Institution: University of Liverpool

Unit of Assessment: UOA6 Agriculture, Food and Veterinary Sciences

1. UNIT CONTEXT AND STRUCTURE, RESEARCH AND IMPACT STRATEGY

1.1 OVERVIEW

The University of Liverpool's (UoL) UOA6 submission represents strategic alignment of 105 staff (102.43 FTE; names in bold), including 20 early career researchers (ECRs). Collectively, our research focus reflects national and international grand challenges: food security, infectious diseases, and life course research. We recognise that the health of humans, animals and the environment are linked, and we tackle challenges at the human-animal interface, putting us at the forefront of the One Health agenda to achieve the UN's Sustainable Development Goals (SDG). Our strategy places a strong emphasis on uniting separate clusters of activity through collaboration and communication, promoting an integrative and additive approach to new research areas and highlighting the coherence of the Institutes' research programmes for an external audience. With the advent of major research initiatives such as the Global Challenges Research Fund (GCRF) and Newton Fund, our international research has extended considerably over the REF period, whilst our PIs continue to respond to and meet the needs of our national and local communities.

UOA6 academics are strategically aligned within six research groups; these primary affiliations reflect their core activities and are enhanced by interdisciplinary collaboration (**Figure 1**). Our research groups work together on pressing challenges and research objectives:

- **Emerging Diseases and AMR,** tackling threats from invasive pathogens and the threat of drug resistance (17 staff, 16.6 FTE).
- **Musculoskeletal,** researching the basic bioscience of gait and movement, and improving function through the life course by molecular and translational studies (20 staff, 19.7 FTE).
- **Functional and Comparative 'Omics,** developing mathematical and computational models to exploit 'omics data, which underpins plant science and crop improvement (17 staff, 16.6 FTE).
- **Evolution, Ecology and Behaviour,** researching fundamental aspects of animal behaviour, dynamics and biodiversity, applying this to fragmented landscapes, and improving laboratory animal welfare (26 staff, 24.73 FTE).
- **Animal Welfare and Productivity,** improving animal health, and hence farm productivity (10 staff, 10 FTE).
- **Infectious Diseases of Livestock,** reducing disease burden in UK livestock and beyond (15 staff, 14.8 FTE).

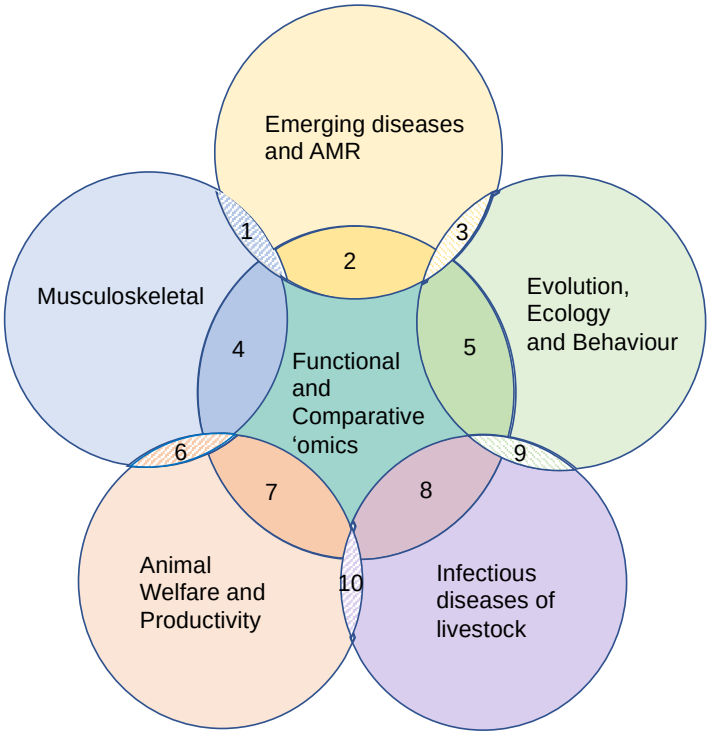

Figure 1. Exemplar projects to reflect collaboration amongst UoA6 staff across research groups

1. Investigating carriage and infections with multidrug resistant bacteria in horses **2.** Caecal Microbiome Transfer: a novel approach to Campylobacter control and improved broiler chicken gut health **3.** MIDGESYM - Symbiotic bacteria in midges: understanding their role in determining vector competence and transmission of viruses **4.** A systems biology approach to musculoskeletal tissue engineering: transcriptomic and proteomic analysis of cartilage and tendon cells **5.** Resistance: The role of genetic architecture and refuge strategy on the evolution of resistance to Bt-crops in lepidopteran pests **6.** The stratification of osteoarthritis to improve equine welfare **7.** Assessments of fish gut microbiota during development, and in response to environmental and dietary change **8.** Genomic analysis of antigenic diversity in Brazilian Trypanosoma vivax strains **9.** Genetic and molecular basis of triclabendazole resistance in *Fasciola hepatica* **10.** Mapping the patterns and drivers of antibiotic use and environmental resistance in the Argentine beef industry.

UOA6 is housed within the Faculty of Health and Life Sciences (FHLS; Institutional Statement, Section 1) and occupies four sites across the main campus (Liverpool) and the Veterinary campus (Leahurst, Wirral). Significant investment has resulted in the revitalisation and co-location of researchers around cognate research groups, which has involved provision of new research buildings where necessary (*e.g.* William Henry Duncan research facility £27M). Four directorates —Clinical, Education, Research & Impact, and Infrastructure & Environment (I&E)—cut across FHLS and provide a framework to drive strategy. I&E directorate centrally manages the Shared Research Facility (SRF), a set of 24 research facilities based in Liverpool available to researchers (see Section 3); these are complemented by large animal and specialist rodent facilities (Leahurst). Since 2014 we have actively integrated multiple individual disciplines within our new Institute of Infection, Veterinary and Ecological Sciences to provide greater breadth and depth. It has re-integrated our research and education activity and allowed us to prioritise our research strengths

and strategically realign our professional services support and governance structure to effectively address the scale and complexity of our activity.

1.2 OUR RESEARCH STRATEGY

Throughout 2014–2020 we have been guided by our five strategic priorities (SP1–5), which have underpinned and driven the growth, career development and excellence of our staff and championed our investment in ECRs, leading to expansion of our research income and postgraduate community.

SP1: Expand our world-leading research excellence in one health, multi-'omic' technologies; emerging infections and resistance evolution; plant health and food security; biological mechanisms in musculoskeletal ageing; evolutionary and ecological responses to change; and conservation at habitat and landscape levels.

SP2: Ensure the sustainability and vitality of our research foci through strategic investment in infrastructure, people and enabling technologies. Nurture our postgraduates, postdoctoral researchers (PDRAs) and support the evolution of ECRs into discipline leaders.

*SP3: Enhance our delivery of impactful research of societal relevance that rises to the challenges facing global society, by adopting the organising principles for SDG impact (*see Section 1.4*).*

*SP4: Grow our strength in interdisciplinary research (see S*ection 1.5) *and further integrate our collaboration by leading new partnerships at local, national and international level.*

SP5. Further develop our values-based leadership of research, fostering a fair and inclusive research environment that supports all staff and students and promote the highest standards of open access, research integrity and ethics.

Following REF2014, our priority was to extend from core Veterinary & Agricultural Sciences to encompass an array of underpinning bioscience, bringing together allied research on laboratory animal welfare and biodiversity preservation in fragmented agri-food landscapes. This has led to an enhanced return of 105 staff, substantially increased from the 56 returned in 2014. Since 2014 we have secured >£94M in grant awards from over 100 different funding sources (Section 3). Our strategy for pump-priming and internal peer review (Section 3) has enhanced the quality of our submission and delivered increased returns. UoL total UKRI award success rate of 32% by number and 26% by value is well above the national average of 21% and 20% respectively (2018/19 UKRI report). UOA6 has had particular success with BBSRC awards, positioning us consistently above the national average (Figure 2).

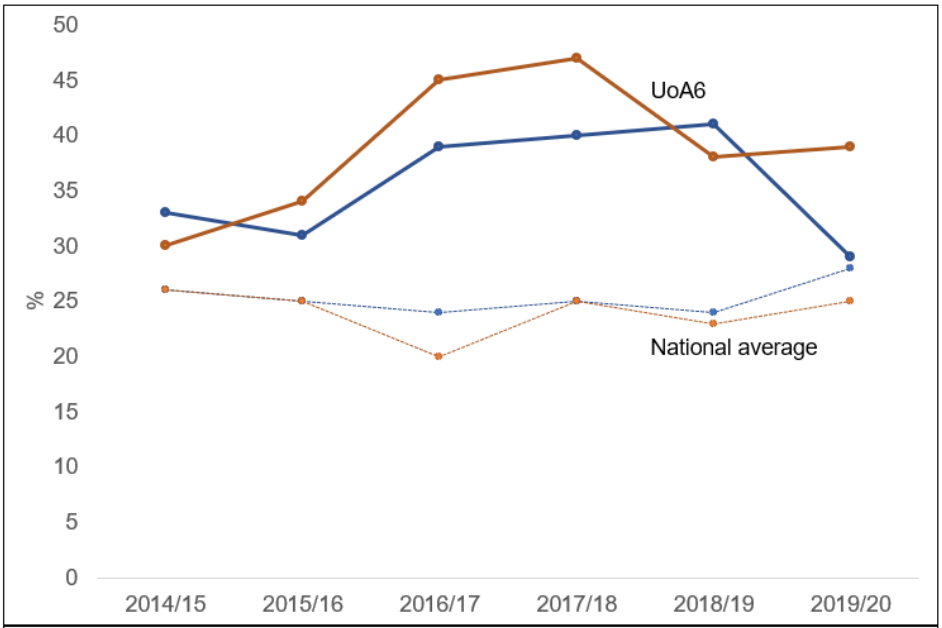

Figure 2. Increase in BBSRC success rates by number (blue) and value (orange) for the period 2014–2020, following the introduction of internal peer review processes in 2015. Average values for number (blue dashed) and value (orange dashed).

Our strategic investment in 2014–2020 has grown our staff numbers (35 new appointments), attracting the brightest talent and bringing vibrancy and greater interdisciplinarity to UOA6, ensuring the continued success of our discipline. The majority of these appointments were through our flagship Tenure Track Fellowships (TTFs) launched in 2014 and featured in Times Higher Education. Our particular success in nurturing independent fellowship applications has seen significant reward within UOA6 (Table 2), reflecting the UoL award success rate for fellowship applications as a whole: 36% and 30% by number and value, well above the national average of 24% and 20%, respectively (2018/19 UKRI report), positioning us top amongst our Russell Group peers. Since 2014 we have strengthened existing collaborations and forged a number of new national and international partnerships such as the N8 Research Partnership established in 2016, https://www.n8research.org.uk/ and Global Burden of Animal Diseases (GBADs) programme (Section 4).

Through extensive UKRI, Wellcome, GCRF and Newton Funding (>£10M) and recruitment of eight members of staff we have extended our international research in **Emerging Diseases and AMR**, primarily in Africa and Asia (**Baylis, Mor, Makepeace, Bell-Sakyi**); launching the GCRF One Health Regional Network for the Horn of Africa (HORN) and leveraging GCRF funds to lead the Tick Cell Biobank and initiate outposts in Brazil, Kenya and Malaysia. Substantial investment (£6.2M) from BBSRC, MRC, NIHR, Wellcome, NIH and DARPA, (**Fevre, Hiscox, Scantlebury, Wigley**) has enhanced our understanding of disease emergence across urban and food systems in Africa (*e.g.* ZooLINK, UrbanZoo); of histoplasmosis in equids in Ethiopia; and helped protect people by developing diagnostics and control strategies for enteric bacterial pathogens in backyard and commercial poultry production in Asia. Our vector-borne disease awards on human and animal diseases spread by midges, mosquitoes and ticks (**Baylis**) is underpinned by ~£2.5M BBSRC, NERC, MRC and HPRU funding. We lead a rapid and effective response to SARS-CoV-2 and COVID-19 by hosting the ISARIC-4C sample biobank (**Hiscox**, £3M from the MRC). We have a continuing major role in driving sequencing and metagenomics efforts for SARS-CoV-2 as part of our collaboration with COG-UK (**Darby, Hiscox, Paterson**) supported by £1.5M from Public Health England (PHE)/UKRI, sequencing over 1000 genomes/week (third highest behind Wellcome Sanger Institute and Public Health Wales). We conduct translational research on severe

coronaviruses and evaluate animal models for COVID-19 through an international research programme led by **Hiscox** (US FDA, $6.6M and European Medicines Initiative, €300K).

Our **Infectious Diseases of Livestock** research on emerging infections, resistance evolution and food security has grown since 2014 and has seen recruitment of six new members of staff. BBSRC, Newton and FAO funded research (>£10M) focuses on the transmission, diagnosis and control of endemic disease of livestock (**Williams D, Oikonomou, Evans, Duncan, Wigley**), extending to understanding basic biological principles underlying disease processes (**Coombes, Jackson**), and host immune responses (**Flynn, Stewart**). We lead programmes on multi-drug resistant pathogens and crop improvement to resist parasites and pathogen attack (**Hodgkinson, Davies, Williams N, Saccheri, Walley**) and lead the recently founded $7M GBADs programme (**Rushton**). NERC and MRC GCRF funding (£3M) was used to develop field models of parasite and pathogen spread through natural rodent populations (**Begon, Fenton, Viney, Paterson**) and has been leveraged to obtain funding from The Bill & Melinda Gates Foundation to control rat borne leptospirosis in Brazilian slum settings.

We have a strong interest in integrating animal health issues, such as obesity, metabolic syndromes and welfare, with social sciences via our **Animal Welfare and Productivity** focus and have invested in a further two academics. **Archer, Pinchbeck, Westgarth, German, McGowan** and **Latham** lead several grants (totalling ~£2.4M) with specific focus on improving animal health, enhancing animal-human interactions for both companions (dogs and horses) and livestock. A programme of work by **Hurst J** and **Stockley** (>£2M, NERC) on laboratory mouse handling and welfare, is complemented by extensive behavioural studies. The Small Animal Veterinary Surveillance NETwork (SAVSNET, **Radford** and **Pinchbeck**), underpinned by BBSRC and Dog's Trust funding (~£1.9M), focuses on disease surveillance and health informatics and captures real-time data at the point of client interaction; leading the way by providing a blueprint since adopted beyond the UK in countries across Europe and in the US.

Novel application of engineering of materials and devices to improve physical health and wellbeing, has seen our **Musculoskeletal** research boosted by a new critical mass of ECRs (**Turner, Wilkinson, Yamamoto, Camp**), many of whom hold external fellowships. With a diverse funding portfolio from Wellcome, BBSRC, Versus Arthritis, HBLB, Horse Trust, MRC and Dunhill Trust (~£1.2M), we host the MRC-Arthritis Research UK Centre for Integrated Research into Musculoskeletal Ageing (CIMA) Initiative (£2.5M 2012–2017; renewed £2M 2017–2022), which explores the ageing process across the musculoskeletal system with an emphasis on both osteoarthritis (OA) and cartilage biology (**Peffers**, **Tew**). A critical mass of individuals working on cartilage turnover in OA (**Poulet, Bou-Gharios, Yamamoto, Peffers, Wilkinson**) is complemented by internationally leading expertise in mouse transgenic matrix biology (**Bou-Gharios**). Our extensive work on tendon/ligament disorders and repair, including novel material approaches (**Clegg, Laird, Comerford,** ~£4M from MRC, BBSRC, HBLB, Dunhill Trust & Versus Arthritis), encompasses Regenerative Medicine in orthopaedic disease (**Clegg, Oldershaw, Turner, Henstock**). The gait group (**Bates, D'Aout, Sharp, Jeffrey, Camp,** ~£2M from BBSRC, Innovate UK and Leverhulme Trust), has a particular focus on the locomotor system and uses a variety of computational modelling and gait assessment techniques.

Our work in **Evolution, Ecology and Behaviour** delivers underpinning research to establish the basis for understanding resilience to environmental change and drive technologies in modifying natural populations for human benefit. Strengthened by a cohort of new ECR recruits (**Dougherty, Garcia Perez, Hall, O'Brien, Zytynska, Parratt**), half of whom hold external fellowships, the group explore evolutionary and ecological responses to change and conservation at habitat and landscape levels. The biodiversity group (**Cornell, Garcia-Perez, Whitlock, Hodgson, Atkinson, Price,** >£4M) have determined fundamental aspects of ecology, such as the definition of the niche; established the roles of landscape fragmentation and changes in biotic interactions to determine biodiversity conservation outcomes, leading to the delivery of packages for community use, facilitating land planning. Our work on evolution in the Anthropocene (**Saccheri, Hurst G, Plaistow, Paterson, Price, Betancourt, Whitlock**), supported by >£10M NERC, BBSRC and an ERC Consolidator grant, drives understanding of evolutionary responses in recent time, including

determining the genetic basis of melanism in peppered moths, the response of insects to parasites and Daphnia to pollution, the impact of climate change on evolution in grassland, and the spread of selfish genetic elements through natural populations.

Our **Functional and Comparative 'Omics** group develops computational platforms to understand the mechanistic underpinning of complex data at DNA, transcriptome, proteome and metabolome levels. Further, we aim to enable 'omics data sharing through development of standards and platforms (**Jones, Bollback, Caddick, De Magalhaes,** ~£11M). These feed into an array of other problem areas, focused around microorganisms, ecotoxicology and photosynthetic efficiency (**Liu, Allison, Horsburgh,** >£4M). Supported by the BBSRC, the US Department of Energy and EU, our work on plant sciences and photosynthetic organisms has worked in tandem with industry to employ biochemical, genetic and field approaches to utilize marginalised habitats and breed for enhanced resilience in leafy vegetables. The group has grown with the addition of five staff, two of whom are ECRs (**O'Maoileidigh, Canniffe**), one recently awarded a BBSRC David Phillips Fellowship. Supported by a NERC Independent Fellowship, and NERC grants (>£2M), **Antczak and Falciani** use multi-omic data and computational biology approaches to identify signals of pollution stress in aquatic environments and in aquaculture. Using funding from the BBSRC, NERC (>£1.5M), **Darby and Makepeace** have identified the importance of the microbiome in key elements of tsetse fly biology and vectorial capacity for trypanosomiasis. **Shirazi-Beechey,** with **Young,** have gained funding from the BBSRC and Industry partners to determine the importance of the microbiome in aquaculture contexts, and development of prebiotics to improve piglet health and growth outcomes.

1.3 OUR RESEARCH OBJECTIVES OVER THE NEXT FIVE YEARS

Our future strategy is grounded in helping to achieve UN's SDGs (notably addressing health, poverty, food security, climate and the natural environment), as well as focusing on post-COVID-19 rebuilding. A foundation of interdisciplinarity strengthened by our global presence allows for an enterprising research strategy over the next REF period:

- Enhance our multidisciplinary USP in One Health research through further integration with basic biological research in ecology, evolution and behaviour and expanding our social science research portfolio.
- Extend our research on the burden of animal disease, the drivers of infectious disease emergence (including climate change impacts) and prediction of pathogen-host interactions.
- Intensify innovation through strengthened collaboration with 'omics technologies, engineering, mathematics and imaging.
- Build on our response to COVID-19 to ensure responsiveness to future disease epidemics by developing agile teams of multidisciplinary researchers who can rapidly apply their expertise to a range of diseases, and respond to local, national and global emergencies.
- Extend our global reach by building on our strengths in Africa and develop these as hubs for more UoL research.
- Expand initiatives to support growth in clinical research strength and provide more support for clinicians to undertake research.

1.4 RESEARCH IMPACT

Impact lies firmly at the heart of UOA6 strategy, and we continue to be proactive in driving the Faculty's impact agenda. Through our work with low and middle income (LMIC) countries (framed by our SDG commitment), we aim to enhance animal productivity, whilst promoting the highest standards of animal welfare, primarily in the UK but also to improve farming in the poorest societies. We have incentivised and supported impact activities to drive innovation within the animal health

industry and translate our basic research for the benefit of animal health and clinical practice. Long recognising that significant investment is required to deliver high quality impact, we have invested heavily at each step in the impact 'pipeline', with the range and scope of support growing over time (Figure 3). To date, £630K pump-priming funds have been awarded to UOA6—more than 50% for impact tailored to the needs of individual stakeholder groups. To translate our research and deliver impact of benefit to the public via Public Engagement (PE) activities, we orchestrate our PE Officers, financed through dedicated PE allocations on UKRI grants, the Wellcome ISSF and through the Faculty PE Grant Scheme (£10,000–14,000 awarded/year), to deliver events to the public free of charge. We also have a number of active patient and public information panels (PPI) to inform and guide our impact activities to achieve the greatest benefit to end users.

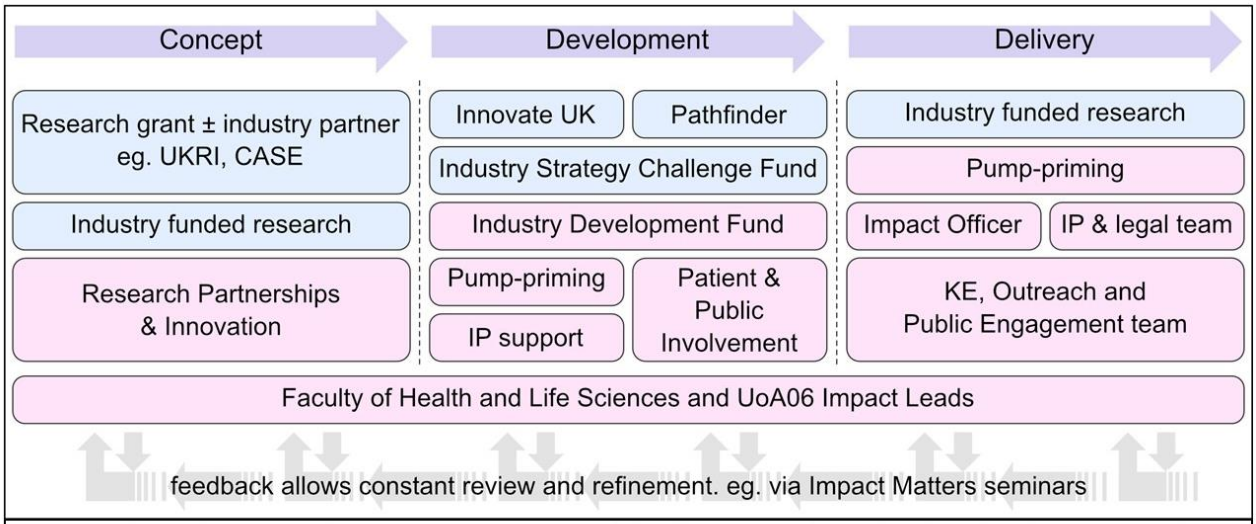

Figure 3. Impact support pipeline from concept to delivery. UoL-funded support is highlighted in pink.

Engagement with impact activities is incentivised in several ways and features heavily both in the workload model and in the criteria for progression as an established means of recognising staff contribution. To date, the Faculty's Impact Matters Series has hosted 30 case presentations with ~500 staff in attendance, involving nine cases from UOA6. To maximise impact at the final stage of delivery, UOA6 has successfully secured additional support from FHLS Impact Officers and Faculty-managed funds such as Impact Accelerator Awards (IAA). Targeting resources primarily to impact cases has enabled us to drive change within a diverse range of stakeholder groups (Table 1). In addition, our long-term vision is best illustrated by drawing on other examples where internal funding underpins research to harness full potential.

Case study: Research to define novel vaccine candidates against the livestock parasite Fasciola hepatica began with funding through InnovateUK and a subsequent BBSRC award to Dr Robin Flynn and his industrial partners. This work led to a prototype subunit vaccine that received its first animal trials at UoL in 2017/18. A BBSRC Pathfinder award allowed initial efficacy testing in ruminants, as well as market and product position research. Substantial investment of £100K from the UoL Enterprise Fund (awarded 2019) is driving large-scale trials in vivo, whilst a dedicated IP commercialisation manager is facilitating engagement with pharmaceutical companies, e.g. ELANCO, about the future commercialisation of this product.

Since 2014 we have promoted challenge-based impact, taking a multidisciplinary approach to work actively with collaborators, policy makers and stakeholders in society to identify complex challenges, formulate relevant questions and take action for sustainable development. Our extensive Overseas Development Agency (ODA) research portfolio addresses needs in LMIC countries and is helping us recognise the strength of the impact framework for realising the SDGs by 2030. We are keen to adopt these best practice approaches in all areas of our impact over the

next five years and have increased our focus on addressing UK needs (for example 'building back better' of the UK economy and society post-COVID-19, and the levelling up of regions in England). We will do this by transforming our ideas into creative solutions, with assets such as Sensor City, Materials Innovation Factory, Virtual Engineering Centre and Centre for Excellence in Infectious Diseases Research (CEIDR).

Table 1. Exemplars of internal support and allocation of resources during delivery phase of impact cases 2014-2021

Stakeholder impact beneficiary	Impact case	PP	Imp O (mnths)
Regulatory organisations	UoL56Micehandling: Refined methods for handling laboratory mice to improve animal welfare, improve research data reliability and increase safety of personnel.	£10K***	3
Veterinary practices and industry	UoL54Equinelaminitis: Equine laminitis - changing practice for diagnosis, management, treatment and prevention by understanding the role of endocrine disease.	£8.5K**	2.5
	UoL53DogCatObesity: Improving recognition, management and prevention of obesity in dogs and cats.	-	2.5
The farming community via the retail sector	UoL59AMRfoodchain: Reducing antimicrobial use in food supply chains.	£1.5K	1
In partnership with industry	UoL58Feedsweeteners: Globally improved porcine welfare and rearing profitability by development of scientifically validated feed additive sweeteners as dietary supplements.	-	2
	UoL57Chickcovaccination: Simultaneous administration of multiple live respiratory vaccine viruses in day-old broiler chicks for better production worldwide.	£17.5K	2
Veterinary practices	UoL60SAVSNET: Small Animal Veterinary Surveillance Network (SAVSNET) research and surveillance initiative leading to behaviour change and improved companion animal health.	£3.5K	2
The farming community	UoL55CO DigDermatitis: Sustainable Control of Digital Dermatitis in Livestock.	£11K	3

****BBSRC Sparking Impact Award, **Knowledge exchange and Impact Vouchers, *Dept provided 30% salary of NERC Knowledge Exchange Fellow. PP = Pump priming, Imp O = Impact officer*

1.5 INTERDISCIPLINARY RESEARCH

Solutions to global challenges require increasingly multidisciplinary approaches. We have invested heavily at the interface of clinical and agri-food research, developing interactions between human and veterinary clinicians, biologists, engineers, mathematicians, computational biologists and

chemical/material scientists. Our interdisciplinarity builds from our local interactions (Figure 1) and extends across the wider University and beyond (see Section 4). Outwith our agricultural, biological and veterinary core outputs, there are three foci of interdisciplinarity (Figure 4):

Maths and Computer Science: Through the **Computational Biology Facility** (**CBF; Jones** and **Falciani**), we have invested heavily to develop computational approaches to support biological research, impact and skill development. An example of this is the development of "Condatis" software (http://www.condatis.org.uk/, led by **Hodgson**), which is used to identify the best locations for habitat creation and restoration to enhance existing habitat networks and increase connectivity across landscapes. The software has been made available through an open access web server, enabling straightforward access, particularly for users in developing countries without access to high-performance computing. Links developed with the Department of Mathematics (Sharkey UOA10) have embedded mathematical modelling capacity within the LUCINDA (**Baylis**) and Veterinary Parasitology (**Williams D**) groups, leading to development of models for several vector-borne viral diseases and intermediate-host parasitic diseases. Examples include a model for the farm-to-farm transmission of bluetongue, which, through further collaborations with climate and computer scientists, culminated in the first mechanistic model for the spread of a disease that could run simulations under past, present and future climates. LUCINDA also integrates host-pathogen biology with computer science, using advanced data mining, algorithms and machine learning to develop, curate and interrogate the world's largest dynamic database of pathogens, their hosts and their distributions (the Enhanced Infectious Diseases Database, EID2, https://eid2.liverpool.ac.uk/), updated in real time and an open-access resource used by researchers globally.

Social Sciences: **Westgarth and Pinchbeck** work across disciplinary boundaries to explore positive (*e.g.* benefits of dog walking and pet ownership) and negative (*e.g.* dog biting and obesity awareness in horses) human-animal interactions. By drawing on the expertise of social scientists (Perkins, Fleming UOA2, Watkins UOA1), we have been able to mitigate against undesirable interaction to improve human and animal welfare and identify where to target future interventions.

Material Science: The comparative musculoskeletal research group have developed strong links bringing together clinicians, biologists, engineers and material scientists to understand various aspects of musculoskeletal ageing. Multidisciplinary engineering, clinical and biological teams **(Clegg, Comerford, Tew, Laird, Peffers)** investigate aspects of tendon and ligament structure and function in ageing. Novel multidisciplinary research is evidenced through internal support of a PhD student to develop links with Liverpool Centre for Mathematics in Healthcare to mathematically model tendon functional decline in ageing, as well as funding by the MRC for a £1.5M Developmental Pathway Funding Scheme grant, which brought together human clinicians and material scientists at the University of Manchester, and veterinary scientists and engineers at UoL to develop and translate a biomaterial implant for tendon repair. **D'Aout's** work on human biomechanics encompasses fundamental and clinically relevant work with academics in the health sciences and applied music department (Coutinho UOA33), *e.g.* to explore the influence of music on the execution of movement, such as the reach task, in stroke patients.

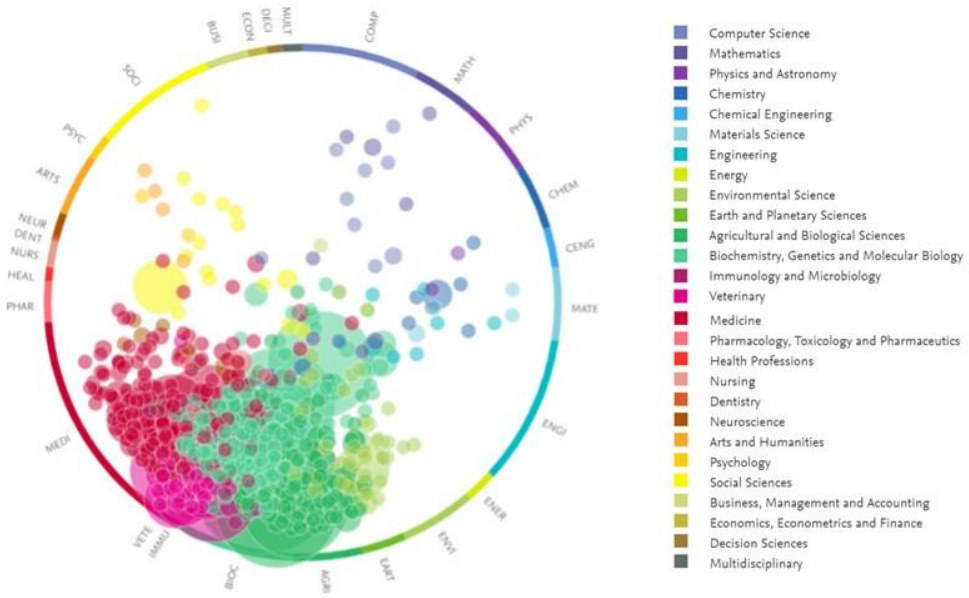

Figure 4. Topic analysis for all University of Liverpool UOA6 publications in the REF period. Each dot represents a distinct SciVal topic in which we have published; dot size indicates the number of publications in that topic (Source: SciVal).

1.6 OPEN RESEARCH ENVIRONMENT

UOA6 delivers on the UoL Open Access Publication Policy (Institutional Statement 2.5) *e.g.* author accepted manuscripts (AAM) and gold OA papers are deposited to the UoL repository within 3 months of acceptance. Staff within UOA6 are encouraged to place pre-prints and underpinning data in appropriate repositories, and an Institutional Repository is provided to facilitate open access to articles, databases and other outputs. UOA6 subscribes to the University's Research Data Management policy, which illustrates our commitment to maintaining the highest standards of rigour and integrity in research. All UOA6 Principal Investigators with UKRI grants complete data management plans (DMP) prior to the commencement of research projects. Much of the data from our work is deposited into the public domain, particularly in the field of genomics, transcriptomics and proteomics, to ensure it is standard compliant. In a staff survey, all respondents had deposited open data during the current REF period, with the majority using multiple repositories: 50% used DNA/RNA sequencing project archives; 25% proteomic databases; 50% bespoke archives for quantitative data (DRYAD, Figshare); 40% GitHub (code); 35% the UoL repository; and 10% other national repositories.

Case study: Many of our researchers work directly on projects designed to ensure reproducibility to deliver international best practice. For example, Professor Andy Jones is Chair of the Proteomics Standards Initiative (PSI), an international organisation comprising academics, industry representatives and journal editors that defines many frequently used data standards for mass spectrometry-based proteomics (mzML, mzIdentML, PSI-MI).

1.7 RESEARCH INTEGRITY

We are guided by the UoL's membership of the United Kingdom Reproducibility Network (Institutional Statement 2.6) to ensure we are compliant with the recommendations within the Concordat to Support Research Integrity. Our strategy aims to pre-empt concerns around integrity

and compliance using a robust system of ethics support. Culturally, within UOA6 we foster a highly collaborative team approach to our science that minimizes researchers working in isolation. We provide core services through staff who advise on experimental design, data acquisition and appropriate data analysis. To inculcate good practice from the beginning, Year 1 PhD students attend compulsory training workshops on principles of data management, reproducible research, ethics and open science. Research 'Away Days' have also provided the opportunity to run Institute-wide sessions on scientific fraud, its causes and its impact. In the event of a lack of rigour or malpractice by an individual member of staff we have robust policies and procedures within the FHLS framework. We make great efforts to ensure that all investigations are fair, and appropriate action is taken both on behalf of the member of staff and to maintain the research integrity of UoL.

All UOA6 research is fully compliant with UoL, Home Office and relevant national and international regulations. The Animal Welfare and Ethical Review Body (AWERB) is a University-level entity chaired by UOA6 **Stewart**: it meets regularly and reports to University Council via the Research Integrity and Governance Committee. It is a statutory legal requirement and much of its composition and functions are proscribed by legislation under the Animals (Scientific Procedures) Act 1986, although it concerns all aspects of welfare and ethics around use of protected animal species. AWERB oversees training sessions and courses to help UOA6 researchers prepare their applications for ethical or regulatory approval. However, we also extend beyond this to proactively promulgate good ethical and welfare practices.

Case study: Research to refine strategies for handling laboratory mice has informed debate resulting in new policy and a widespread change in laboratory mouse handling practice across industry and academia; this has improved animal welfare and reliability of animal-based experiments. Recommendations have been implemented through dissemination, widespread training programmes and distributed materials working closely with UK National Centre for the Replacement, Refinement & Reduction of Animals in Research (NC3Rs). These recommendations have also recently been adopted by the UK Home Office Animals in Science Regulation Unit following a formal review in early 2019 to promote rapid implementation (with support training) across all laboratory animal units in the UK. Targeted engagement with large pharmaceuticals have ensured international industry uptake of recommended practices, with both Novo Nordisk and AstraZeneca plc adopting the recommended practice. In 2020 PI, Professor Jane Hurst was awarded an OBE in recognition for this work.

2. PEOPLE

2A STAFFING STRATEGY AND STAFF DEVELOPMENT

At the heart of our strategy are our people, investment in whom has allowed us to strengthen our multidisciplinary research base, further develop our critical mass and expand our existing capabilities. We recognise succession planning is vital to future-proof our discipline, and we have made a sustained commitment to appointing ECRs. This is balanced by substantive, strategic appointments at senior level, to provide leadership and mentoring; this, combined with a strong commitment to retaining and promoting staff within existing departments, has led to a vital and sustainable staffing body.

2A.1 RECRUITMENT

We have invested in 35 new staff and four existing staff have been confirmed into new roles; including 23 Fellows/TTFs, 20 of whom are ECRs (Table 2). We made two strategic Chair appointments, **Rushton** (2016, N8 AgriFood Chair) and **Viney** (2018). One appointment at Reader (**Mor**), six at Senior Lecturer (SL) level (**Flynn**, **Davies**, **Antic, Bollback, Wigby, Neary**), six at Lecturer level (**Oldershaw**, **Betancourt, Sharp (ECR), Parratt (ECR), Barribeau** and **Crosby-Durrani (ECR)**) and one Independent Researcher (**Bell-Sakyi**). We are committed to supporting and mentoring 'home grown' talent, *e.g.* of 11 TTFs appointed prior to 2014, eight have progressed to at least SL, with two awarded a Personal Chair. Six of these TTFs were women, all of whom were successfully confirmed in post, and four have progressed to SL or Chair. Similarly, **Betancourt** was a new appointment (Lecturer) in 2016, following which she was promoted to SL then Chair in 2019. This highlights a very positive trajectory for our ECRs and is crucially important as women account for 73% of our <50 age group and 50% of our new Fellow/TTF appointments.

Table 2. Staff appointed into UOA6 who hold Independent Fellowships and TTFs, the majority of whom are ECRs

Appointment date	Staff name	Appointment funding/Fellowship scheme	Research group
2015	Antczak*$	NERC Fellowship	OMICS
	Henstock*	TTF	MSK
	Poulet*	Versus Arthritis Career Development Fellowship, TTF	MSK
2016	Kluiters*	BBSRC Anniversary Future Leader Fellowship	EDAMR
	Walley^	N8 AgriFood Fellow	OMICS
2017	Scantlebury	Wellcome Trust Research Career Development Fellowship, TTF	IDL
2018	Camp	BBSRC Future Leader Fellowship	MSK
	Blagrove	TTF	EDAMR
	Dougherty	Leverhulme Early Career Fellow	EEB
	Garcia Perez	TTF	EEB
	Hall	TTF	EEB
	Vineer	TTF	IDL
2019	Canniffe	TTF	OMICS
	Hodgson*^	UKRI Future Leaders Fellowship	EEB
	O'Maoileidigh	BBSRC David Phillips Fellowship, TTF	OMICS
	O'Brien	BBSRC Discovery Fellowship, TTF	EEB
	Turner	NC3Rs Fellowship, TTF	MSK
	Tulloch	TTF	EDAMR
	Wilkinson	Versus Arthritis Foundation Fellowship, TTF	MSK
	Yamamoto	Versus Arthritis Foundation Fellowship, TTF	MSK
	Zytynska	BBSRC David Phillips Fellowship, TTF	EEB
2020	Millins	TTF	EDAMR
	Subramaniam	TTF	EDAMR

*Not classified as ECR for the purposes of REF, ^ hold tenured posts, $fellowship provided springboard to relocation in EU.

Cognisant of 'The Concordat to Support the Career Development of Researchers' and in line with our Athena SWAN action plans (all staff are within departments holding a Silver or Gold Award), our recruitment processes have been developed to ensure that we are consistent, open, transparent and equitable *(Concordat Principles 1, 6)*. In order to attract researchers of the highest potential from a broad base, we advertise job vacancies widely on both traditional platforms (*e.g.* UoL website, jobs.ac.uk) and through social media (*e.g.* Twitter). We pay careful attention to address EDI within specific requirements for the role and practice several levels of internal review by academic and professional service staff. Short-listing and interviews are conducted by a mixed panel of senior staff and ECRs, who independently rank candidates based on merit, using a designated skills matrix. To mitigate against unconscious bias and to ensure transparency of

decision-making, all staff involved in recruitment have to complete EDI and unconscious bias training, a process closely monitored by our local HR representative.

2A.2 STAFF EQUALITY, DIVERSITY AND INCLUSION

Our commitment to EDI is evident throughout this document with our staff benefitting from UoL's charter commitments (Institutional Statement 3.2). A framework of compulsory training, renewed every 3-5 years, ensures all staff are aware of their rights and responsibilities, *e.g.* Diversity and Equality Training (*Concordat Principle 6*). Benchmarking UOA6 against the Equality and Higher Education Staff Statistical Report 2019, Advance HE, we have identified numerous areas where we meet or exceed national standards, *e.g.* 5.9% of Category A staff disclosed a disability, (5.1% HE report) and 69% are <50 years (61.2% HE). UOA6 has 37 women (35%), slightly below the sector benchmark (41.4% HE); however, women account for 50% of our new Fellow/TTF appointments and UOA6 has 27 male and 11 female professors compared with 25 and 7, respectively in 2014, demonstrating our commitment to retaining women at the critical career transitions and ensuring they progress to the most senior levels. 25% of staff in UOA6 are non-UK (15% EU; 10% OSI), approaching the 30.8% UK average, and we have extended our numbers of BAME colleagues, with 6.25% representation (9.9% HE value), which is encouraging; we are committed to further increasing staff diversity. Selection of outputs was transparent and consistent with UoL's Code of Practice and DORA objectives. To create scores, all manuscripts were read by two individuals and moderated by a large panel of staff at different career levels, which was balanced by gender and included members of our Athena SWAN team. Mid-ranked early papers (2014-2017) were re-visited. Selection was initially by algorithm, supported by checking to ensure each staff member's best output was selected. The main EDI safeguards to avoid individual biases were:

a) Large and diverse panel moderation.
b) Metric based reassessment

2A.3 RETENTION AND PROMOTION

Recognition and reward is key to the wellbeing and retention of our staff. We value all our staff and strive to achieve best practice around promotion and progression, which has been vital to achieving our high retention rate in 2014–2020. Early in this REF cycle we revised our promotion procedure by implementing a panel of senior academics to review all staff for progression annually. This is a very successful approach with 40 out of 70 (57%) of eligible UOA6 staff (TTF to Reader) promoted since 2014, including seven recently appointed staff. Notably, in the last five years there were 56 promotions: 36 progressed one level, 16 were promoted twice and four people achieved three levels of progression. Our established Professoriate can apply for a 1-3% salary increase annually, resulting in 15 successful applications since 2014. In 2016, the Professorial levels exercise introduced four new levels and benchmarked all existing professors to these new criteria; this resulted in the immediate regrading of five staff to Professorial Level 2, followed in subsequent years by the promotion of another five senior academics to Level 2, two to Level 3 and one to Level 4. Confirmation in post for TTFs/ECRs are dealt with by a bespoke panel, using tailored criteria. To date, all TTFs appointed in UOA6 successfully completed their probationary period and transitioned to open-ended contracts. Staff appointed with personal fellowships (*e.g.* **Yamamoto**) were awarded TTF status in line with our policy (*Concordat Principles 2, 4*). Several of our own PDRAs have been successful in making the transition to TTF since 2017, *e.g.* **Blagrove, Dougherty, Scantlebury** and **Subramaniam**. Overall, 93% of our staff are on an open-ended contract, recognising that long-term investment in people provides the security they need to flourish.

Case study: Professor Mandy Peffers was awarded her PhD in 2013 at UoL and completed her Wellcome Veterinary Integrated Research Fellowship in 2015, changing the second part of her fellowship from a clinical residency to a postdoctoral research fellowship. Through CIMA she secured £66K to fund the laboratory work for which she received her FRCVS by thesis. In 2015 she was awarded a Wellcome Intermediate Clinical Fellowship and promoted to Senior Lecturer. In 2018 she applied for promotion to Reader but was instead promoted to Personal Chair. She

was successfully awarded a one-year extension to her fellowship to study extracellular vesicles to treat osteoarthritis (due for completion March 2021). Since 2014 she has received internal pump-priming matched funds, totalling ~£17K and has won >£1.5M in research grants from Wellcome, Horserace Betting Levy Board, Horse Trust, Pet Savers, MRC, Orthopaedic Research UK.

2A.4 FOSTERING EARLY CAREER RESEACHERS

a) Tenure Track Fellowships (TTF) scheme: this runs over five years with tightly defined expectations and a fixed maximum teaching commitment in the first three years of appointment, facilitating development of independent research capability. On induction, a structured plan of activity is developed, a mentor is appointed and the Head Of Department (HOD), who is best placed to allocate access to equipment and resources, oversees progress. In years 1-3, pump-priming funds are prioritised to fellows, and applications for substantive competitive external funding are supported, following which an end of year 3 review takes place. We have recruited 17 TTFs since 2014; many are appointed with externally-funded fellowships or demonstrate an established track record of securing funding and are building research independence (Table 2). The TTF pathway is helping address the widely acknowledged 'leaky pipeline' responsible for attrition rates of women in science; by recruiting the very best ECR talent and securing their futures.

b) Wellcome Institutional Strategic Support Fund (Wellcome ISSF): In 2016, the UoL secured a third award, worth £2.5 million over 5 years (£6.25M in total awarded to date). This staff development package, provides a versatile and flexible portfolio of funding through competitive awards, with a total of >£730K awarded to UOA6: Equality and Diversity (£6K), Public Engagement (£11K), Interdisciplinary and Industry (£15K), Non-clinical Fellow Support (>£200K), Veterinary Postdoctoral Fellowships (>£380K), Veterinary Research Taster (£71K) and Veterinary Clinical Leave Fellowships (>£100K). The extensive impact of Wellcome ISSF is woven throughout this statement.

c) Fostering Liverpool Infection and Global Health Talent (FLIGHT): Our FLIGHT initiative was set up to provide positive messaging about 'aiming high' for competitive external fellowships, supporting ECRs to obtain their own funding and develop an independent research career. Regular seminars and workshops support staff and emphasise the importance of researchers' responsibilities and taking ownership of their futures *(Concordat Principle 5),* whilst internal review of CVs and applications provide support and guidance. This has delivered sustained growth in independent fellowship awards, many awarded to UOA6 academics (see Table 2). Our success rate of 36% and 30% by number and value, respectively (UKRI report 2018/19), positions UoL top amongst Russell Group universities. All fellowship holders within FHLS are considered for transfer to the TTF scheme no later than mid-way through their external fellowship, with the majority making a successful transition (Table 2).

2A.5 STAFF DEVELOPMENT

Our staffing policy is based around recruiting and retaining excellent researchers (*Concordat Principle 1*). Our success in supporting staff depends upon clear and effective line management. Staff development is centrally co-ordinated and delivered via The Academy (Institutional Statement 3.3.1). The role of the HOD is to mentor academic staff (>90% of UOA6 have a personal mentor), conduct staff appraisals (PDRs), ensure equity in workload allocation and to facilitate internationally competitive research and effective teaching (*Concordat Principles 2, 3, 4, 6*). We actively engage with the Research in an Inclusive and Sustainable Environment (RISE; Institutional Statement 3.3.3) project.

Targeted support for junior and fixed-term contract staff is available via the Career Coaching Scheme that gives participants access to mentors with subject-specific experience (*Concordat Principles 3, 4, 5*). Notably, we developed the sector-leading **PROSPER** scheme (Institutional Statement 3.3.2) that provides structured career and development support for PDRAs. To facilitate career development, we offer an internal small grants scheme, *e.g.* **Postdoctoral Career Awards;**

in its inaugural year (2019), £85K was awarded to 10 PDRAs, eight of whom are women. Our ECR and Returners Fund has awarded >£10K to three individuals and we prioritize allocation of other pump-priming funds to ECRs (Section 3), *e.g.* 50% of the ODA Research Seed Fund (£34K) was awarded to ECRs. Contributions made by researchers are recognised through co-authorship: 254 and 634 papers published since 2014 had PDRAs as first or co-author, respectively, with a rise from 13.7% to 17.4% first author PDRA publications from 2014 to 2020. Where appropriate, PDRAs are named as co-researchers on grant submissions and we target more senior PDRAs thinking of developing fellowship proposals, by reviewing CVs and proposals *(Concordat Principles 1, 2, 3, 4*). Wellcome ISSF has proven an invaluable means of developing researchers, *e.g.* Wilson, MPhil funded by the ISSF, then a PhD on the MLW Research Training fellowships; and Pilgrim, intercalated on our MSc supported by ISSF funding, then secured a BBSRC DTP PhD studentship and now has a one-year ISSF postdoctoral fellowship. We established a £150K independent support fund in 2016 (Johnston Researcher Development Fund) offering grants to all research-only staff to aid their transition from researcher to academic or to alternative career paths outside of academia. The fund has awarded nearly £60k to 24 UOA6 PDRAs.

Case study: PDRA Dr Maya Wardeh was awarded a prestigious BBSRC NPIF Fellowship (Big Data approaches to identifying potential sources of emerging pathogens), which was supported by an internal pump-priming (BBSRC-IAA) award. The project focuses on developing a network model to investigate sharing, transmission and emergence of pathogens between host species, utilising Big Data and machine learning to help identify potential future emerging pathogens. She has now been selected to apply for a UKRI Future Leader Fellowship.

2A.6 EMPLOYMENT FLEXIBILITY AND SUPPORT

All university staff can access a range of family-friendly options, notably parental, compassionate, domestic and personal leave. The University's flexible working policy allows individuals to vary or adjust their pattern of work based on their personal circumstances. The majority of UOA6 staff temporarily or permanently adjust their work patterns with agreement from line management. Our local 'Family-Friendly Fact Sheet' signposts staff to the Carer's Network, Parent's Network and ECR Network. We provide financial support to students and staff during, or on returning from, leave. This includes PDRA and fixed-term contract staff, when other forms of funding are not available. A defined departmental Wellbeing Budget supports local health and wellbeing support, advice, guidance, signposting and activities, *e.g.* Wellbeing Walks; Art Events; Midweek Meditation, and complements the University's annual Health and Wellbeing Week.

Case study: An academic appointed as TTF in 2013 has taken two periods of maternity leave since her appointment. For the second of these periods of leave (nine months) her PDRA was placed on an extended nine-month contract to cover her absence and facilitate supervision of PhD students and smooth running of the laboratory. This provided her with the necessary time away from work but ensured continuity in her research, which helped in the confirmation in post assessment and subsequent appointment to a tenured post. It also had an important impact on the career of the PDRA, who went on to secure a substantive post as lecturer at another institution.

2A.7 DEVELOPMENT OF VETERINARY CLINICAL RESEARCHERS

Working to ensure we develop clinically-trained veterinary researchers of the future we instil an interest in research from the earliest opportunity, inspiring students via the **BBSRC STARS** scheme, the Academy of Medical Sciences **INSPIRE** scheme and using Wellcome ISSF funding to support vacation research projects and providing matched funding. In 2014–2020 a total of 106 undergraduate students have undertaken vacation research projects with UOA6 staff, and more than 200 additional students have attended other events such as summer research schools and research conferences. We offer enhanced PhD stipends for veterinary scientists, as well as supporting more established staff with our Wellcome ISSF Veterinary Fellowship schemes:

1. **Clinical Leave Fellowships**—four veterinary clinicians, **Oikonomou**, **Walmsley**, Killick and **Duncan** have been awarded ~2 years research leave to re-engage with high quality scientific research and develop a clinical academic career. Higgins has been allocated funds to support a UKRI Future Leader Fellowship (FLF) application, which is currently under consideration.
2. **Postdoctoral Fellowships**—seven veterinary PhD graduates, **Scantlebury**, Anderson, Pilgrim, Turlo, Zamboulis, Thomas and Beesley have received >£380K for ~1 year to develop research ideas and generate preliminary data for external fellowships.
3. **Research Taster Fellowships**—three veterinary graduates with general practice experience (Scott, Gledhill, Wilson) have been awarded ~£71K collectively, enabling them to obtain initial research training and gain research experience.

2B RESEARCH STUDENTS

Within U0A6 263 PhD studentships have been awarded since 2014; with increasing numbers of awards made year on year (Figure 5). This represents sustained growth and a substantial increase from 2.24/FTE in 2014 to 2.56/FTE in 2020. This success is testament to our PGR strategy, especially our increased success with UKRI doctoral training partnerships (DTPs) and reflects the strength of our recruitment strategy, our focus on PhD student development and wellbeing and our progress-monitoring process.

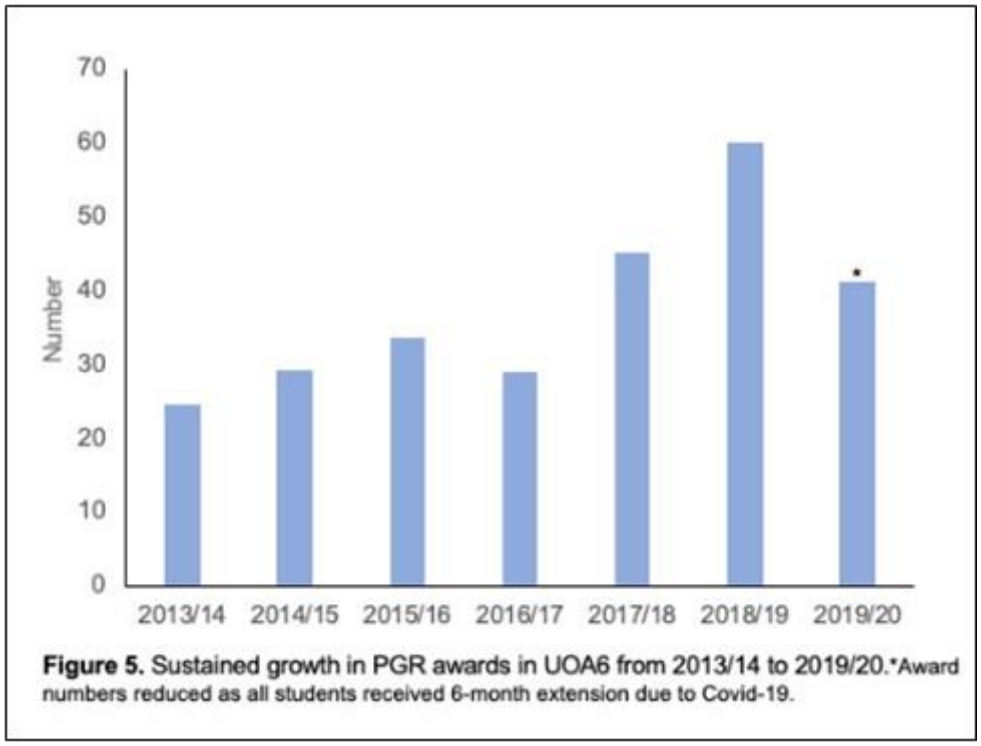

Figure 5. Sustained growth in PGR awards in UOA6 from 2013/14 to 2019/20.*Award numbers reduced as all students received 6-month extension due to Covid-19.

2B.1 RECRUITMENT OF RESEARCH STUDENTS

We have invested heavily to generate a diverse funding base (Figure 6) with which to support PGR recruitment, and we have proactively developed innovative partnerships to attract exceptional students (>75% having first class honours or a Masters qualification). Internal investment has enabled us to expand our PGR training by providing leverage for matched funding from UKRI, charity, industry and levy bodies. This has facilitated considerable success with UKRI DTPs, which are supported by 50% contribution from UoL; two of which (BBSRC and NERC) are led by UOA6

academics. A particular feature of the DTPs is the focus on close academic-industry partnerships, *e.g.* our Associate Partners in BBSRC DTP3 include Fera, Tesco, CIEL, KWS, Procter & Gamble, AIMES, Centre for Process Innovation and the Agriculture and Horticulture Development Board (AHDB). Over 50 (~20%) of our studentships are CASE awards, with partners including Unilever, Boehringer Ingelheim, AHDB and Natural England.

BBSRC DTP—Led by **Jones,** this partnership with Universities of Newcastle, Liverpool and Durham, displays excellence in research in BBSRC priority areas, with the largest contribution from Liverpool (£17.2M out of the £35M total). Through effective doubling (50% University matched funding), there has been sustained growth through DTP1 (2013-2015, 90 students), DTP2 (2016-2020, 129 students) and DTP3 (2020-2025, 140 students, plus additional allocation of six studentships in 2020/21). All students complete a minimum three-month placement, often in commercial or industry enterprises, to experience an alternative research environment. The success of UoL is recognised by it becoming the lead institution in DTP3, including a commendation from UKRI for our plans to develop a bespoke EDI platform for PGR entry.

NERC DTP—Led by **Fenton**, Adapting to the Challenges of Changing Environment (ACCE) DTP brings together the academic strengths of the Universities of Liverpool, Sheffield and York, and the unique scientific expertise and resources of the Centre for Ecology and Hydrology and the Natural History Museum. A successful bid in the second round of NERC's DTP programme will support 22 new PhD studentships a year (2018-2023) in ecology, evolution and conservation.

CIMA—Successful renewal of our collaboration CIMA, https://www.liverpool.ac.uk/ageing-and-chronic-disease/cima/), in partnership with the Universities of Newcastle and Sheffield: 75% contribution from UoL to fund 5 studentships per year who undertake 1+3 year MRes/PhD training. The postgraduate provision through CIMA was particularly commended by the MRC at the Centre renewal in 2017.

MRC-DiMEN—A partnership amongst the Universities of Liverpool, Newcastle, Sheffield and Leeds that trains the next generation of researchers to tackle the major health problems facing the population. Funded from 2016/17-2020/21, it provides up to 30 fully-funded studentships across the partnership per year (50% of funds underwritten by each host institution). It focuses on three complementary themes: Genetic Influences on Health; Ageing and Disease; Bioinformatics and Personalised Medicine. To date 119 awards have been made, 29 to Liverpool, of which seven were to UOA6 staff, including CASE awards with government and industrial partners.

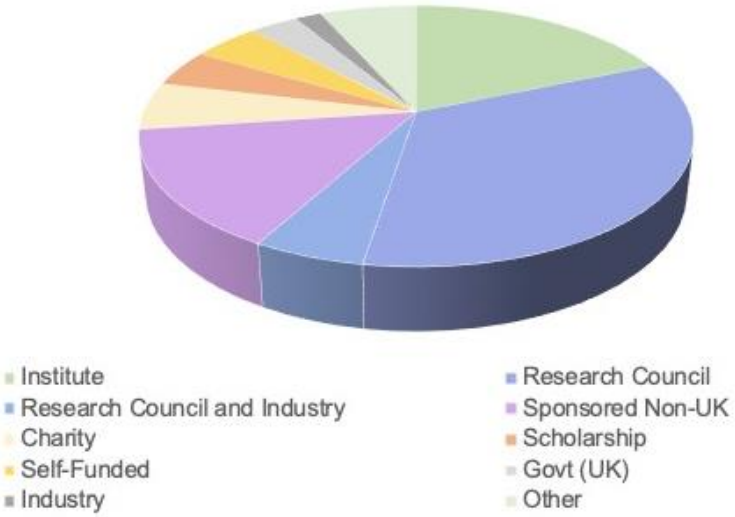

Figure 6. Relative proportion of PGR funding by source for the period 2014-2020

2B.2 PGR EQUALITY, DIVERSITY AND INCLUSION

We recognise the importance of implementing fair, clear, explicit and consistent policies for the recruitment, selection and admission of students, and our postgraduate admissions procedures are designed to ensure that applicants are treated wholly on the basis of their current achievements and potential. We have proactively formed research partnerships with other institutions to develop PhD studentship programmes, with up to 50% funding contributed by UoL. Our partners are within the UK (*e.g.* Pirbright Institute), the EU (*e.g.* Marie-Curie Scheme), and further afield (Table 3). We have also established an International PhD Bursary Scheme where we pay a contribution to tuition fees and offer scholarships competitively to international students. Aside from EU students, we currently host students from 54 countries and have established programmes with a number of institutions (Table 3). The majority (59.5%) of our 263 PGR students registered since 2014 are female, 68.23% are registered as Home/EU and 31.77% as overseas, making for a diverse cohort of students (Figure 7).

Table 3. Institutions with which UOA6 have established joint PGR training programmes

Institution	**No. PGRs**
Central Luzon State University, Philippines	9
Chulalongkorn University, Thailand	4
Mahidol University, Thailand	5
A*STAR, Singapore	5
RIKEN, Japan	1
Science without Borders, Brazil	2
Xi'an Jiaotong-Liverpool University (XJTLU)	20

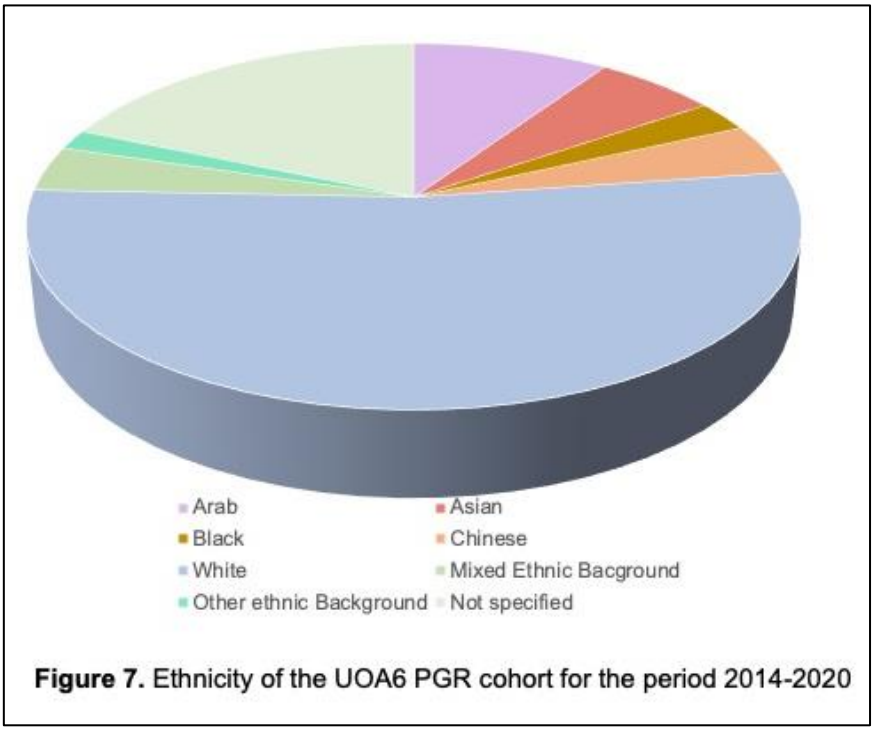

Figure 7. Ethnicity of the UOA6 PGR cohort for the period 2014-2020

2B.3 RESEARCH STUDENT TRAINING, PROGRESS AND WELLBEING

PGR students are guided, supported and their progress is monitored within the UoL PGR framework (Institutional Statement 3.5). Our average time to completion for students in UOA6 is 3 years 8 months, and our high retention rate is reflected in the large number of awards since 2014 (Figure 5). To facilitate timely submission, students record a monthly meeting with supervisors, complete an Annual Report and attend an annual Independent Progress Assessment Panel. In the rare instances where progress is not satisfactory, the Institute Director of Postgraduate Research facilitates an additional review process and mediates between supervisors and students with support from HODs. Training and development are aligned with the four domains of the Vitae Researcher Development Framework structured around a combination of core training, flexible bespoke training opportunities, transferrable professional skills (*e.g.* entrepreneurial and communication skills) and subject-specific advanced training and broad scholarship skills (*e.g.* networking, public value of research). Training needs are identified and monitored through Development Needs Analysis (DNA) assessments and delivered through personal development programmes by the Liverpool Doctoral College.

UOA6 academics have gone above and beyond to lead best practice around PGR training and support in a number of ways:

- A **PGR Mental Health and Wellbeing Catalyst Project** (Institutional Statement 3.5) funded by the Office for Students and Research England (£150K, awarded to **Price** and Jones K). A major output is the Peer Wellbeing Ambassador programme which undertook a bespoke training programme including Mental Health First Aid to offer (a) signposting and (b) wellbeing events. Rolled out institutionally with now 19 ambassadors across FHLS supported by PGR Wellbeing Staff Advocates and a Programme Lead at Faculty Level.
- Annual 'Wellbeing of postgraduate research students' survey based on that used by Vitae in 2018. Feedback led to changing stipend payments to all PGRs from 3 months to monthly.
- Online mental health and wellbeing training modules (1) now mandatory for supervisors and (2) available for non-supervisory roles (*e.g.* postdocs).
- Development of a 'Campus Wellbeing Map' to clearly identify support services for PGR students, launched at the University '*Wellbeing Week'* in May 2019.
- Informal support network via the Postgraduate Society that runs an active social and career development programme.
- Buddy System: New students are assigned a 2nd/3rd year PhD student.

3. INCOME, INFRASTRUCTURE AND FACILITIES

3.1 RESEARCH FUNDING AND STRATEGIES FOR GENERATING RESEARCH INCOME

Over the reporting period, our total spend is **£84.6M,** with our PIs collectively securing >**£94.7M** from >500 research awards. Our diverse funding portfolio spans multiple UKRI agencies (BBSRC, MRC, NERC, EPSRC), UK charities, European Commission and Industry and we have had particular success with GCRF and Newton funding. We have extended our total annual income from £11M in 2014 to £13M by 2020. Consistent with our strategy we have seen growth in our key target areas: UKRI funding, UK government funding and competitive UK-based charities (**Figure 8**).

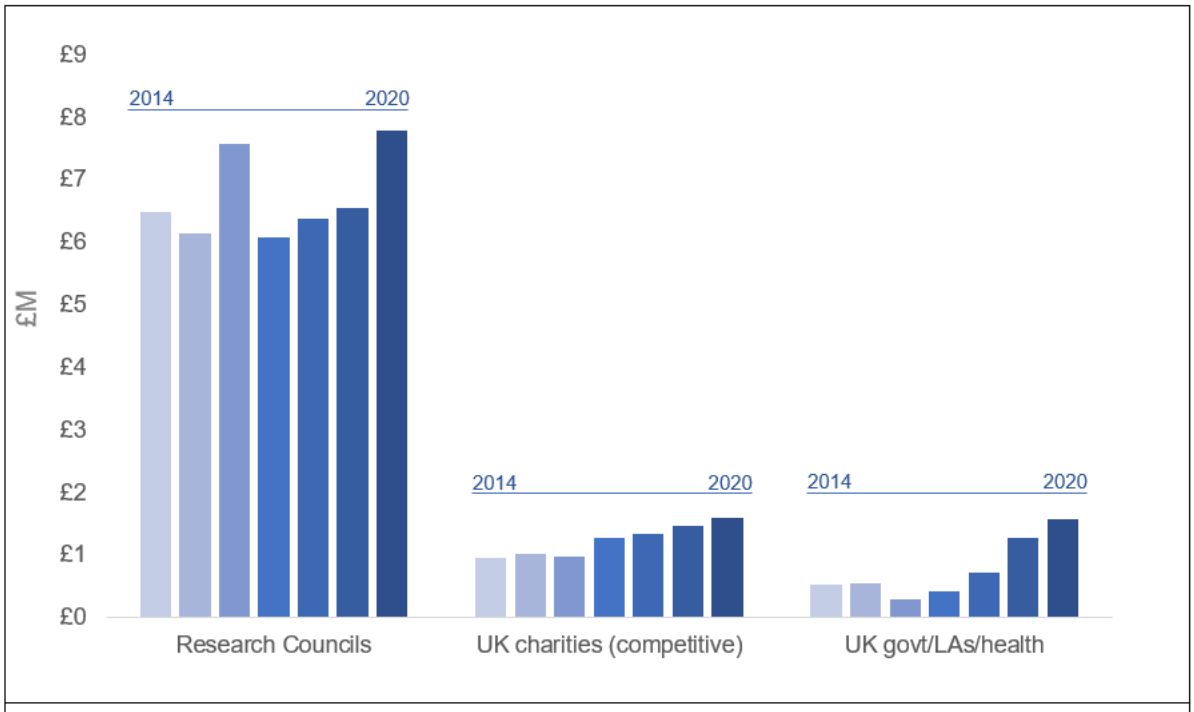

Figure 8. Research income (spend) for UOA6 from 2014 to 2020, showing areas of growth consistent with our research strategy

Guided by our strategic priorities (Section 1), we have focussed our activities around a number of major initiatives; we have supported these by leveraging financial resources from within FHLS and by provision of specialist professional services support to facilitate and enhance the efficiency and effectiveness of the application process. Our greatest investment is strategic recruitment of staff (Section 2A), supported by specific initiatives for facilitating income generation:

The **Research and Partnerships Development (RPD)—**Housed within Research, Partnerships and Innovation (RPI; Institutional Statement 2.1), the RPD provides support for project management for large or strategic bids, facilitates impact and knowledge exchange and promotes engagement with ODA funding agencies. Within RPD, the **Peer Review College (PRC),** first established in 2015, delivers mandatory review schemes for MRC and NERC applications, supports fellowship applicants, assists with ERC proposals and promotes best practice around internal review for other funders, *e.g.* BBSRC.

GCRF and Newton Fund—Our considerable expertise in One Health research and our network of staff and collaborators based in ODA countries, ideally positions us to respond to the expansion of funding offered through the GCRF and Newton Fund calls. A rigorous process of internal review backed by support from RPD staff with specialist ODA expertise has provided a successful framework to deliver more than £16M of UKRI GCRF-funded research with >20 partner ODA countries. An important adjunct to this external income is the strategic ringfencing of finances within FHLS for activities that fall within the GCRF portfolio: pump-priming ODA research and accelerating

impact, *e.g.* BBSRC GCRF IAA. Our positioning in Africa provides a point of entry for other UoL staff working internationally and supports international research students.

UKRI FLF (Institutional Statement 4.1.1)**—**Representatives within the RPD team have championed the scheme helping to drive ECR interest, as well as providing crucial intelligence to inform the process. To date one FLF was awarded to UOA6 (2019) and four, submitted in 2020, are currently under review, with two due for submission in early 2021.

Industrial Strategy Support Fund Industrial Strategy Challenge Fund (ISCF)—Our strong track record of collaboration with industrial partners and with assets, such as Sensor City, Materials Innovation Factory, Virtual Engineering Centre and CEIDR, positions us to realise the Strategy's aim of transforming our future. Liverpool established an internal ISCF pump-priming fund, designed to facilitate development of partnerships and consortia with industrial collaborators in anticipation of funding opportunities under ISCF. Beneficiaries of ISCF awards include **Williams D** (£130K, ISCF Transforming Food Production), **D'Aout (**£207K from the Industrial Strategy Applications Awards) and **Westgarth** (£55K, Translational Research Access Programme, TRAP). Launched in 2018, TRAP fosters interdisciplinary projects with the Faculties of Science & Engineering and Humanities & Social Sciences.

Pump-Priming—To date, UOA6 staff have secured over £630K from 13 different internal pump-priming schemes, the majority of which promote impact, support ISCF activity or prime our overseas work (Table 4).

Table 4. Internal pump priming funds awarded since 2014 to UOA6, to support collaboration

Pump priming scheme	**Date scheme started**	**Funds secured by UOA6**
Enterprise Investment Fund Industrial Strategy Challenge Fund	2010 2017/2018	£147K
BBSRC IAA (including GCRF IAA)	2018	£184K
ECR and Returners Fund	2016/2017	£8.5K
KE and Impact Voucher	2010	£110K
ODA COVID-19 rapid response	2020	£21.5K
ODA Seed Fund	2016	£114K

3.2 MAJOR AND PRESTIGIOUS GRANT AWARDS MADE BY EXTERNAL BODIES ON A COMPETITIVE BASIS

Our large grant awards are focussed around our strategic research aims and underpinned by our strategic priorities (Section 1). Here we highlight major funding delivered as a result of strategic allocation of resources and infrastructure to facilitate success.

NERC Environmental Omics Facility (NEOF) led by **Paterson** (£13M) is a national capability award from NERC Science and Facilities Section won in a competitive bid against other universities and research institutes. The award is worth £2M p.a. for 5 years with an additional £3M of transformational capital. It is led by UoL with University of Sheffield as a partner and is split 75:25 Liverpool:Sheffield (*i.e.* £1.5M p.a. to UoL). NEOF is a unique national centre of excellence that provides a coherent, comprehensive pathway for users to access expertise, capability and training in multiple and complementary environmental 'omics. It builds on more than 10 years of experience in supporting world-leading environmental 'omics via the NERC Biomolecular Analysis Facility (NBAF). The new facility exceeds the remit of the previous facility, and of NERC's commissioning

call, in extending capability into metabolomics and proteomics, thereby providing an integrated offering, which is the future of environment 'omics. The success of NEOF is in recognition of the research environment at UoL that provides sustainable, long-term support for open-access technology centres in genomics, metabolomics and proteomics that are co-located within a single building. Facility staff contracts, including two additional posts specifically for training and analysis in NERC multi 'omics are underwritten by the University, which allows development and maintenance of core skilled research staff.

One Health Regional Network for the Horn of Africa (HORN, GCRF)—led by **Baylis** (£8M), HORN was launched in 2018 in Nairobi, Kenya. This multidisciplinary, international partnership is developing a network of individuals and organisations in Kenya, Ethiopia, Eritrea and Somalia that can undertake high quality research into the link between people's health and wealth, and that of livestock and the environment. The HORN project has a structured process to build research capacity of partner organisations, invest in infrastructure, provide training to researchers and support staff, and fund and support co-created interdisciplinary research projects. It is currently funding >30 separate research projects, some multinational, in the region.

Health Protection Research Unit—the NIHR Health Protection Research Unit in Emerging and Zoonotic Infections **(HPRU EZI)** established in 2014 **(Hiscox, Baylis;** ~£9M to date) brings together the UoL, Liverpool School of Tropical Medicine (LSTM), University of Oxford and PHE. The University's commitment, in the form of specific contribution to the HPRU infrastructure, (PGRs, lectureships, academic clinical and veterinary fellows and administrative and technical support), equates to >£800K in phase 1 (2014-2019) and >£900K in phase 2 (2020-2025). The HPRU has supported PhD students with PIs in UOA6 (x5), and provided pump-priming to develop academic fellows in the veterinary/epidemiology area (*e.g.* **Tulloch, Blagrove** and Wardeh).

Global Burden of Animal Diseases (GBADs)—led by **Rushton** ($7M), GBADs was initiated through a resolution at the The World Organisation of Animal Health's (OIE) General Session in 2016 that called for further applied research on animal disease losses and animal health expenditure. Over a period of three years UoL have developed and led a consortium of international organisations, academic institutions, NGOs and private sector organisations as well as interacting with governments in India, Australia, UK, The Netherlands, USA, Canada, Brazil and Ireland supported by the BMGF and DfID working with OIE, FAO and ILRI. The GBADs programme was launched January 2021 with support from BMGF, DFID, European Commission and Norwegian Aid. The programme will deliver a range of methodologies grounded in academic excellence from economics, population and epidemiological science, databases on disease burdens and education programmes.

ZooLINK—together with the **UrbanZoo** MRC initiative (**Fevre**) examines the risks of disease emergence across urban and food systems spaces (£2.9M). They represent substantial investment from BBSRC and MRC on the epidemiology, ecology and socio-economics of disease emergence in Nairobi and zoonoses in livestock in Kenya.

SAVSNET—the world's first comprehensive active research surveillance system for companion animals was established at Liverpool in 2008. SAVSNET collects electronic health records at scale from UK veterinary practices and diagnostic laboratories and is recognised by **Animal** and **Plant Health Agency (APHA)** as supporting UK disease preparedness and surveillance. SAVSNET has been supported by funds of £1.9M from charities (£1.1M), industry (£74K), government (£55K) and UKRI (BBSRC £742K) in a range of research and surveillance activities as well as developing data sharing methodologies. The wide-ranging impact of SAVSNET was recognised by the BBSRC through the award of the 2019 Innovator of the Year Team Award for Societal Impact. In 2019 we were awarded £184K (The Horse Trust), to build on SAVSNET and develop EVSNET (Equine Veterinary Surveillance Network) to fill the void in national equine surveillance.

AMRC charities—We have put a strategic emphasis in developing funding from AMRC charities such as the Wellcome Trust and Versus Arthritis. The success of this strategy is shown by the growth in UK Charity income from £0.9M in 2014 to £1.5M in 2020 (Figure 8).

BBSRC ALERT—UoL has supported BBSRC ALERT equipment bids with matched funding and supports maintenance contracts for the equipment. Awards totalling >£9M have been secured from the BBSRC scheme to enhance the capability of the UK research base remit (four ALERT 13, three ALERT 14, one ALERT 16, one ALERT 17, one ALERT 18 and four ALERT 19).

3.3 ORGANISATIONAL INFRASTRUCTURE SUPPORTING RESEARCH AND IMPACT

An integrated approach to the development and delivery of enabling technologies, to provide all members of FHLS with the equipment and expertise to pursue outstanding science, has seen substantial investment since REF2014 in our **Shared Research Facilities** (**SRF**), overseen by the I&E directorate (Figure 9).

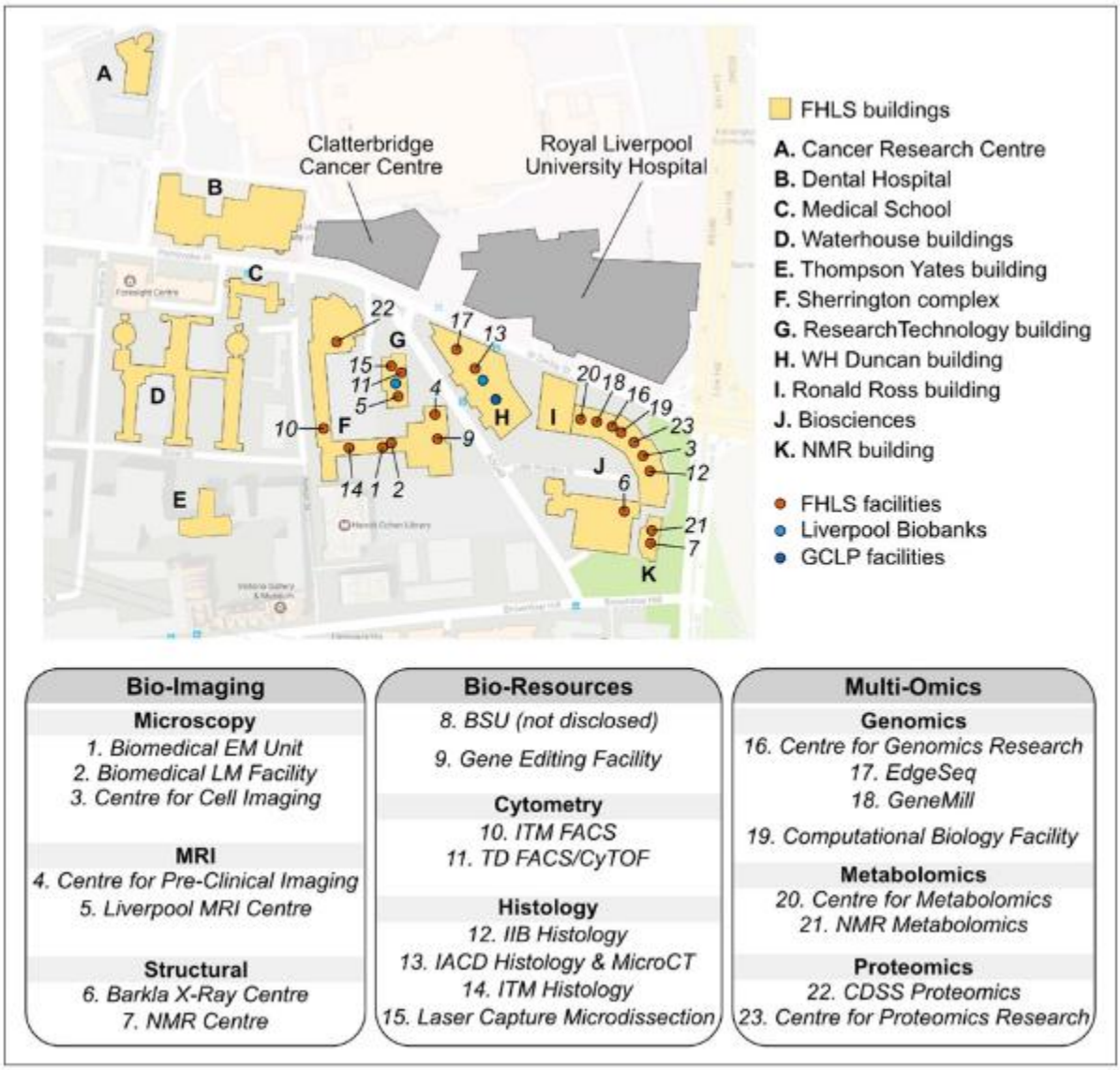

Figure 9. Campus map showing extent and location of shared research facilities (SRFs)

The **SRF** have played an integral role in the development of UOA6's multi-omics theme (genomics, proteomics and metabolomics) and underpins all our activities (Figure 1). Leadership of the **CBF** (Section 1.5) is provided by **Jones** where eight staff are now employed as Data Analysts and Software Developers (salary costs ~£350K p.a.). The **Centre for Genome Research** (**CGR,** led by **Paterson, Darby)** conducts work funded by UKRI, UK charities and industry, with around 150 collaborators, 350 projects and 14,000 samples processed per year and has key strategic

partnerships with NERC and Unilever. The CGR has an annual turnover of ~£2.5M, equipment worth ~£5M and collaborates to produce ~60 papers per year and collaborates with >250 institutions. The **Centre for Proteome Research** (CPR, led by Eyers UOA1) contains state-of-the-art instrumentation in mass spectrometry (MS), funded through considerable investment from UoL, BBSRC (ALERT) and NERC. The SRF running costs total ~£6.1M per year with the majority (~£4.7M) of costs recovered, with an additional ~£1.4M contribution from UoL. An additional subsidy of £200K funds the SRF Voucher Scheme, which has proved to be a huge success, operating for 16 rounds and providing subsidised access to SRF to pump-prime, or improve the quality of data. In 2014-2019, 59 vouchers were awarded to UOA6 staff, totalling >£218K, ~30% of vouchers and the associated costs (~£65K) went to staff who were Fellows/TTFs at the time; with 50% of those awards going to women. Review of the overall pump-priming impact of the voucher scheme found that for every £1 invested, there was £23 of subsequent external grant funding that could be attributed. Since 2014 there has been a more focused and concerted strategy to work with partner organisations, including other HEIs, the NHS and industry; we have worked with partner HEIs to run their own voucher scheme (*e.g.* Liverpool John Moore's University, LSTM and Royal Veterinary College), as well as offering an Innovation Pump-Priming Fund allowing SMEs up to £10K worth of access to SRF in order to undertake a collaborative project.

3.4 OPERATIONAL AND SCHOLARLY INFRASTRUCTURE SUPPORTING RESEARCH AND IMPACT

Advanced Research Computing facilities provide free access to the central computing cluster, which includes 136 nodes each with 40 cores and 384GB of memory and three nodes with 4 GPUs each. There is space and power to house project-specific hardware. As part of the offering, we have an arrangement to easily burst from this cluster onto AWS or Azure cloud resources. This is primarily for resilience purposes, but can also be exploited by groups needing additional short-term computing access via the cloud. There is also a Condor pool that exploits idle Teaching Centre computers for high-throughput work. Licenced software includes most used suites such as MATLAB, Maple, the Intel compiler with its Math Kernel Library and Abaqus. A team of support staff can provide advice on taking full advantages of these facilities as well as help to install and tune computational packages. Our recently-appointed, inaugural **Head of Research Computing** for Health and Life Sciences (Gannon) is now building a Faculty-wide Research Computing strategy, investment plan and service delivery roadmap to enhance provision in the coming years and thus support our strategic objective of growing our data science capabilities.

3.5 NATURE, QUALITY, PROVISION AND OPERATION OF SPECIALIST RESEARCH INFRASTRUCTURE AND FACILITIES

We have invested in a number of bespoke facilities, enhancing our specialist research capacity, including:

Henry Wellcome Laboratory of Mammalian Behaviour & Evolution (Leahurst)—a unique world-class facility for the study of wild rodents (Wellcome Trust SRIF grant and matched funding from UoL, >£3M). The facilities include 4000m^2 of secure outdoor rodent enclosures linked to an external field laboratory. Six outdoor enclosures provide natural vegetational habitats protected from predators, while 2 x 250m^2 enclosures replicate a built environment, funded by a BBSRC strategic LoLa grant to investigate the use of scent lures and repellents to improve the efficiency and humaneness of rodent pest control.

Leahurst Veterinary Campus—invested >£4.5M to enhance the equine and small animal hospitals, Home Office Licence facilities for equine and large animal work and provide smaller-scale but unique resources: a temperature-controlled snail room for propagation; an insectary that can house mosquitoes and biting midges in bespoke temperature controlled rooms, with CL3 capabilities for the study of high risk vector-borne pathogens. Across campus, 166m^2 CL3 capacity is maintained, including a refurbished 21.3m^2 at Leahurst (£50K).

The **experimental poultry unit** was upgraded in 2017 (£150K) and allows study of a range of poultry and zoonotic infections including GMO, underpinning both fundamental and applied research with a number of industrial partners, *e.g.* vaccine research with Ceva Animal Health and Boehringer Ingelheim, and microbial feed additives with DuPont.

The Tick Cell BioBank (Liverpool)—the world's only dedicated culture collection for generation, storage and distribution of cell lines derived from ticks and other arthropods. Through provision of cell lines and training, this BBSRC GCRF-funded biobank underpins in-house, UK and international research on ticks, other neglected arthropods and disease transmission to humans, livestock and companion animals.

Glasshouse and plant growth facilities—facilities for transgenic (CL3) and non-transgenic plant collections. Facilities include a suite of Snijders plant growth cabinets providing high specification environmental control of temperature, humidity, and light regimes, six walk-in growth rooms with dedicated light and temperature control and a dedicated plant tissue culture room.

Brian Moss Aquatic Mesocosm Facility—refurbished as part of a £1.2M NERC research project, this facility at Ness Botanic Gardens features 50 newly refurbished ponds with temperature control and monitoring systems, making it one of the largest and technologically most advanced in Europe for investigating environmental impacts on freshwaters, including climate warming and effects of run-off from land. It is used to investigate limits to adaptation by organisms such as the water flea *Daphnia magna* in the face of global climate change.

3.6 SIGNIFICANCE OF MAJOR BENEFITS-IN-KIND

We have benefitted from multiple benefits in kind from a number of sources, including:

- CNRS SOLEIL synchrotron facility, Paris, France (900 hours, €456K), Science and Technology Facilities Council (STFC) Diamond Light Source, Oxfordshire, (600 hours, £490K).
- Advanced access to Illumina, Pacific Biosciences, 10x Genomics, Agilent, NimbleGen and Affymetrix prior to general release.
- An INTERREG grant awarded to the School of Engineering (PI: Dr Zhongwei Guan UOA12) paid for the building of an adhesive-free timber lab space at the mesocosm facility at Ness Botanic gardens (£80K). Overheads from a NERC Highlight grant awarded to **Plaistow** (NE/N016017/) paid for renovating the mesocosm facility and furnishing the new lab space (£100K).
- Natural History Museum's (NHM) British Lepidoptera collection, the Forestry Commission's Kielder Forest, Northumberland, Cheshire Wildlife Trust, farm access in Wales and England, access to the London Underground and Chester Zoo Conservation Scholars have full access to biological samples, specialised databases and the Zoo's labs where they have conducted analysis (£50K).
- Doñana and Peñelara National Parks (Spain): access to field labs, meteorological stations and technologies; ministerial and county level authorization to conduct field research in the Masai Mara National Reserve (Kenya); a field laboratory in Western Kenya and access to veterinary research within a Human Demographic Surveillance Site (HDSS) in Butajira, Ethiopia.

4. COLLABORATION AND CONTRIBUTION TO THE RESEARCH BASE, ECONOMY AND SOCIETY

4.1 ENABLING AND FACILITATING COLLABORATION

International collaboration is incentivised and underpinned by a number of internal initiatives, such as the ODA Research Seed Fund that provides up to £10K pump-priming funds for research with LMICs; to enable proof-of-concept, workshops and relationship building. At a national level, UoL hosted the N8 AgriFood (N8AF), International Conference 2018 (People, Health and Food Systems, Challenges and Solutions) and through N8 have leveraged funding for a Centre for Excellence for Sustainable Food Systems (CESFS, https://www.liverpool.ac.uk/centre-for-sustainable-food-systems/). CESFS has pump-primed five new projects led by UOA6 in collaboration with researchers at Sheffield, Lancaster and Newcastle. In addition to CIMA and HPRU-EZI (Section 3), we have a Wellcome collaborative award bringing together groups at the universities of Edinburgh, Glasgow, Lisbon and the German Cancer Research Centre [£2M, 2017-2020]. We are active members of the International Veterinary Vaccinology Network (University of Edinburgh, Roslin-led). During the 2014-2021 REF period the majority (>80%) of our publications involved extensive national and international collaboration (Figures 10 and 11).

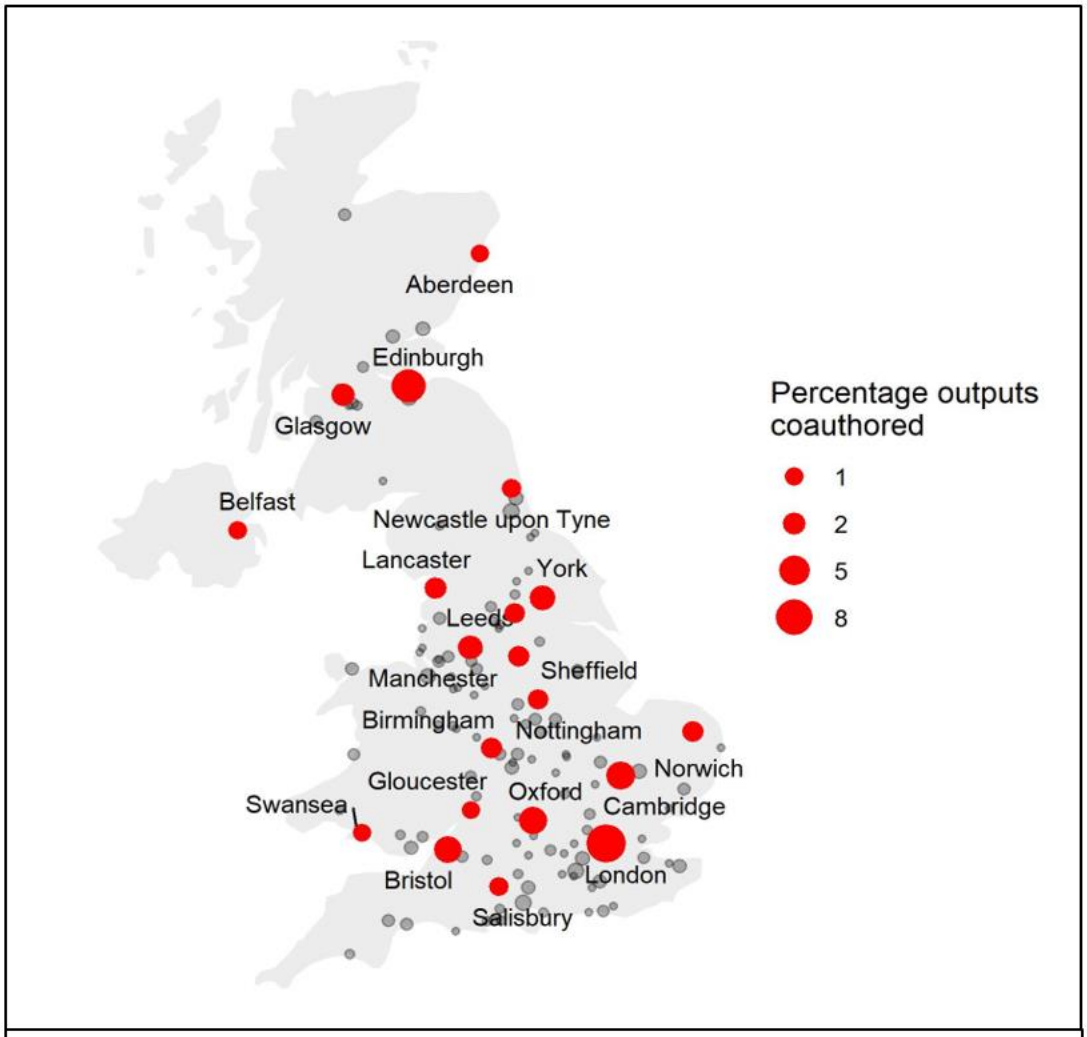

Figure 10. UOA6 National collaborations defined by co-authored outputs published between 2014 and 2020. Dot size represents the percentage of outputs at each location. The top 20 collaborating locations are highlighted in red.

In line with our research strategy there has been substantial investment and growth in new partnerships and sustained support of successful international collaborations:

- Our research in Kenya and Ethiopia, through ZooLINK, UrbanZoo **(Fevre)**, HORN **(Baylis, Mor)**, provides a platform for staff to undertake their own research programmes in collaboration with local researchers. Investment in Kenya supplemented by contributions, worth £1M per year, from the **ILRI-CGIAR Program on Agriculture for Nutrition and Health**. A permanent presence in Kenya allows integration with national and regional strategy, policy and capacity-building activities, such that the Liverpool team (senior staff member plus six PDRAs and several PhD students) are able to contribute directly to processes that have impact at a national and regional scale (*e.g.* membership of national steering groups and policy advisory committees of the national government).
- We have strengthened links with the **Malawi-Liverpool-Wellcome Centre in Blantyre**, Malawi, developing a strategy for collaboration in One Health research and, through the Wellcome Clinical PhD programme (2008 to date), undertake joint research on Salmonella in humans and livestock.
- In Asia, we are leading collaborations around poultry health with universities in Thailand and Philippines (in collaboration with Universities of Leicester, Edinburgh and SRUC), building upon prior BBSRC DfID funding.
- We have strong links with China, with Northwest A&F University on poultry and pigs, and a BBSRC China Partnering Award with Lanzhou Veterinary Research Institute.
- **Wellcome-funded** work is well established in the Mekong Delta and we have been awarded contracts from FAO Bangkok with funding from USAID to develop a framework in antimicrobial use in livestock with a focus on Thailand, Vietnam and Indonesia.
- The **DARPI project** (Drivers for Antimicrobial Resistance in poultry in India) is a collaboration with RVC, Edinburgh, Royal Holloway and the University of the Arts.
- We have established tick cell biobank outposts in Brazil, Kenya and Malaysia through the **BBSRC GCRF-funded Tick Cell Biobank** (Section 3.4)
- We are developing vaccines for African trypanosomiasis in collaboration with LSTM, the Sanger Institute and University of São Paulo, Brazil.
- We have developed collaboration with the College of Veterinary Medicine and Agriculture (CVMA, AAU) and the National Veterinary Institute (NVI), Bishoftu and international charities SPANA and Brooke and Gambia Horse and Donkey Trust (International NGOs). We work with the Ministry of Agriculture, Department of Livestock Services in Gambia.

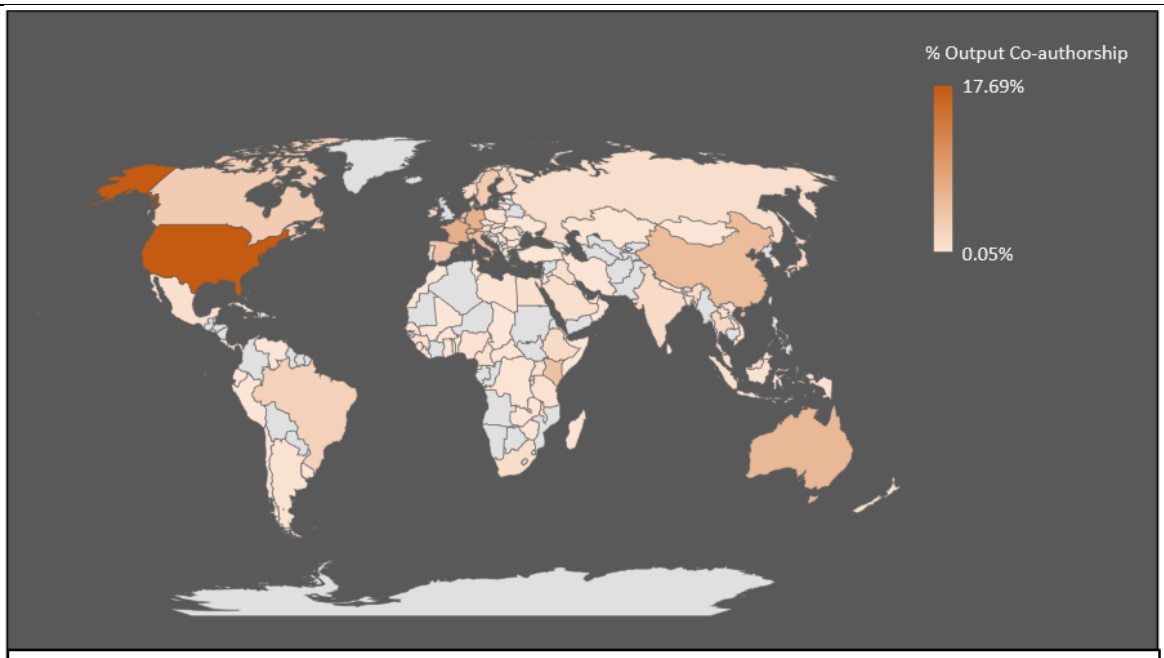

Figure 11. UOA6 International collaborations defined by co-authored outputs published between 2014 and 2020

4.2 INTERDISCIPLINARY RESEARCH AND OUR RESPONSIVENESS TO NATIONAL AND INTERNATIONAL RESEARCH PRIORITIES

Through our collaboration and research networks we are well positioned to respond to national and international priorities for emerging pathogens. Our work on Ebola during the West African crisis involved our links with the European Mobile Laboratory (EMLab) and the EU EVIDENT-funded project. We provided staff to EMLab and PHE laboratories to run clinical diagnostics in Guinea and Sierra Leone and led the viral sequencing effort for the EMLab. In 2016, we redirected our high-containment mosquito-virus infection work to study the emergence of Zika virus, with funding from the MRC emergency fund and provided expert advice to the UK government on the risks posed by attending 2016 summer Olympics in Brazil. Our response to COVID-19 demonstrated our agility in repurposing our extensive infrastructure and staff resources to enable nationally leading contributions and research impact as the pandemic developed. The University, LSTM and the NHS established a city-wide Liverpool STOP COVID initiative that has allowed cohesive, rapid and scaled responses across the research pipeline. Liverpool STOP-COVID is contributing to 13 NIHR Urgent Public Health studies. **Hiscox** is a co-opted member of the Department of Health committee, New and Emerging Respiratory Virus Threats Group (NERVTAG), whilst **Stewart** is a member of the WHO Expert working group on animal models for COVID-19. Recognising that poorly resourced countries in Africa may struggle to respond rapidly to the COVID-19 outbreak, we used funding from the HORN project to support research by funding project partners in Kenya, Ethiopia and Somalia to undertake priority research (four projects funded for £80K) and running an online, week-long event open to teams from across the Horn of Africa, to co-develop COVID-19-related research projects, of which the top six were funded (total £200K).

4.3 OUR ENGAGEMENT WITH KEY RESEARCH USERS AND BENEFICIARIES AND OUR WIDER CONTRIBUTIONS TO THE ECONOMY AND SOCIETY

Our structure has allowed co-location and effective collaboration of true multidisciplinary teams which cross conventional disciplinary boundaries. Through our staff **(Rushton, Walley, Williams D, Hodgkinson, Oikonomou, Wigley)** we are active members of the N8 AgriFood Programme which combines multidisciplinary research and translational capabilities to respond to the global

challenge of food security and works with the Foreign and Commonwealth Office's Science and Innovation Network; the Department for International Trade and the Department for BEIS to build global partnerships. We have a strong track record of collaborating with industrial partners and a well-publicised route via which external partners can access our research capabilities, consultancy services and technological developments, which includes the Knowledge Transfer Partnerships (KTPs) scheme. Areas where we have substantial interaction with industry include:

- Poultry producers in both meat and egg sectors such as **Moy Park** and **The Lakes Free Range Egg Company**. Collaborative research and consultancy with vaccine companies producing viral (**Ganapathy**; Boeringer-Ingelheim) and bacterial vaccines for chickens (**Wigley;** Ceva Animal Health and Pacific Gene Tech), ranging from proof-of-principle through to testing vaccine regimens, engagement and dissemination of research to poultry veterinarians and policy-makers through the British and World Veterinary Associations and the more informal Poultry Disease Group.
- Our collaboration with **Tesco Sustainable Dairy Group (TSDG)**, receiving £650K of funding delivers an extensive portfolio of translational research activity. Research into calf welfare, antibiotic use, dairy cattle lameness and parasite control is delivered directly to the Tesco supply chain, informing both policy and practice of 10% of UK milk production.
- Research groups studying dairy cattle lameness, sheep lameness and liver fluke work with the UK farming industry national levy boards **AHDB, Hybu Cig Cymru (HCC)** and **Quality Meat Scotland** (**QMS)** through funded PGRs and industrial partnership awards. Research outputs feed directly to farming industry stakeholders, inform policy and practice on antibiotic use, and transform farming practices with regards to endemic disease control. We work closely with farming organisations such as The Farmer Network, Farming Connect, and UOA6 staff sit on the management board for the industry advisory group—Control of Worms Sustainably (COWS, **Williams D)**—and act as consultant to National Animal Disease Information Service (NADIS).
- Through collaboration with **DEFRA, APHA** and **Veterinary Medicines Directorate (VMD)** our research feeds into policy on the use of veterinary medicines, *e.g.* anthelmintic use and distribution (legal distribution categories) and advice for appropriate use through the Summary of the Product Characteristics (SPC; **Hodgkinson, Williams D**). Outputs from projects feed into VMD and RUMA (Responsible Use of Medicines in Agriculture Alliance) to inform best practice. **Baylis** prepares assessments on the risk of bluetongue entry into the UK.

As a centre for veterinary clinical excellence, we lead a number of multicentre studies that deliver translational research to stakeholders. We engage with veterinary professional bodies, charities, veterinary practices and hospitals across the UK to enhance our equine and companion animal clinical research and impact. Examples include:

- A multicentre multinational study of calicivirus in vet visiting cats at 64 veterinary practices from six countries (industry-funded with collaboration European industry partners). The world's first specialist weight management clinic for cats and dogs, undertake pioneering clinical research into companion animal obesity, funded by industry.
- The Pathology department specialises in zoo animals, wildlife and forensic pathology. Its close research links with **Chester Zoo** (with who we hold a MOU) and research in avian malaria and investigations into elephant herpes virus have informed treatment and management changes in the Zoo's collection; whilst their research on squirrel pox virus has informed the **National Trust** and the **National Wildlife Trusts** on management of red squirrel populations. Their input to **RSPCA** has changed their forensic evidence collection policy nationally.
- Our international reputation in equine colic research resulting in UoL leading both an international equine colic audit involving collaborating clinics in Europe, North America, Asia

and Australasia and an international, multicentre randomised controlled trial investigating use of lidocaine in post-operative colic (in conjunction with the **Liverpool Clinical Trials Research Centre** and funded by The Horse Trust).

- Multicentre studies of antimicrobial use and resistance in companion animal and equine veterinary practices and hospitals in collaboration with veterinary professional bodies (funded by The Horse Trust, VMD) and co-lead on **EU-COST Action [European Network for Optimization of Veterinary Antimicrobial Treatment (ENOVAT)].**

In terms of our engagement with the public, since 2014, UOA6 staff have delivered multiple activities to a wide range of audiences, with ~100 different events reaching >41,000 members of the public. These include:

1) Meet the Scientists (~3 events per year since 2015), hosted in the World Museum, Liverpool; this allows us to engage with the local community, we have had >13,000 public attendees at these events.

2) Pint of Science: over 50 UOA6 researchers, from PGRs to senior academics participate in this international festival, talking to the public about their research in pubs. Specific strands of events are aimed at ECRs new to public engagement.

3) External Festivals, *e.g.* Cheltenham Science Festival, Manchester Science Festival, Big Bang North West and the BlueDot Festival. Considerable engagement around food safety issues, with the public, stakeholders and policy makers from the food industry, such as the "A twisted bug's life" exhibit at the BBSRC Great British Bioscience Fair held in London November 2014; a giant walk-through gut that allowed the public to understand how pathogens interact with the gut in food poisoning.

4.4 OUR WIDER INFLUENCE, CONTRIBUTIONS TO AND RECOGNITION BY THE RESEARCH BASE

In addition to the contribution and recognition already articulated, we have staff who operate in many high-profile roles:

- **Clegg,** Chair REF2021 Sub-panel 6 and member of Main panel A; **Pinchbeck,** member Sub-panel 6.
- 37 of our staff have founded, lead or are partners in nationally or internationally recognised research networks/partnerships, *e.g.* lead for Newton foundation UK-Kenya links programme (**Hurst G**), Chair of international body for data sharing in proteomics (**Jones**), Co-director, The Onchocerciasis Vaccine for Africa Initiative (**Makepeace**).
- Seven are involved in advising government, *e.g.* **Fevre** is active in shaping national policy in Kenya.
- 17 are panel members on UKRI awards committees (NERC, BBSRC, EPSRC, MRC). Eight are on Charity funding committees, one as Chair (**Stockley**).
- At least 21 sit on advisory boards, *e.g.* L'Oréal UNESCO award for women in Science, UK and Ireland and Commonwealth Scholarship Commission (**Shirazi-Beechey**)
- 31 have established industry partnerships as consultants, or as advisors, with an additional 18 working with SMEs.
- Prestigious awards include: Fellowship of the RCVS and Queens Medal from the RCVS (**Clegg**); 2017 Association for the Study of Animal Behaviour Medal (**Hurst J**); BSAVA Simon Award for Outstanding Contribution for Small Animal Surgery (**Comerford**).