business Magazine (Martin). Converge Challenge and ILG Enterprise Award (Prendergast). ECVAA Morpheus Award 2019 (Clutton). 2020 Vet School of the year, WVA/CEVA global animal welfare awards (UoE).</p>
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