Institution: University of Surrey

Unit of Assessment: UoA 3 Allied Health Professions, Dentistry, Nursing and Pharmacy

1. Unit context and structure, research and impact strategy

Unit Context and Structure

The Faculty of Health and Medical Sciences (FHMS), the submitted Unit for the 2014-2020 REF period, has designed an interdisciplinary research and impact strategy to deliver a '**One Health**' vision. This vision recognises that in modern society, **human health is interconnected with the health and welfare of animals and the environment**. Therefore, our strategy to achieve our 'One Health' vision is to bring together research in human medicine, veterinary medicine and the environment in a fertile environment that is inherently interdisciplinary.

Zoonoses, such as the COVID-19 pandemic, are exemplars to justify the need for our 'One Health' vision. However, the reach of our strategy is much broader than infectious diseases alone.

Our approach is inherently interdisciplinary, by which we mean we bring together different research fields, such as quantitative practices, qualitative disciplines and 'wet' laboratory chemical and biochemical methodologies that are necessary to achieve our strategy.

This approach yields synergy in our research outcomes, innovation and impact; it is guided by the unifying principle that the **health and welfare of humans cannot be considered in isolation**. For example, we can use the same technology in a human or animal vaccine (a multidisciplinary approach), but vaccinating animals to prevent a human disease (rabies) is interdisciplinary.

First posited as an ambition in our REF2014 submission, a step-change to deliver our 'One Health' strategic intent was enabled by the opening of the School of Veterinary Medicine (SVM) in October 2014. Together with the founding School of Biosciences and Medicine (SBM) and School of Health Sciences (SHS), FHMS was then comprised of three Schools and in recognition of the implicit opportunities for our research strategy, the School of Psychology (SP; submitted in REF2014 to UoA4, Psychology, Psychiatry and Neuroscience) was included in 2015.

To deliver our **'One Health' vision** we have worked hard to create a strong research culture, meaning a collaborative and inclusive environment in which researchers are valued for their contributions and supported to produce impactful and rigorous research. With this culture we have established six Research Themes that are described below. These create foci of critical mass around which we recruit strategically and target funding calls tactically. These strategic approaches have led to improvements in income, outputs and impact and, importantly will support a sustainable environment beyond REF2021.

Developments since REF 2014

Our research has enjoyed considerable success during the current assessment period. We have seen growth in all component metrics:

- Overall research income/year for REF 2014 of £6.98M, increased to £9.21M/year over the present assessment period with total income rising from £34.89M (REF2014) to £55.26M (present assessment period);
- Sustained improvement in output impact as evidenced by the number of our publications with a Field-Weighted Citation Index (FWCI) ≥ 1.7 (the UK average for medical-related journal publications) increasing from n=648 (REF2014) to n=1217 (present assessment period);

- Increased proportion of internationally collaborative publications in medicine-related journals from 39.5% (REF2014) to 47.5% (present assessment period);
- Increase in PhDs awarded for those students registering in the present assessment period to 545 compared to 432 for REF2014.

Consistent with the foundations laid in our REF2014 submission and complementing the research activities and aspirations across FHMS, we have made a panoply of strategic appointments during the current assessment period to increase the capability of our research and impact and deliver our 'One Health' vision. These appointments include: 31 lecturers, eight senior lecturers; five readers and 13 professors. Moreover, we have made 6 distinguished, strategic 'Vice-Chancellor's Fellow' appointments each at 0.2 FTE, four of whom are clinically qualified, to either bring or retain specific research capability within FHMS.

Creating Impact

Integral to delivering our 'One Health' vision is our drive to contribute greater health, environmental and economic benefits to society. Our commitment in this regard has delivered the Impact Cases Studies (ICS) for the present submission and a culture change leading to many more in development. These ICS exemplify our strategic intent to improve health and well-being and include healthcare interventions that have been implemented in the clinic either nationally or internationally.

These nine Cases are not our only contributions to achieving a 'One Health' impact on society through our research, but they are the most developed for the present submission. Because of its infancy, the selected impact cases do not yet benefit directly from SVM input.

Nevertheless, emerging ICS include three that are led by veterinary-based research colleagues and again exemplify our recognition of how research in animals can benefit their welfare and that of humans. These three developing Impact Cases are: (i). Mathematical models - qualifying what defines an endemic region, working closely with the World Health Organisation to draft new guidelines to set the targets to control and eliminate specific Neglected Tropical Diseases for 2030 (Horton and Prada); (ii). Developing with Zoetis a commercial *Escherichia coli* vaccine (PoulVacE) for poultry - improving animal welfare and productivity enhancing economic efficiency for farmers (La Ragione); (iii). Osteoarthritis - understanding joint homeostasis enabling pharmacological interventions to improve the quality of animal and human life (Nalesso).

At the annual appraisal meeting between those with research as part of their contract and their line manager, the appraisee is asked to: "Demonstrate impact through your research (e.g., informing industry / policy makers, developing commercial applications, promoting research through public engagement or the media, developing impact case studies (where appropriate), and knowledge exchange activities)". Consideration of the beneficiaries of such developing impact is included in these appraisal discussions. This process is supportive and provides opportunity to reward success in impact with promotion and to intervene with resource to accelerate and facilitate ICS development.

Supportive intervention for emerging impact includes liaison with: FHMS-embedded Partnership team members whose role is to facilitate relationship building with commercial and other beneficiaries (see also Section 4.1); our central University Impact Officers, who contribute their professional expertise in impact and knowledge exchange to shape impact case development; financial resource in the form of the Executive Dean's (Griffiths) Discretionary Impact Fund that provides additional funding tailored through internal peer review to develop impact.

Delivering our One Health vision

The FHMS Research Executive Board (FREB) oversees all aspects of research strategy, including impact, through fortnightly meetings. FREB consists of 14 senior FHMS leaders, of whom 57%

are women, chaired by the Executive Dean. FREB ensures our strategic oversight through horizon scanning and decision making on University, national and international research and impact opportunities.

Our fundamental approach to deliver our 'One Health' vision is to identify, focus our investment on, and therefore grow our research strengths. These strengths are captured by our **six Research Themes**, which are described below.

While the Research Themes provide tactical focus to deliver our research strategy, they are permeable, allowing our colleagues the freedom to work across Themes and disciplines. Indeed, while the majority of colleagues' research portfolios align to a Research Theme, not all do. A preeminent example is our Leverhulme Trust Quantum Biology Doctoral Training Centre, the world's first centre dedicated to training interdisciplinary scientists in quantum biology led by McFadden together with Prof Jim Al-Khalili of the Department of Physics, part of the Faculty of Engineering and Physical Sciences (FEPS). This discipline is an emerging strength and as such we are growing critical mass by investing in a further three PhD studentships in addition to the 16 funded by the £1M award from the Leverhulme Trust (2018-23), and 50% of a lectureship in Quantum Biology (Kim).

The sustainability of our research is defined by FREB oversight ensuring each Research Theme is comprised of a balanced portfolio of career stages, from senior leaders (Professor/Reader) to increasingly early-stage researchers (Senior Lecturer/Lecturer).

Our six **Research Themes** are:

1. **Chronobiology and Sleep**

Colleagues identifying in this Theme exploit multidisciplinary approaches in both humans and animal models to increase understanding of the function, underlying mechanisms, and contribution of sleep and endogenous biological rhythms to both mental and physical health across the lifespan.

The Surrey Sleep Research Centre, led by Dijk, and Section of Chronobiology, led by D. Skene, comprise 10.2 FTE academics [4 Professors, 1 Vice-Chancellor's Fellow (Lockley), 2 Readers, 4 Lecturers] supported by a team of research fellows, postgraduates and technicians. Colleagues combine broad expertise in physiology, molecular biology, neuroscience, psychology, engineering and pharmacology. Their research is underpinned by world-class pre-clinical and clinical facilities, which are co-located in the Clinical Research Building (CRB) housing eight environmentally controlled individual monitoring bedrooms with the capacity for serial blood sampling, full polysomnography, assessment of cognitive function, and dynamic modulation of the light environment.

A major research focus is the relationship between disruptions to sleep and circadian rhythms, and non-infectious (e.g., dementia) and infectious disease susceptibility, incidence and progression. Perturbations to the sleep and/or circadian clock may be a driver, outcome or treatment target for a range of diseases, and their long-term monitoring is key.

Key achievements include: understanding the mechanisms underpinning maintenance of cognition during the waking day and how it deteriorates when sleep or the circadian clock is disturbed, in situations like shift-work, emergency response or jet lag (Muto *et al.*, 2016); recognising mistimed sleep impacts the circadian system at the level of the transcriptome (Archer *et al.*, 2014); discovering circadian rhythms in cortical excitability, that have implications for clinical scenarios including optimising neurorehabilitation (Ly *et al.*, 2016).

Demonstrating a single daily dose of tasimelteon was sufficient to synchronise the circadian system of totally blind individuals (Lockley *et al.*, 2015) and underpinned the ICS achieving

FDA/EMA approval for treatment for non-24-hour sleep-wake disorder ("HETLIOZ®: First FDA/EMA approved drug for sleep-wake disorders in the blind", D. Skene, Lockley).

The future strategy is: to focus on real-world monitoring of sleep and biological rhythms across short (< 24h ultradian, 24h circadian), medium (seasonal to annual) and long (lifespan) intervals in both healthy and patient populations to assess health and performance outcomes, disease progression and the success of interventions.

2. Infection and Immunity

Research in this Theme encompasses the study of viruses, bacteria and parasites that cause significant morbidity and mortality globally and reduce the sustainability of food and farming. These aspects are complemented by immunology research that is focused on finding better ways to empower the immune system to protect individuals from pathogens, but without triggering the inappropriate immune responses that cause illness.

Colleagues identifying with this theme, which is led by Chambers, number 30.9 FTE [12 Professors, 3 Vice-Chancellor's Fellows (Lusignan, Pallen, Russell-Jones), 3 Readers, 10 Senior Lecturers, 8 Lecturers, 1 Research Fellow].

Our Veterinary Health Innovation Engine (vHIVE) contributes by supporting digital innovation in animal health care with direct links to industry (Zoetis) and the Royal College of General Practitioners (RCGP) Research and Surveillance Centre collects and monitors data weekly from >1,700 GP practices across England and Wales and includes an online database of 50 years of influenza data.

Key achievements include: establishing a model for Kaposi's sarcoma-associated herpesvirus persistence and pathogenesis in humanised mice (McHugh *et al.*, 2017); identification of novel mutations leading to colistin resistance in *Acinetobacter baumannii*, a major cause of nosocomial infections (Gerson *et al.,* 2019); developing a novel approach (microRNA crosslinking and immunoprecipitation, miR-CLIP) to capture and identify the interaction partners of noncoding RNAs (Imig *et al.,* 2014); analysis of the most comprehensive available dataset on Canine Distemper Virus in Africa to examine long-term patterns of infection in a large, multi-host ecosystem (Viana *et al.,* 2015).

The future strategy is: to expand the international impact of our research on zoonotic diseases and host immunity by maximising opportunities with our research partners (Pirbright, Animal and Plant Health Agency (APHA), Zoetis, National Physical Laboratory (NPL), LGC (formerly the Laboratory of the Government Chemist), Quadram Institute, Royal Surrey County and Frimley Park hospitals). One example of progressing this future strategy is that we will appoint a Professor of Vaccinology jointly with Pirbright Institute to facilitate collaboration between the two organisations.

3. Nutrition and Food Security

In this Research Theme, led by Grassby, our goal is to bring new thinking, knowledge, applications and governance to enable individuals to make healthy and sustainable choices for themselves and others. A measure of our success in this regard was the award in 2017 of the Queen's Anniversary Prize, a first for the discipline of nutrition. This theme is represented by 11.2 FTE [4 Professors, 3 Readers, 2 Senior Lecturers and 3 Lecturers].

Areas of emphasis include:

- defining the impact of diet and lifestyle on micronutrient status, health outcomes and disease prevention - vitamin D, vitamin B complex, iodine, selenium - (Lanham-New, Rayman, Bath, Ahmadi, R. Elliott, Mold, Hart);

- understanding the metabolic fate of macronutrients - cholesterol, lipids, starch - in the context of cardiovascular disease and diabetes (Fielding, Griffin, Grassby, Robertson);
- analysing nutrition data to benefit public health and support consumer understanding and behaviour (Rayman, Hart, Bath, Raats, Ahmadi).

The significance of our research in Nutrition and Food Security is reflected in our submission of three ICS on: (**i**) the contribution of our nutritional analyses to the health of UK military personnel ("Improving the Resilience of UK Military Personnel: Optimising Nutritional Strategies", Lanham-New); (**ii**) informing the first ever vitamin D intake recommendations for the UK and the European Food Safety Authority ("Population Vitamin D Requirements: Development, Evidence and Change in UK Policy", Lanham-New); (**iii**) eliminating iodine deficiency and subsequent thyroid disease by shaping the iodine supplementation of food products ("UK dietary sources of Iodine: Impact on product reformulation, policy and public awareness", Rayman and Bath).

Key achievements include: demonstrating, in a meta-analysis, the association between maternal iodine status, foetal gestational age and child verbal IQ (Levie *et al.,* 2019); identifying a pathway by which insulin resistance can be reduced in adipose tissue through the inhibition of the interaction between hormone-sensitive lipase and the glucose-responsive transcription factor ChREBP (Morigny *et al.,* 2018); determining the role of low-density lipoprotein receptor-related protein 5 (LRP5) co-receptors in human white adipose tissue biology and fat distribution (Loh *et al.*, 2015).

Our future strategy is: to grow the contribution of our nutritional analyses to the food industry by strengthening our existing partnerships with global brands (Mondelez; McCain) and local SMEs (In The Buff; FreshBetter) and increasing our reach through partnering with additional corporations. A particular opportunity to drive new collaborations in this regard is via our FoodBiosystems BBSRC-Doctoral Training Partnership (DTP; see below).

4. Healthy Ageing and Supporting Long-term Conditions

The life-expectancy of those living with conditions such as dementia, cardiovascular diseases, metabolic illness, cancers and genetic conditions is increasing. This rise in life expectancy is not matched by a rise in quality of life, largely due to a lack of understanding of the processes of ageing and of how best to provide care to people as they age. Our research in this Theme is improving age-related changes and preventing social isolation. Led by Jeevaratnam, this Theme is supported by 40.9 FTE [19 Professors, 1 Vice-Chancellor's Fellow (Frampton), 1 Professorial Research Fellow, 8 Readers, 3 Senior Lecturers, 17 Lecturers and 1 Research Fellow].

Key achievements include: clarification of previously unknown mechanistic pathways for cardiovascular excitation and regeneration (Quinn *et al.,* 2016, Di Benardini *et al*., 2014); demonstrating novel causal relationships between genetics and clinical outcomes (Scott *et al*., 2017, Couto Alves *et al*., 2019 and Ehret *et al*., 2016; and establishing state-of-the-art evidence to support clinical decision making to ensure the best therapeutic intervention (Venkatesh *et al*., 2018 and Dakin *et al*., 2018).

Our future strategy: involves developing real-world solutions to ageing and frailty through translational collaboration with medical device manufacturers, pharmaceutical companies, architectural designers and the construction industry.

5. Understanding Relationships with Social and Physical Environments

In this Theme, we seek to understand how the complex interactions between social and physical environments with cognitive, social and emotional processes influence health and

well-being. This Theme, led by Timotijevic, is supported by 33.1 FTE [7 Professors, 3 Readers, 1 Senior Research Fellow, 1 Principal Research Fellow, 6 Senior Lecturers and 16 Lecturers]. The Theme encompasses the following cross-fertilising areas of emphasis:

- studying interactions between humans and their physical environment, to understand their impacts on health, well-being and sustainability (Environmental Psychology; Gatersleben, Chris Jones, Ratcliffe);
- social emotions and equality in relations (SEER) (Hegarty, Fasoli, Hepper, Hilpert, Hopkins-Doyle, Russell);
- development of the brain through the lifespan (Farran, Cohen Kadosh, Opitz, Silvanto, Violante);
- wellbeing and productivity in the healthcare workplace: workforce, organisation and wellbeing (Maben, Taylor, Carey, Stenner).

Key achievements include: developing ways to tackle excessive consumption to promote sustainable lifestyles (Elf *et al.,* 2019); understanding developmental relations between spatial cognition and mathematics in primary school children (Gilligan *et al.,* 2018); establishing the effectiveness of interventions designed to reduce sexual prejudice (Bartos *et al.,* 2014).

Our future strategy is: to develop interventions to improve health and well-being, (e.g., for neurodegeneration, synergising with the work of Dijk, Seibt and Violante) by exploiting our investment in research infrastructure and technology (e.g., Biopac, Eyetracking, Mobile EEG, Virtual Reality) and driving inter-disciplinary approaches within FHMS and beyond.

6. Digital Health and Data Science

Our work in this Theme is creating the opportunities afforded by digital technology to change the way that illnesses in animals and humans are diagnosed, monitored, prevented, treated and experienced. The Theme engages 10.5 FTE [3 Professors, 1 Vice-Chancellor's Fellow (Li), 2 Readers, 1 Senior Lecturer, 6 Lecturers] and is led by Armes.

Key achievements include: Modelling the impact of environmental conditions on infectious diseases such as Rift Valley Fever (Lo Iacono *et al.,* 2018) and Ebola (Redding *et al.,* 2019); contributing to understanding the molecular mechanisms of type 2 diabetes through genome-scale studies of three-dimensional chromatin architecture in human pancreatic islets (Miguel-Escalada *et al.,* 2019); assessing the effectiveness of telephone-delivered interventions for reducing symptoms associated with cancer and its treatment (Ream *et al.*, 2020*)*.

Our future strategy is: to develop interventions that improve quality of life, accompanying our increase in life expectancy. For example, implementing into clinical practice digital solutions that reduce the cost of patient care, while improving quality, such as by enabling citizens to live safely for longer in their own home, avoiding hospitalisation and residential care.

Interdisciplinary Research

Implicit in delivering our 'One Health' vision is our interdisciplinary way of working, exemplified through the permeability of our six Research Themes. Interdisciplinarity is encouraged through: sandpit events; establishment of interdisciplinary working groups; recognising and addressing societal challenges within research strategy; seed corn funding to catalyse research opportunities; funding for conference attendance; funding for sabbaticals and secondments; interdisciplinary seminar programmes.

Examples of how these activities have enhanced vitality and sustainability yielding partnership awards include:

- An MRC-funded project (£183k to FHMS) "The impact of host restriction of *Escherichia coli* on transmission dynamics and spread of antimicrobial drug resistance" bringing together veterinarians and bioscientists (2017);
- Our Digital Health Technology Accelerator (DHTA) project is a partnership with six other organisations, each of whom brings essential capability and together, collective synergy. Partners bring together artificial intelligence, machine learning, biomedicine for medical and veterinary healthcare. They include: the Centre for Vision, Speech and Signal Processing (Barnaghi) in the Faculty of Engineering and Physical Sciences (FEPS); Surrey and Borders Partnership NHS Foundation Trust; Surrey Heartlands Health and Care Partnership; Kent, Surrey and Sussex Academic Health Sciences Network; Wessex Academic Health Sciences Network; Cisco; SETsquared Partnership;
- Novel Strategies to Detect and Prevent the Emergence of Antimicrobial Resistance (AMR) in Zoonotic Pathogens, an EPSRC-funded (£139k to FHMS) project brings together bioscientists and engineers (2015);
- Commercial partnership with Zoetis and Enterprise M3 Local Enterprise Partnership, providing £8.5M to bring together veterinarians, biomolecular scientists, engineers and healthcare professionals to create vHIVE (2016). Importantly, vHIVE unites all three University of Surrey faculties to deliver this initiative, including Surrey Business School of the Faculty of Arts and Social Sciences (FASS) and the 5G Innovation Centre (FEPS);
- NIHR Applied Research Collaboration, Kent, Surrey and Sussex (NIHR ARC KSS), led by University of Kent and hosted by Sussex Partnership NHS Foundation Trust brings together stakeholders from across the Kent, Surrey and Sussex geographic region, including: NHS Trusts, local authorities, universities, communities and other partners to support the development and implementation of research to improve health and social care for patients and families in the region, focusing on key areas of need. Funding amounts to c£9M (£917k to FHMS; 2019-2024).

The driving principle behind our approach to interdisciplinary collaboration is to fund either completely or jointly, PhD studentship projects for which the collaborating supervisors represent different research fields and organisations. Multiple such projects extend between FHMS and other universities and between FHMS and other organisations, described throughout these pages, including section 4.

Open Research

During the current period of assessment, FHMS has undertaken two strategic approaches to Open Research (OR) practice. First, we foster communities of OR practice, as demonstrated in our leading, organising and participating in various initiatives, training and working groups related to OR (detailed below). Thus, Farran was appointed (2019) from FHMS as the inaugural University Lead for Research Culture and Integrity. She is one of sixteen "Institutional leads" from UK Universities working alongside the UK Reproducibility Network (UKRN) to improve the quality of our research through training in key skills (e.g., transparent and reproducible workflows) and the sharing of successful and effective practice (e.g., open research policies, hiring and promotion policies) across partner organisations.

Farran established the University of Surrey OR Working Group that has launched a University-wide OR showcase event (2020) and published (2020) the University OR position statement. The University has recently demonstrated further commitment to OR by creating a research fellow post dedicated to promoting and evaluating OR at Surrey, also to be based in FHMS.

Second, OR has been embedded into the research culture and strategy of FHMS, with specific objectives around open practices. Open access is expounded in our research strategy as making outcomes available as soon as possible, in order to foster the widest and most expeditious knowledge exchange. Furthermore, aside from using our open access repository at publication,

many colleagues deposit manuscripts, data, code and other outputs in open repositories at submission; examples include OSF, PsyArXiv and bioRxiv. This has led to, e.g., open source tasks being undertaken by researchers in Switzerland (Swiss Federal Institute of Technology Lausanne, EPFL) and Imperial College London based on open access code from Violante. We also publish analyses of Open Data, such as the UK Biobank (Ahmadi; Lanham-New; Blackbourn).

Taken together, our approaches expect and enable fully open and reproducible analyses pathways from all FHMS researcher active staff, students and their collaborators.

Research Integrity

A culture of excellence in the context of data reproducibility pervades FHMS. It is exemplified by three notable appointments: (i) our senior advisor in animal welfare (Wolfensohn), awarded an OBE in 2012 for services to animal welfare, reflecting her authority and esteem; (ii) a joint appointment (Huggett) between the unit and LGC. Amongst other analytic functions, LGC hosts the function of the Government Chemist and advises Government and the wider community that depends on analytical science; (iii) the University Lead for Research Culture and Integrity (Farran, as above).

Huggett assesses methodological performance, in terms of reproducibility, in the context of harmonisation and ensuring accuracy between laboratories, of molecular methodologies and providing solutions to support reproducible measurement. His reputation in the field of reproducibility in biology is recognised by his authorship of International Organization for Standardization (ISO) guidelines for *in vitro* diagnostic testing (ISO TC 212 17822 WG4; ISO/DIS 17511) and quantification (ISO TC 276/ WG 3 ISO 20395).

FHMS colleagues participate in two regulatory committees: (i) University Ethics Committee (UEC), which focuses on research with human participants (14 FHMS members: Archer, Barberis, Chrysanthaki, Hilpert, Jones, Mason, Nelson, Patton, Riddell, Ritchie, Silvanto, Stenner, Sterr, Williams); (ii) Animal Welfare and Ethics Board (AWERB; La Ragione, Ritchie, Van Der Veen, Wolfensohn). Both committees make explicit the core elements of research integrity such as honesty, transparency, rigour, care and respect in accordance with "The Concordat to Support Research Integrity". To support the development of UEC and AWERB members, FHMS delivers training via away days for research students and staff from across the University.

2. People

Staffing Strategy

We recognise that our colleagues are our most valuable asset in order for us to deliver the highest quality research. Our staffing strategy is therefore to recruit and retain the best people with the right skills that will add critical mass to our pillars of research excellence that are described by our Research Themes. Retention depends upon supporting and developing colleagues and rewarding them, e.g., by promotion and increasing their job satisfaction.

During the current REF period, we have recruited 31 Lecturers, eight Senior Lecturers, five Readers and 13 Professors demonstrating our commitment to investing in research-active staff. These colleagues represent a mixture of adding capacity and replacing leavers. Our staff profile on the census date therefore comprises 157 headcount, 54 Professors, 22 Readers, 75 Lecturers, 6 independent Research Fellows.

Importantly, our staffing strategy is underpinned by our commitment to ensure sustainable growth, which depends on minimising fixed term positions (FTPs) and is evidenced by our proportion of FTPs in 2014 being 8.1%, reducing to 6.5% by 2019.

In addition, our numbers of 'Teaching Fellows' have increased to enable 'Teaching and Research' staff to grow their protected time for research, evidencing our commitment to, and investment in,

research. In 2014 the ratio of Teaching Fellows to Lecturers was 1.3:1, with 66 teaching fellows in FHMS, compared with 1.8:1 in 2019, equating to 115 Teaching Fellows. Nevertheless, we pride ourselves on providing research-led teaching, in which our research-active colleagues deliver key lectures, laboratory classes and tutorials to complement our curricula.

Implementation of Staffing Strategy

We have built capacity and capability within our Research Themes by strategic recruitment. Examples include, two Lectureships in the Chronobiology and Sleep Theme (Seibt, Revell); in the Infection and Immunity Theme, ten Lectureships (Couto Alves; Fachetti; Hingley-Wilson; Jimenez; Maluquer de Motes; Maringer; Martinez-Estrada; Mayerhofer; Okoro; Riddell), four Senior Lectureships (Betson, Horton, Behboudi, van Vliet) one 0.2 FTE Senior Lectureship (Huggett), one Reader (Barberis), three 1.0 FTE Professors (Chambers; Dunn-Walters, Proudman) three 0.2 FTE Professors (Emery, Steinbach, Pallen). The Healthy Ageing and Supporting Long-Term Conditions Theme has been supported by many recruitments including: Lecturer: Asim, Campagnolo, Chrysanthaki, Cohen Kadosh, Evans, Gilligan, Kaakinen, Martinez Estrada, Moss, Nalesso, Patton, Ratcliffe, Riddell, Ritchie, Seibt, Smith, Smyrnias, Violante, Wyles; Senior Lecturer: Dibb, Hanna, Jeevaratnam, Chris Jones, Whitaker; Reader: Armes, Field, Mason, Taylor, Williams; Professor: Bacon, Barley, Griffiths, Heiss, Lyon, Maben, McGregor, Nicholson, Prokopenko, Ream, S. Skene.

To assure the highest quality, we recruit from prestigious universities nationally and internationally. For example, Hilpert from Switzerland; Mayerhofer from Germany; Barberis from The Netherlands; Maringer from the USA; Asim from Cambridge; Campagnolo, Prokopenko from Imperial College; S Skene and Farran from University College London; Armes, Dunn-Walters, Maben, Ream, Taylor from Kings College London; Martinez-Estrada from Oxford.

Implementing this strategy has been made possible through two approaches. First, our planned growth: we have built capacity through the growth of the School of Veterinary Medicine (SVM) following its launch in 2014 and through our investment in the School of Psychology (SoP). Second, through the strategic alignment of the research capabilities of our existing School of Biosciences and Medicine and School of Health Sciences with SVM and SoP, creating our unified FHMS.

Additionally, attrition through retirement has allowed us to take advantage of new opportunities. For example, a strategic decision was made to launch a programme of immunology research that would provide brand new capability in our 'One Health' agenda by directly underpinning our Themes of: Infection and Immunity; Sleep and Chronobiology; Healthy Ageing and Supporting Long-term Conditions.

Four academic research posts in immunology were created: one Professorial and three Lectureships. The Professor of Immunology (Dunn-Walters) was recruited in 2015 and provides leadership, subject expertise and career guidance to the three Lecturers recruited subsequently (Martinez-Estrada; Mayerhofer; Riddell).

Characteristic of our recruitment strategy these individuals were hired with targeted deployment of resource (i.e.- 'start-up packages') to enable their success. Each Lectureship was assigned budget for a 3-year PhD student, consisting of stipend, full tuition fees at the Home/EU rate and £10,000 per annum consumables budget. Recognising the need to recruit to the professorial vacancy an individual with an established track record and an extant dynamic research group, this post was supplemented with £250k capital funding to provide the necessary physical infrastructure.

We recognise achievement within research and impact through our annual appraisal process and the concomitant merit-based promotions and annual performance related pay bonus scheme, which includes both incremental salary rises and one-off bonus payments. During the REF period, two colleagues were promoted from Research Fellow to Senior Research Fellow; one from Senior

Research Fellow to Principal Research Fellow; 13 from Lecturer to Senior Lecturer; 11 from Senior Lecturer to Reader; five from Reader to Professor.

Further recognition is through FHMS nomination of candidates to our Vice-Chancellor's Annual Awards; e.g., our Innovator of the Year finalist was Dunn-Walters (2019) and Simmonds won Researcher of the Year (2018).

Output selection

Outputs have been selected in a fair and transparent way, in line with our University's own policies and values and in accordance with our REF 2021 Institutional Code of Practice. The gender balance of our 136.8 FTE is 53% female and 47% male, with 50% of our selected outputs attributed to females and 50% to males. A total of 28 individuals (19 female; 9 male) submitted themselves to our Research Independence Process, two of whom were deemed to be independent and both were female. There is close correlation between age category (49% FTE aged 30-45 years; 42% aged 45-60 years; 9% >60 years) and output selection (48%, 42% and 10%, respectively). Full-time colleagues amount to 76% FTE and part-time 24%; this split is mirrored precisely in the selected outputs attribution. Four percent of our FTE identify as disabled and 3% of our outputs are from these individuals. These data reveal no detectable bias in our output selection process.

Supporting and promoting equality and diversity

FHMS is committed to providing an inclusive and equitable environment in which staff and students can thrive. Our recruitment processes prevent discrimination and ensure everyone from PGR student to senior professor is given equal opportunity, regardless of protected characteristics. Recognition and celebration of equality, diversity and inclusion (EDI) have been influenced positively in FHMS by our engagement with Advance HE's Athena SWAN charter: FHMS holds one Silver and two Bronze awards.

These awards acknowledge our collective commitment to, and progress, on gender equality and in turn, this supportive culture extrapolates to other protected characteristics. We recognise the benefits of gender equality, and equality and inclusion more widely, and work hard to embed EDI into our practices. We work proactively to foster an inclusive culture and share best practice across FHMS. Likewise, early interception and remediation of poor practice is possible. This effective communication is facilitated by our FHMS EDI Committee (FEDIC), chaired by Director of Faculty Operations (Lawson). FEDIC's remit is to: *(i) take a proactive approach to celebrating and promoting EDI, (ii) enable all colleagues to work in an environment of mutual respect and thereby supporting each of us to fulfil our individual and collective aspirations*. FHMS staff are also well represented on University EDI committees/networks to ensure the bi-directional flow of EDI best practices.

Practical examples of our EDI work are: an increase in women senior academics during the current assessment period - the proportion of women at Reader level increased from 30.8% (2014) to 47.4% (2019); ensuring gender-neutral language is used in our staff recruitment adverts and documents; ensuring recruitment panels are representative of diverse staff groups, comprise at least 25% minority gender, include representation from an independent department; all staff undergo Unconscious Bias (UB) training; requiring selection panels to reflect on applicants' gender balance before shortlisting, compelling panels to seek further applications if necessary; establishing that all candidates listing a disability who meet core competencies are normally invited to interview (Disability Confident); promoting shared parental leave to recognise our colleagues have important life responsibilities outside of our lecture theatres and labs- direct beneficiaries include Locker, Maluquer de Motes.

In accordance with our Athena SWAN action plans, we do not schedule meetings before 10am and after 4pm that could be detrimental for staff with caring responsibilities.

Our EDI work has influenced the wider University environment and beyond, including: chairing the Microbiology Society EDI Committee (Blackbourn); recipient of the British Psychological Society Award for Promoting Equality of Opportunity, 2017 (Hegarty); our FEDIC Race Equality representative (Williams) successfully campaigned for changes to University's Report + Support system to include microaggressions in descriptors of racism; Furthermore, Williams has taken the overarching role of Academic Lead for Equality, Diversity and Inclusion at the University of Surrey; Robson founded the British Veterinary Ethnicity and Diversity Society and organised the UK's first EDI conference in Veterinary Medicine at Surrey (2020).

Staff development

We are committed to providing engaging development opportunities to enable our staff to obtain and maintain the necessary skills and experience so that they can achieve ongoing career fulfilment and success and so that we can retain them.

These staff development opportunities include: research writing week, when all local meetings are suspended; writing retreat, when successful academic staff mentor colleagues to develop their approaches to writing and consider appropriate targets; tuition fee reductions and opportunity to apply for study time for staff who are undertaking either MSc or PhD; establishment-funded researchers to support senior colleagues with key programmes of research; peer review process for bids and publications; bid development support, providing internal and external consultants and professional infrastructure support, particularly for projects with multiple collaborators; Executive Dean's professorial lunch for horizon scanning and strategic planning; skills workshops to help staff learn new skill sets such as in statistical and software packages.

Women are proactively encouraged and supported to attend leadership training and development programmes, including those of the Institute of Leadership and Management (Whitaker) and especially Advance HE's Aurora programme (participants include G Elliott, Hingley-Wilson, Lemanska, Williams, Winsky-Sommerer).

Workload Planning

We have embraced workload planning to ensure that time is formally allocated for scholarship and development, including the maintenance of clinical skills. Within our planning model, expectations about teaching and academic administration workloads are clearly defined which means that time allocation for research is protected. In terms of our absolute requirement to continuously support the development of our staff, colleagues are allocated in their workload plan 150 hours for 'Scholarship', defined as 'maintenance and advancement of own personal knowledge and skills: reading literature, attending professional conferences with financial support from FHMS to do so, maintaining professional or clinical skills, acquiring new skills, etc.'

Mentoring

Further support for our staff to develop to their maximum potential comes from our mentoring scheme. Colleagues on probation are assigned a 'Senior Colleague' who fulfils this role until probation is complete (typically three years). We also have a 'Buddy System' in which probationary lecturers during their first six months' employment are assigned a lecturer colleague to enable settling in from an operational and pastoral perspective, such as answering 'how do I place a reagent order', etc.

Beyond probation, academic colleagues are actively encouraged to engage with a mentor, who can provide another channel of support to help guide staff in developing their academic portfolio, advise towards their promotion aspirations and support towards personal goals. For example, one senior colleague (Blackbourn) mentors, through a 'mentoring contract', six individuals from across FHMS. Four have been promoted during the current assessment period: one Lecturer to Senior Lecturer; two Senior Lecturers to Reader; one Senior Lecturer to Professor.

We support leadership by engaging experienced professional coaches (Dr Raymond Dempsey; Mark Abraham, OBE) to grow our leadership styles and to foster teamwork and effective working practices.

Sabbatical leave

Although our workload planning protects time for research, we recognise the importance of sabbatical leave. Our policy enables staff to be released for specific periods of time to generate strategic impact, major research grants, new collaborations, especially international, and publications.

During the current assessment period, six Category A colleagues have taken sabbatical leave. Three examples are: (i) McFadden, taking six months' sabbatical leave resulted in his award of our Leverhulme Doctoral Training Award in Quantum Biology (2018); (ii) Johnston, who was awarded three months' sabbatical leave in recognition of special family circumstances restricting his ability to complete the writing of publications and grants, leading to his award in 2019 of a BBSRC project grant (£810k); (iii) Gallagher was granted 12 months' sabbatical leave to establish collaborations in the USA, China and Japan and was awarded a Fulbright Scholarship at Tuskegee University (Alabama, USA); as a result she wrote "Slow Ethics and the Art of Care" (2020).

Innovation and Business Partnering

We recognise the bidirectional nature of the innovation life cycle and that to benefit from it we need to accelerate our collaborations with industry, public and third sector bodies. This strategy enables us to deliver solutions to real world challenges, protecting and exploiting intellectual property and influencing policy.

Our approach to stimulate these opportunities is through strategic, joint appointments and research collaborations between FHMS and relevant partner organisations, including: secondment at NPL (Lemanska); joint appointment with LGC (Huggett); University spin-out company to support industry and other sectors (Airbus, United Nations, NYC, UK Medical Schools Council, St George's and Manchester Medical Schools, NATO and Aviva) in using our automated Multiple Mini Interview (MMI) system for staff recruitment (Callwood); Monash University, joint funded PGR student (Hart); Lighter Life, joint funded PGR student (Robertson); APHA, joint funded PhD studentship (Maringer); secondment at IKEA (Gatersleben and Elf) helping to embed the concept of living sustainably within IKEA. Further detail, including the resource to support partnering opportunities, is provided in Section 4.

ECR career development support

We embrace a broad definition of ECR encompassing PhD students, postdoctoral researchers and lecturers on probation (up to four years post-appointment), without imposing limits on time post-PhD. This all-encompassing approach encourages an inclusive atmosphere for all aspiring researchers. Indeed, we have a strong culture of support for ECRs, with all early career postdoctoral researchers and lecturers formally allocated an internal mentor with whom they can discuss their concerns, aspirations and development needs on an 'open door policy' basis and within the framework of our mentoring scheme.

Our ways of working ensure all our ECRs benefit from the widest range of development opportunities. These include: weekly ECR seminar programme at which individuals take turns to present their latest research findings to their peers and supervisors; organised social networking events; organised corporate information and training events, when research supply and equipment industry representatives are invited to either sponsor seminars or deliver their own presentations on current topics such as latest technologies, devices, reagents.

Our commitment to The Concordat to Support the Career Development of Researchers is exemplified by implementing protected time for development opportunities. All ECRs have the

equivalent of one day/week for their own development, e.g., participating in professional and development courses; building their own research niche, networks, collaborations. ECRs have the opportunity to join the Institute of Directors' (IOD) membership programme, helping them build professional networks. Our research committees at School (e.g., Poirier and Hussain in SVM) and FHMS (e.g., Banks) also have ECR representation.

One of our early career researchers (Coleman) contributes to our University governance *via* the Excellence in Research Working Group (ERWG), which is implementing the Concordat and reports to the Senate-level University Research and Innovation Committee. Time is allocated in Coleman's workload plan to attend meetings, as well as to encourage and explain the benefits to all ECRs within FHMS to participate in training opportunities. To ensure this working group represents FHMS needs, our ECR Forum, composed of eight contributors reports into ERWG.

Postgraduate research (PGR) student recruitment, training and supervision

Since all research staff recruitment is aligned to delivering our One Health vision, the recruitment of our PGR students also follows that strategy. Hence, our PGR students are recruited to work within those scientific disciplines described by our Research Themes. This approach enables the intrinsic integration of our PGR students into our research culture and promulgates our ethos of achieving research excellence.

A proxy for our success in training PGR students is their publication track record. Those students graduating with PhDs or MDs during the reporting period have either authored or co-authored more than 400 peer-reviewed papers, including highly cited work across all our Research Themes. For example, nine papers have been cited at least 30 times, with one cited 130 times; they include topics of work-related ruminations, food labelling and consumer choice, meal timing and circadian systems, ischemic disorders and diabetes, and distraction interventions for pain and anxiety management during conscious surgery.

Our PhD student funding streams are multifarious and include: Leverhulme Trust-funded 'Quantum Biology' Doctoral Training Centre (McFadden; Leverhulme Trust contribution £1.05M; 2018-23) to support 21 PGR students through additional FHMS financial input equating to 28.6% for each student; FoodBiosystems BBSRC-Doctoral Training Partnership (DTP) (R. Elliott, BBSRC contribution £11.2M, 2020-28). This DTP has over 50 associate and affiliate partners from universities, the agri-food industry and non-governmental organisations. Of the 105 PGR students supported, 22 will be FHMS-trained from this DTP; Jeevaratnam's interdisciplinary DTP entitled "Engineering novel Model systems to accelERate aGEing research (EMERGE)" will fund five PhD students to work collaboratively towards developing novel *in vitro* models to understand ageing mechanisms in multiple physiological systems (Dunhill Medical Trust, £414k, 2020-2023).

Other examples abound, including: BBSRC/Mologic iCASE studentship Project (Griffiths); BBSRC/GSK iCASE studentship (Avignone Rossa); EPSRC/NPL Project iCASE studentship (Hingley-Wilson); Surrey and Sussex NHS Healthcare Trust (SASH) (Heiss); four studentships funded by Zoetis (La Ragione, Horton); multiple PhD studentships funded jointly between FHMS and the Pirbright Institute (e.g., Locker, G. Elliott, Dunn-Walters). Examples of charitable PGR funding include: Lorna and Yuti Chernajovsky Biomedical Research Foundation (Maluquer de Motes; McVey); British Heart Foundation (Camelliti); Abbeyfield Research Foundation Gallagher and Mold); Humanimal Trust (Van Vliet and Ogden).

(i) Supervision and training

All PGR students are supported by at least two University of Surrey academics. Where one supervisor lacks necessary supervisory experience, then the other will have demonstrable experience. Depending on their project requirements, many PGR students benefit from additional supervision, most commonly provided external to the University from organisations such as universities, research institutes or companies located either within the UK or overseas.

PGR students are integrated into the research community and culture of FHMS and the University more widely. Across FHMS there is a community of designated PGR Student Representatives and academic PGR Directors, representing all research disciplines; these individuals are available to provide personal and academic guidance, as necessary. A highly trained team of laboratory technicians, funded by FHMS, provides our PGR students with technical training on specialised instruments and working in regulated facilities. The team also provides administrative support (e.g., for risk assessments, standard operating procedures, etc) and guidance on legislative aspects of research conduct.

Other forms of support and training include: PGR student seminar series attended by PGR students and supervisors with weekly seminars providing opportunity to develop presentation skills; informal discussion and networking between PGR students that is facilitated and encouraged *via* PGR Club events, such as weekly lunch meetings with discussion around particular aspects of their own PGR journey that may include challenges with a methodological issue or rehearsal of a conference presentation. In regard to the latter, our FHMS annual Research Festival at which we showcase our research activities and have a plenary lecture given by an external research luminary provides an opportunity for PGRs and ECRs to communicate their own research projects faculty-wide.

(ii) Monitoring progress

After the first 12 months of study, PGR students are required to submit a short thesis on progress and future plans that is subject to a formal 'Confirmation *viva*' by two academics independent of the supervisory team. Upon satisfactory completion of this examination, PGR students are formally registered for their PhD study.

PGR students have the responsibility of submitting monthly progress reports, followed by regular, and at least monthly, face-to-face meetings with their supervisors. A formal six-monthly review meeting occurs between PGR student and supervisors for a reflection on progress and training. Reports are moderated by a PGR Director and formally recorded. High level dialogue on PGR issues occurs at the FHMS Research Degrees Committee, comprised of PGR stakeholders and chaired by the Associate Dean Doctoral College (R Elliott).

We have a long-standing track record of participation in the Postgraduate Research Experience Survey (PRES). PGR Directors work with the PGR student representatives using the survey data to develop annual action plans to enhance our PGR student experience. The benefits of this approach, linked with parallel University-wide initiatives, are clearly evidenced by increases in the approval scores across all nine categories of PRES during the current assessment period, with particularly marked increases for Supervision (12%), Progress and Assessment (12%) and Responsibilities (15%). PRES approval scores from PGR students within FHMS compare favourably with those for the University as a whole, exceeding the University score in 6 of 9 categories, including the headline Overall Approval category (85.7% for FHMS compared with 84.3% for the University) for which the University was ranked 7th in the UK in 2020. Further evidence that these approaches succeed is our submission rate for the current assessment period ranging from 94-99% within four years, depending on cohort entry date.

(iii) PGR students with a clinical background

PGR students with a clinical background undertaking either full- or part-time postgraduate training add a vibrant diversity to our FHMS PGR student population and represent 45% of it. This 'clinical cohort' reflects the variety of allied health professions within the NHS. As a measure of the scale of our commitment to clinical research studentships, during the current assessment period, we recruited 270 PsychD students, of whom 15 were part-time and 41 MDs (19 part-time). Our research environment facilitates and accommodates the integration

of those students working within the NHS, who are often part-time and juggling postgraduate study with families and senior posts. Further cultural enrichment of the PGR cohort is afforded by 27% being from overseas.

Integration of clinical academics

We are committed to facilitating our clinical researchers' integration into our research culture and helping develop their careers. We recognise that achieving both is integral to achieving our research strategy and maximising our impact. These clinical academics play a strategic role in our creating synergy between their clinical (either medical or veterinary) and academic workplaces ensuring our research is firmly grounded in clinical need and driving its impact. Importantly, these colleagues are frequently members of our research committees (e.g., Proudman, Horton, Ream) and have line management responsibility for our research colleagues (described below), driving the integration of our clinical colleagues within our research environment. Examples of our clinical academics and evidence of their integration and development with us include:

Heiss, appointed 0.5FTE to FHMS in 2018 from the University of Düsseldorf, where he headed the Vascular Medicine programme in the Department of Cardiology, Pulmonology, and Vascular Medicine. He takes line management responsibility for seven research-active colleagues, clinical and non-clinical in FHMS. For the remainder of his time, he is Clinical Professor of Cardiovascular Medicine with SASH.

Jeevaratnam, a veterinary clinician by training, was appointed 1.0FTE in 2014, promoted to Reader in Clinical Physiology in 2019, and appointed Head of Department of Veterinary Pre-Clinical Science in 2017, where he line-manages eight research-active colleagues. He has been awarded almost £1M of competitive research funding, including the "EMERGE" Dunhill Medical Trust DTP described above. He is FHMS lead for our Research Theme Healthy Ageing and Supporting Long-term Conditions.

Rusbridge, appointed 0.4FTE to FHMS in 2013, promoted to Professor in 2018, is a Royal College of Veterinary Surgeons Specialist in Veterinary Neurology and Chief of Neurology at Fitzpatrick Referrals, a veterinary hospital. She line manages three research-active colleagues, has supervised to completion four diplomats of the European College of Veterinary Neurology, a specialist, clinical, post-graduate qualification and two PhD students. She sits on the Kennel Club/British Veterinary Association Neurology Working Group and Petplan Charitable Trust Scientific Committee.

Other practising clinical researchers in FHMS abound, including, but not limited to: Field; Lyon; Maben; Michael; Nicholson; Pandha; Russell-Jones; Whyte.

3. Income, infrastructure and facilities

Income

Commensurate with the strategic multidisciplinary growth of FHMS since REF 2014, through our launch of the School of Veterinary Medicine (SVM) and the merger of the School of Psychology with FHMS, there has been an upward turn in research income. Thus, in 2014-15, FHMS research income amounted to £6.81M, growing by 44% (£3.03M) in 2018-19 to £9.84M. Our 2019-20 income fell slightly to £8.16M, which we attribute to the consequences of the COVID-19 pandemic. Overall during the REF period we have secured £55.26M from a portfolio of UKRI Funding Councils, NIHR and charities; cumulative examples with our FHMS colleagues as either Principal or co-Investigator include £7.73M (BBSRC), £3.73M (MRC), £4.81M (NIHR) and £2.2M (Wellcome Trust).

Our success in research income growth has been achieved as a result of our vibrant research environment, which has facilitated our strategic approach to designing and submitting funding applications in a targeted manner. Organising our colleagues into six Research Themes, whilst

encouraging seamless interaction between Themes, has enabled this coordinated and interdisciplinary approach to bidding for funding. Exemplars of funding in each Research Theme include:

1. Chronobiology and Sleep

Rodent models of neurodegeneration to explore the role of sleep and potential treatment targets (e.g., PI: Seibt; Wellcome Trust, £95k, 2017-2020; PI: Winsky-Sommerer; Lilly, £180k, 2012-2016).

Importantly, much work in this Theme is undertaken with human study subjects. Collaboration with Imperial College London in the UK Dementia Research Institute (UK DRI) Care Research and Technology Centre (PI: Dijk; £20M awarded from DRI, £5M to FHMS, 2019-2025) located in the Clinical Research Building (CRB) involves the development, validation and implementation of novel, well-tolerated technology to monitor and improve sleep in people living with dementia. Through a collaboration with Columbia University, colleagues are exploring how immune function varies across the day and seasons (Surrey Co-I: D Skene; NIH, £333k, 2016-2021) which could have implications for diagnostics and treatment efficacy. The interplay between food, metabolism and the circadian system has consequences for obesity and metabolic disorders (PI: Johnston; BBSRC, £1M, 2019-2022; PI: Johnston; MRC, £787k awarded, £222k to FHMS, 2017-2020) and the relationship between sleep and cardio-metabolic disease is under investigation (Surrey Co-I: von Schantz; NIH, $2.6M awarded, $105k to FHMS, 2019-2023).

Ageing and lifelong health are underpinning interests of FHMS and cut across our Research Themes. For example in this Research Theme, we use human models of ageing (bedrest, where the head of the bed is lower than the foot) to explore the influence on circadian disruption (PI: Archer; BBSRC, £565k, 2015-2018).

2. Infection and Immunity

Our African Livestock Productivity and Health Advancement Initiative with Zoetis is funded by The Bill & Melinda Gates Foundation (£1.1M; Cook, La Ragione).

Our virus research focuses on the biology of important human pathogens and the novel insights they can deliver for general human cell biological processes. These insights include immune evasion strategies used by poxviruses to understand how cells fight virus infections (e.g., PI: Maluquer de Motes, BBSRC, £350k, 2015-2018; BBSRC, £521k, 2020-2023); mechanisms by which viruses remodel the cellular translational landscape (e.g., PI: Locker, BBSRC, £385k, 2018-2021; BBSRC, £503k, 2019-2022); and temporal-spatial regulation strategies used by herpesviruses for gene expression and morphogenesis (e.g., PI: G. Elliott, MRC, £511k, 2020-2023; BBSRC, £484k, 2020-2023).

An area of emphasis is antimicrobial resistance (AMR) research in animals, humans and the environment (~£2M BBSRC and NERC funding; Chambers, McFadden, Ritchie, La Ragione). This research activity extends across Europe with La Ragione and Horton's leadership contribution to the €91M pan-European, 38-partner programme "One Health European Joint Programme (EJP)" on zoonoses, AMR and emerging threats that brings €3.4M to FHMS (Horizon2020; 2018-22).

Research on the mycobacteria responsible for tuberculosis is undertaken by McFadden, Chambers and Stewart (£2.1M BBSRC and NC3Rs funding) and Simmonds holds a £1M Wellcome Trust Investigator Award for her work on Buruli ulcer and opportunistic infections.

Dunn-Walters' group is one of a consortium of four with groups from University College London and King's College London to study class switching of antibody genes using single cell

technologies, molecular modelling of structures and developing bioinformatics tools for the community (BBSRC Strategic LoLa; 2020-25; £1.15M to FHMS).

Avignone Rossa's interdisciplinary collaboration on water treatment with University of Surrey engineers is learning how to remove potential pathogens, antibiotics and bioactive molecules (£700k funding, EPSRC).

3. Nutrition and Food Security

Iodine is essential for producing thyroid hormones and for normal foetal brain development. The EUthyroid project investigated iodine intake of the European population with the aim of harmonising and sustainably improving iodine intake in Europe (Surrey Co-I: Rayman; Horizon2020, €3.375M, £132k to FHMS, 2015-2018).

Our research examines the metabolic mechanisms of cholesterol response to saturated fat (PI: Griffin; BBSRC, £420k, 2017-2021) to prevent and manage cardiovascular disease. Stable isotopes are used to study food metabolism in humans directly (PI: Fielding: BBSRC, £341k, 2019-2022) using an isotope ratio mass spectrometer (PI: Fielding; BBSRC, £203k, 2017-2018). We use potatoes containing carbon-13 labelled starch to determine the rate and extent of digestion of starch in humans (PI; Robertson; BBSRC, £592k, 2016-2020).

Raats' work unites interdisciplinary research contributing to the design and planning of the development of the food and nutrition infrastructure across Europe (PI: Raats; Horizon2020, €311k, 2015-18; PI: Raats; Horizon2020, €781k, 2018-23). Hart is collaborating with other European partners to develop an information and communication technology (ICT)-based system for providing personalised nutrition (Surrey PI: Hart; €8.15M, €405k to FHMS, 2018-2022).

4. Healthy Ageing and Supporting long-term Conditions

As a measure of our interdisciplinarity, our UK DRI project, described above, is one of many projects that falls within this Research Theme. Others include:

Dunn-Walters' partnership in the MRC/BBSRC Systems Immunology of the Lifecourse flagship consortium: "Multiscale analysis of B cell responses in ageing" (MABRA) an interdisciplinary programme comprising immunology, mathematics, and bioinformatics led by KCL (£2.2M awarded, £627k to FHMS, 2014-2020);

Wu's UK-USA international collaboration to identify functional determinants of bladder overactivity and dysfunction in ageing (BBSRC-NIH, £1M to FHMS, 2016-2021);

Campagnolo and Camelliti's research developed an *ex vivo* model for the study of epicardial cells in 3D cardiac slices to investigate their regenerative medicine potential following myocardial infarction (PI: Campagnolo; NC3Rs, £269k, 2017-20);

Nicholson's research is developing the evidence-base and providing tools for community services to care better for frail elders approaching end-of-life and their carers (PI: Nicholson; HEE/NIHR Senior Clinical Lectureship, £486k, 2019-2024).

5. Understanding relationships with Social and Physical Environments

Studies are exploring how human health and well-being are affected by nature (PI: Gatersleben; Dunhill Medical Trust/Whiteley Village, £128K, 2020-22; PI: Gatersleben; ESRC/Natural England, £218k 2020-21).

Ensuring new generation sustainable, digitally-empowered, modular 'smart homes' meet occupants' immediate and future needs is being undertaken in a multi-disciplinary project led by Chris Jones (Innovate UK, £641k awarded, £223k to FHMS, 2020-22).

Our SEER group has explored how current sexual orientation structures and norms privilege and exclude through gendered language, institutional practices and processes (PI: Hegarty; Horizon2020, £115k, 2016-18; PI: Hegarty; British Academy, £10k, 2017); recognition of the value of this work was achieved by our hosting the 2020 European Association for Social Psychology Summer School.

Cohen Kadosh is exploring how children and adolescents learn to make sense of the social world (Academy of Medical Sciences, £50k, 2017-19) and Violante is developing a framework capable of shaping interactions between brain networks that support cognitive functions, (BBSRC, £471k, 2019-21). This work benefits from access to Magnetic Resonance Imaging (MRI) facilities through the Combined Universities Brain Imaging Centre (CUBIC) consortium.

Maben and Taylor are synthesising evidence on nurse, midwife and paramedic poor mental health at work (NIHR, £260k, 2020-2022). Carey and Stenner (alongside Hart and Skene, S.) are evaluating supplementary prescribing by dieticians and independent prescribing by radiographers (NIHR, £500k, 2019-2023).

6. Digital Health and Data Science

We employ mechanistic models, statistical techniques and artificial intelligence to understand host-pathogen interactions, modes of transmission and how development of antimicrobial resistance is affected by environmental factors (La Iacono, La Ragione, van Vliet and Chambers; Horizon2020, €160k, 2019-22). Our Veterinary Health Innovation Engine (vHIVE) is a major contributor to the animal perspective of this Theme.

We work to reduce both the human and economic cost of hospitalisation by interrogating datasets of symptoms acquired from Internet of Things-enabled sensors installed in: our UK Dementia Research Institute (UK DRI) Care Research and Technology Centre (Dijk); our 'smart homes' (Chris Jones); the homes of patients living with, or at risk of conditions such as dementia, diabetes and cancers e.g., our Technology Integrated Health Management (TIHM) for Dementia project (Ream; see Section 4.3.vi); our Digital Health Technology Accelerator (DHTA) facility (Blackbourn), sited in our Clinical Research Building and funded (£1.4M; 2019-2021) through our Local Enterprise Partnership (Enterprise M3), to provide an interface for colleagues from academia, SMEs and the NHS to synergise and provide a pipeline into the NHS for innovations in digital healthcare technologies.

BEATdiabetes is evaluating the clinical and economic consequences of a lifestyle change programme to manage type 2 diabetes using digital solutions in primary care (PI: Cooke; Innovate UK and NHS England, £545k, 2019-22). eSMART evaluated the cost-effectiveness of real-time mobile phone-based remote monitoring at improving symptom management in people with cancer across European and the US (PI: Armes; EU FP7, £1.27M, 2013-19).

The LongITools project seeks to understand how the cumulative influences of environment, lifestyle and genetic factors conspire to induce disease (obesity, type 2 diabetes and cardiovascular disease; Prokopenko and Kaakinen, EU Horizon2020, €682k to FHMS, 2020-24).

Organisational Infrastructure

These funding successes have been enabled by strategic oversight of research direction by our Faculty Research Executive Board (FREB). Thus, supported by our University-funded Research Facilitation Officer, FREB horizon scans for funding opportunities. Our Associate Dean Research

and Innovation provides a two-way conduit between FHMS and the University to ensure high-level strategic complementarity.

In this way, FREB supports identification and prioritisation of applications to those funding opportunities that meet our strategic ambitions and for which we are appropriately equipped to submit the most compelling case. Appropriate operational support is furnished by FREB, such as market competition analyses and metrics data mining to deliver the highest quality funding proposals.

Most pre-award support around the mechanics of grant submission is delivered by University central teams. Examples include costing proposals; advice on process aspects of submitting proposals; legal and contract support; mock panels; sponsor analysis and visits; institutional letters of support; clinical trial sponsorship; research ethics, integrity and governance. Likewise, a University central team oversees post-award logistics, such as monitoring finances.

Our grant writing support is provided through the 'Bid Development Support' (BDS) system. In this process, grant applications exceeding £50k in value and led from FHMS undergo internal peer review. Collectively, our approaches to raising research income have proven very successful, for example our BBSRC 2019/20 success rate was 26% from 23 applications.

Given the increasing complexity of the facilities required for the breadth of our research activity, coupled with our University's Health and Safety vision "Towards Zero" to maximise employees' and students' health, safety and well-being by minimising incidents and accidents, we have invested in our technical support team, increasing their number to 60 FTE during the current REF period. They provide the infrastructure to support our research activities by managing fundamental laboratory functions, including health and safety, maintenance of equipment, operation of specialist technical facilities, such as flow cytometry, confocal microscopy, pathology and the animal Biomedical Research Facility.

Aside from supporting these laboratory functions, our technical team provides critical expertise providing 'laboratory memory' for protocols etc, and to operate, organise the use of, and train in the use of our technical facilities. A measure of the institutional support and recognition we give to our technical team is that we have signed up to the Technician's Commitment.

Facilities and Physical Infrastructure

The delivery of our funded research objectives, which in turn facilitates funding renewals and therefore a sustainable research environment, is enabled in part by our recognition of the need for up to date, cutting edge facilities for the delivery of the highest calibre of research and its impact. Hence, our research capabilities have been enhanced through **£51.1M** investment in research infrastructure during the REF period. This amount is aside from the **£60M** investment in the SVM buildings, including five containment level 2 laboratories, tissue culture, imaging facilities, etc.

The University invested £7.5M in a state-of-the-art small animal facility, the **Biomedical Research Facility** that includes two containment Level 2 laboratories for Ritchie's work on antimicrobial drug resistance with *Vibrio* species and *E. coli* pathotypes, including enterohaemorrhagic *E. coli.* The Biomedical Research Facility also has dedicated neurology and sleep research facilities to support the work of Winsky-Sommerer, van der Veen and Seibt into the molecular bases of circadian rhythmicity. Having this state-of-the-art facility enabled the award of and delivery on Wu's BBSRC-NIH grant on the ageing bladder described above.

Our clinical translational research facilities are centred in the **Clinical Research Building**. Here, five pillars of infrastructure are housed under one roof: Clinical Research Facility; Surrey Clinical Trials Unit; Surrey Sleep Research Centre; UK DRI Care Research and Technology Centre; DHTA. Here, studies are supported on humans at all phases, from first-in-human through to large scale pragmatic trials as well as trials of complex interventions. Facilities include: residential capability for study subjects; advanced sound attenuation, light and temperature control, and

isolation from all external time cues; electroencephalography (EEG) sleep and circadian rhythm research laboratories; ambulatory sleep EEG recording systems; individual sleep laboratory bedrooms with infrared CCTV monitoring. During the REF period, we have invested £8.5M to ensure the facilities in this building continue to enable particularly our Chronobiology and Sleep research, in turn contributing to our Impact Case Study "HETLIOZ®: First FDA/EMA approved drug for sleep-wake disorders in the blind" (D. Skene, Lockley).

Benefitting from close proximity to these translational research facilities in the Clinical Research Building are our adjacent **Research Design Service-South East** headed by Egan, **Surrey Health Economics Centre** led by Gage, and Lusignan's **RCGP Research and Surveillance Centre**. Collectively, these have contributed to: Hunt and Creagh-Brown's £153k NIHR award to evaluate mitigating muscle wasting in hospital intensive care patients by repetitive occlusion stimulus; Gage's NIHR Health Services and Delivery Research award on how the composition of the GP workforce affects outcomes for patients (Gage: £1.3M).

Our Infection and Immunity Research Theme work benefitted during the REF period from the building of a second **Containment Level (CL) 3** suite to meet our increasing capacity needs, with a £1M University investment. These facilities have supported over £3M in funding during the current REF period, examples of which include: molecular studies of NF-kB inhibition by Dengue virus in the mosquito *Aedes aegypti* (PI: Maringer; £451k, MRC, 2018-2021); the development of a bovine alveolus model to replace cattle in the study of host-pathogen interactions in bovine tuberculosis (PI: Chambers; £425k, NC3Rs, 2016-2019); development of a recombinant BCG vaccine to control TB in cattle (PI: McFadden; £520k, BBSRC, 2014-2018).

Our £11M **Veterinary Pathology Centre**, having CL3 facilities, provides surveillance to over 50% of registered livestock in the UK and supports pathology at DEFRA, DSTL, Pirbright, PHE; e.g.- enabling screening of road kill badgers for tuberculosis infection (PI: Palgrave; £250k, Defra, 2016-17).

Other biomolecular research facilities include:

Bioimaging Core Facility: incorporating a Becton Dickinson FACS Aria Fusion cell sorter located in a containment level 2 hood (£250k), providing the capability to sort, e.g., virus-infected cells. The latter combines with two existing confocal microscopes, including a NikonA1 for live cell analysis;

Genomics Facility: with Illumina MiniSeq next generation sequencing (NGS) system with multiple Nanopore units. NGS-associated equipment such as for library preparation is also in place (e.g., Dolomite Microencapsulator for single cell RNAseq experiments, PCR, BioAnalyzer, Covaris, PippinPrep);

Bioinformatics Facility: (headed by Coutos-Alves), consisting of a high-performance computing node, server and data storage is staffed by two research officers each with five years' post-doctoral training who provide consulting, training, and specialist analyses ranging from next-generation sequencing to metabolic flux control.

Stable Isotope Facility: includes four Gas Chromatographs, three being linked to Agilent Mass Spectrometers, and one linked to an Isotope Ratio Mass Spectrometer; funded in part by Fielding's mass spectrometry grant described above. Together, they provide capability to carry out metabolic flux measurements in humans, as well as in animal and *in vitro* models.

Biolog Facility: high throughput OmniLog Phenotypic Array System and data analysis software, for studying kinetics of respiration and metabolism of prokaryotic and eukaryotic cells.

These facilities contributed to the success of: Dunn-Walters' BBSRC Strategic LoLa grant described above (£1.15M, 2020-25); McFadden's BBSRC grant (£671k, 2014-2019) on identification of nitrogen source and metabolism of *Mycobacterium tuberculosis* during intracellular replication; Beste's BBSRC grant (£572k, 2020-2023) on the role of the anaplerotic node in redox homeostasis and pathogenesis of *Mycobacterium tuberculosis* and its exploitation as a therapeutic target.

Our School of Psychology facilities have benefitted from a £5M refurbishment and include:

> **Brain Activity Monitoring Facilities**: non-invasive brain stimulation techniques, such as transcranial electrical stimulation, including direct current and alternating current, Transcranial Magnetic Stimulation and high-density 128 channel EEG that can be used across the lifespan (babies to adults).
>
> **Mixed Reality Facilities**: our 'X-Reality' laboratories are equipped to create and deliver Virtual Reality, Mixed Reality and Augmented Reality environments to study mechanisms underpinning observational learning and reduction of fear and anxiety.

Examples of awards these facilities have underpinned include: an industrial partnership with FrieslandCampina Ingredients N.V. to investigate the influence of prebiotic intake on the microbiome gut-brain axis (PI: Cohen Kadosh £669k, 2020-2023); BBSRC funding to investigate dynamic modulation of brain states (PI: Violante; £470k, 2019-2022;); ESRC funding to investigate perceptual organisation (Silvanto; £166k, 2019-2022).

Facilities and Physical Infrastructure Contribution to Impact

Examples of our facilities that have contributed to impact include: the residential sleep laboratory facilities of our Clinical Research Building in which the research was undertaken leading to the Impact Case Study "HETLIOZ®: First FDA/EMA approved drug for sleep-wake disorders in the blind" (D. Skene, Lockley); our RCGP Research and Surveillance Centre, underpinned by University funding to the value of £0.5M per annum, enabled our Impact Case Study entitled "Improving patient care quality through data analytics of electronic medical records"; our Stable Isotope Facility contributed to identifying the liver-selectivity of the insulin analogue detemir that in turn led to our Impact Case Study "Improving diabetes patients' well-being with insulin analogues" (Russell-Jones).

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

The impact of our research is augmented by our inherent propensity to collaborate, which is driven by the recognition of the value of interdisciplinary working to deliver our 'One Health' vision. In the following pages we explain the extent of our collaborations, which in turn extol the opportunities to work across disciplines; generate impact to benefit society; engage with communities to maximise the extent of the reach of our research into society.

We have multiple strategic partners, many of which are reinforced by joint academic appointments with FHMS and indicated with the surname of that individual: APHA (Steinbach); Pirbright Institute (Behboudi); Department for Environment, Food and Rural Affairs (Defra); LGC (Huggett); NPL (Lemanska); Centre for Environment, Fisheries and Aquaculture (Cefas); Surrey and Borders Partnership NHS Foundation Trust; Royal Surrey NHS Foundation Trust (Creagh-Brown; Forni); Surrey and Sussex Healthcare NHS Trust (Heiss; Field); Frimley Health Foundation NHS Trust; Brigham and Women's Hospital, USA (Lockley); Quadram Institute (Pallen); Kent, Surrey and Sussex Academic Health Sciences Network; The Academy- Surrey Heartlands Health and Care Partnership.

Supporting Collaboration and Interdisciplinary Research

Our academic colleagues are supported in maximising the opportunities presented in collaborative working and in growing the strength and breadth of our collaborative networks by our FHMS-embedded Partnership team members:

(i) Aside from our Zoetis/Veterinary Health Innovation Engine (vHIVE) partnership described above, we have a multitude of projects with commercial partners. Examples include: a clinical trial for colon cancer of neoadjuvant nivolumab and ipilimumab with Bristol Myers Squibb (£863k, Michael); an avian pathogenic *Escherichia coli* (APEC) vaccine in field trials with Huvepharma (£856k, La Ragione); a rapid, highly sensitive and specific COVID-19 diagnostic test developed in partnership with Vidiia, Lancaster University and Brunel University (£152k, La Ragione); a pre-operation clinical wipe study with Gama Healthcare (£515k, Revell); development, provision and evaluation of patient surveillance data in partnership with GlaxoSmithKline (£927k; Lusignan). These projects are facilitated and managed by our FHMS-based Industry Partnerships Manager (Hargreaves).

A significant commercialisation opportunity from such partnerships has been the licencing by Pandha to Lionex for a monoclonal antibody to measure prostate cancer biomarker EN2, and expected to generate c€160k pa. Such licensing and spin-out opportunities are supported by our FHMS Technology Transfer Manager (French).

(ii) During this REF period we have received £6.64M in philanthropic research funding. Our Advancement Team helped facilitate these gifts including the £1M Longhurst Legacy to the School of Veterinary Medicine; the £500,000 Marcus Lee alumnus gift to establish a Chair in Vaccinology and £1.1M from the Prostate Project for prostate cancer research.

(iii) FHMS has fifty-seven formal international agreements with Universities and Higher Education Institutions overseas, overseen by our International Partnerships Officer (Lawton). E.g.- partnerships in twenty-two countries, such as the University of São Paulo (Brazil), Shanghai Jiao Tong University (China), and the University of Milan Bicocca (Italy). A formal structure of collaboration exists within our University Global Partnership Network (UGPN): a consortium of North Carolina State University (USA), the University of São Paulo and the University of Wollongong (Australia). UGPN provides starter funds catalysing research collaborations across the network and reports a 6:1 return on investment in leveraged funds.

These relationships extend the reach and impact of our research and benefit our students who frequently visit our partnering organisations. Thus, our PGR students have opportunity to engage with a wide range of international partners for placements and research visits. Recent exemplars are Harvard Medical School (USA), Karolinska Institute (Sweden) and University of Salzburg (Austria).

Examples of Collaborations and Interdisciplinary Working

Each of our Research Themes drives effective academic and research-user collaboration and interdisciplinary research to deliver synergy in our outcomes:

(i) Chronobiology and Sleep

Our expertise and chronobiology and sleep research facilities for both human (Clinical Research Building) and animal (Biomedical Research Facility) have enabled collaborations nationally and across the world in academia and industry. Moreover, chronobiology is linked to two companies, founded by our researchers, Stockgrand Ltd and SurreyAssays Ltd (Directors: Arendt, Skene, Middleton) providing melatonin assay reagents, and measurement of melatonin/metabolite respectively, for innumerable teams across the world.

D Skene has worked with colleagues in Brazil on various studies. For example: at the University of São Paulo with Moreno to understand work schedules, light exposure and their effects on sleep, biological rhythms and wellbeing of workers in an Amazon extractive reserve and at the Federal University of Paraná, with Lima and Louzada, together with Swann (Imperial College London) to investigate sleep deprivation in Parkinson's disease.

In sleep research, we have undertaken many pharmaceutical collaborations including: with Janssen in a first-in-human trial to investigate the effects of pharmaceutical intervention with the orexin system on sleep/wake physiology (Dijk); with Lilly to identify biomarkers of antidepressants (Winsky-Sommerer).

(ii) Infection and Immunity

Given the breadth of expertise in this Research Theme (Section 1), the extent of collaborations is equally considerable. We collaborate to understand immune system modulation by pathogens, the environment and as a consequence of ageing.

Blackbourn works with Mutocheluh (KNUST, Kumasi, Ghana) to understand how aflatoxins contaminating foods drive hepatocellular carcinoma by suppressing innate immunity.

Dunn-Walters works with Neil and Malim (KCL) to investigate the molecular basis for Ebola virus replication, pathogenesis and protection; Dunn-Walters also works with Coolen (KCL; Nijmegen, The Netherlands) and Fratelli (KCL) on systems approaches to understand B cell responses in ageing.

Our expertise in RNA biology generates international, interdisciplinary collaborations. Examples include Gerber's collaborations with Switzerland on post-transcriptional regulation of germ cell apoptosis in *C. elegans* with Allain, Hall and Hengartner (Zurich) and Zavolan (Basel). Gerber also works on RNA-binding proteins and cancer (with Miles, Ohio) and on glycolytic enzymes (with Heinisch, Osnabrueck).

Our infection vector work includes Chambers' studies of European badgers with Oxford (Pybus) and Ehlers (Berlin) to identify a new polyomavirus.

Horton, Prada and Del Rio Vilas work on infection vectors, modelling and managing rabies transmission with Robertson (Loughborough) and the US Centers for Disease Control (CDC). Emphasising the inter-disciplinarity of this work, Prada is an Engineer, working as a mathematical modeller in FHMS.

(iii) Nutrition and Food Security

Collaborations in this Theme include Grassby's joint research project on nut mastication and digestibility with the US Department of Agriculture (USDA; Baer), Quadram Institute (Grundy, Parker, Wilde) and University of Messina Italy (Bisignano, Mandalari, Raciti, Smeriglio and Trombetta). Lanham-New works with some of the largest food producing corporations worldwide on vitamin D fortification strategies, including Kellogg's, Warburtons, Marks and Spencer.

(iv) Healthy ageing and supporting long term conditions

Nalesso's work to understand molecular mechanisms (e.g., Wnt signalling) driving osteoarthritis and develop new pharmacological interventions to treat patients involves collaboration with McCormick (Queen Mary University, London), Gill (Royal Surrey County Hospital), Campanella (Royal Veterinary College) and within FHMS, makes use of our mass spectrometry facilities and expertise by collaborating with Fielding.

Rusbridge's work on Chiari malformation and syringomyelia (CMSM) epitomises our 'One Health' research agenda and multidisciplinary working. In collaboration with the Kibar (University of Montreal), Rusbridge is identifying genetic markers for canine CMSM to translate the findings into genomic studies on humans. Working with colleagues across the University (Cirovic and Wells, Medical Imaging Group), she is applying machine learning to develop a medical image analysis tool that can screen susceptible breeding dogs and be translated into human studies.

(v) Understanding Relationships with Social and Physical Environments

Our work into the ways people think, act and feel in response to their physical and social environments relies upon its international reach in order to have the breadth needed to understand our societal challenges. An exemplar is Fasoli's work on reclaiming of homophobic labels and sexual objectification in the era of social media in which he collaborates locally with Rusconi and internationally with Carnaghi (University of Trieste, Italy); Canale, Guizzo, Calcagni (University of Padova, Italy); Bianchi (Lusofona University, Portugal).

Barley's work in developing a training and evaluation programme around de- escalation techniques to manage violence and aggression in adult acute and forensic mental health wards is a UK-wide collaborate with University of Manchester (PI: Price), London South Bank University (Callaghan) and University of York (Gilbody). This work is taking place in two Trusts: South West Yorkshire Partnership NHS Foundation Trust (PI: Price) and West London NHS Trust (PI: Barley).

(vi) Digital Health and Data Science

Our Technology Integrated Health Management (TIHM) for Dementia project also partners with the Centre for Vision, Speech and Signal Processing; Surrey and Borders Partnership NHS Foundation Trust; smart monitoring provider, Howz. Capability in statistical multi-omics methodology and software development is one of our largest assets in this Theme, and hence an exemplar of collaboration: in academia, Prokopenko and Kaakinen work with Magi and Fischer (Estonian Genome Center, Estonia), Kutalik (University of Lausanne, Switzerland), and Morris (University of Manchester), while Uniqer Sarl (Lausanne, Switzerland) is our industrial partner.

Examples of Wider Contributions to the Economy and Society

Across our entire research portfolio, captured by our six Research Themes, we are driven to tackle societal challenges, far beyond our nine submitted Impact Cases. At least one further example is outlined per Research Theme to evidence our wider contributions:

(i) Chronobiology and Sleep

Sleep and chronobiology research have made many contributions to raising awareness of the importance of sleep and circadian rhythms for health and well-being across the adult lifespan. Dijk contributed to the report of the Parliament Office of Science and Technology reports on Sleep and Shiftwork and presented at the workshop "Shift work, Sleep and Health" at Westminster (2018).

D Skene's work on circadian rhythmicity has included the development of an intervention to shift to a more societal norm the sleep pattern of 'night owls': individuals whose internal body clock dictates later-than-usual sleep and wake times, for example an average bedtime of 2:30a.m. and wake-up time of 10:15a.m. Insufficient levels of sleep and circadian misalignment can disrupt many bodily processes, increasing the risks of developing cardiovascular disease, cancer and diabetes. This intervention can benefit niche settings, such as industry or sporting sectors, which have a key focus on developing strategies to maximise productivity and optimise performance at certain times and under different conditions.

(ii) Infection and Immunity

Chambers and La Ragione worked with the Glasgow School of Art (Alastair McDonald) on the AMRSim project to raise the awareness of how personal behaviours can impact infection control in a veterinary hospital, through the use of a visual tool to make the 'invisible visible' as part of a pedagogical interactive workshop. The study demonstrated the value of a novel educational methodology that could be transferable to other healthcare settings.

Asian Elephant conservation. Steinbach's research group is working collaboratively with the APHA and zoos in the UK and Europe to identify, characterise and combat one of the biggest threats to Asian Elephant conservation, the Elephantid betaherpesviruses (EEHV) that are causing a lethal, haemorrhagic disease affecting young elephants. They were the first to decode the complete sequence of EEHV-1 and started a research programme on treatment and prevention of the disease, results of which have been included into the prevention and treatment strategy of Chester Zoo.

(iii) Nutrition and Food Security

Avignone Rossa's work to sustain coffee production by treating environmentally damaging wastewater from coffee production and generating electricity was recognised by his award of the Newton Prize (2018).

Avignone Rossa developed a low-cost microbial fuel cell using bacteria to break down the organic contaminants in coffee wastewater as well as producing electricity. The research team have trialled the novel fuel cell in Colombian coffee farms in a six-month evaluation and a cooperative of Colombian coffee farmers has expressed their interest in installing these devices on their farms. SMEs, Fair Trade coffee producers (PACT coffee, Miko Coffee Ltd., Tchibo) and Agri-Tech East are all in discussion with Avignone Rossa to scale up the use and production of these microbial fuel cells.

(iv) Healthy ageing and supporting long term conditions

Pandha's work on antiangiogenic therapy for patients with metastatic renal cell carcinoma (RCC) in the adjuvant setting for patients at high risk of tumour recurrence after nephrectomy has led to sunitinib malate being identified as the first ever drug to show efficacy in RCC in the adjuvant setting.

(v) Understanding Relationships with Social and Physical Environments

Hegarty's work to enhance equality has contributed to basic science, clinical application, public understanding, and education and was recognised by his 2017 Award for Promoting Equality of Opportunity from the British Psychological Society. Hegarty's research on cisgenderist language in psychological research led to a reform of language practices in the World Professional Association of Transgender Health.

(vi) Digital Health and Data Science

Ream's work on TIHM for Dementia, funded through NHS England and NHS Improvement's NHS Innovation Test Bed Programme, has generated understanding of how combinations of networked digital technologies can lend support in managing dementia to patients and their carers in their homes. Awards for this innovation include: "Best Mental Health initiative" at the eHealth Insider (EHI) awards, 2017; "NHS Future" category in the NHS70 Parliamentary Awards for the South of England (2018); "Improving Care with Technology" in the Health Service Journal (HSJ) awards, 2018. TIHM is currently being rolled out in new populations and geographies including: older adults (Surrey and Borders NHS Partnership Foundation Trust);

people with learning disabilities (Surrey and Borders NHS Partnership Foundation Trust); Birmingham Community Health Services; GP surgeries in Hillingdon.

Engagement with diverse communities

We pride ourselves in our engagement with diverse communities through our outreach and public engagement activities. Colleagues are allocated time in their work plans to encourage such participation. There is an overall familiarity with and competence in engagement by FHMS colleagues due to the breadth of disciplines we embrace that absolutely depend upon face-to-face interaction with the general public: veterinary and human medicine, psychology. Furthermore, our FHMS Marketing Manager (Dimbylow) mediates engagement of our research colleagues with all media outlets, from our University independent topical news and views site, "The Conversation", to radio and TV.

We participate in University of Surrey Bright Club and Pint of Science outreach events held locally to engage the community. Our Pint of Science festival runs annually over three nights in May in three Guildford Pubs and has reached over 1,700 people while Bright Club occurs three times a year to sold-out audiences at various Guildford venues reaching an audience of over 1,000. Our presenters in 2018 and 2019 included Chris Jones and Dunn-Walters.

Our 'Surrey Healthy Ageing Research Partnership' (SHARP), run by Riddell was established in 2017 to engage older local members of the public with interest in our research. We have c150 people on our mailing list and c50 attend each workshop. Some of these people also contribute to either the design of research projects or participate in studies.

The Innovate Guildford free Science and Arts Festival is run annually by Guildford Borough Council giving more than 5,000 local residents a chance to explore science, technology and the arts through interactive displays, exhibits, entertainment and workshops. Our colleagues participating include Ogden on "Mindless Eating"; Dijk on "Sleep"; Lanham-New on "Healthy Nutrition". Ogden has also presented on "Mindless Eating" at the Surrey County Show, the biggest one-day agricultural fair in the UK, welcoming c40,000 visitors each year and has published two books on a similar theme for public audiences: "The Psychology of Health and Illness" Open Access book for University of the People (2017) and "The Psychology of Dieting" Routledge: London (2018).

Proudman engages extensively with the UK Thoroughbred industry, chairing the industry-wide Thoroughbred Research Consultation Group, which advises the Horseracing Betting Levy Board on racehorse health and welfare priorities for research funding. Proudman also provides expert consultancy to the equine feed supplement company, Tharos and to Aintree Racecourse.

Given the societal impact of AMR, we have a moral responsibility to explain it through outreach and public engagement events. Hingley-Wilson is our vanguard for this work, which has involved at least five events reaching from infant age (Bright Horizons nursery, 2018) to adults, including our AMR stall at the Science Museum Superbugs exhibit (>2,000 visitors; 2018). The stall featured AMR questions on a 'spin-the-wheel quiz', guess the amount of antibiotics required by a drug-resistant Tuberculosis patient and one of our own single-cell antibiotic resistant bacteria videos.

Sustaining the discipline

We are proud of our heritage of collegiality, which is founded on the premise of synergy: that we can achieve more and to a higher standard by working together. Evidence in support of our contributions during the REF assessment period to our research communities include:

Eighteen colleagues **contribute to the peer review process** by their membership of funding agencies: *MRC Infection and Immunity Panel* and *MRC COVID-19 Agile Response Panel* - G. Elliott; *Dunhill Medical Trust Chair of Grants Committee, UKRI Future Leaders Fellowship Panel MRC Eminent Independent Scientific Review Board, BBSRC Grants Committee D, Fondation*

Cariplo (Italy) Research Grants Panel, Co-Chair BBSRC COVID-19 Research Assessment Panel, UKRI-BBSRC COVID-19 Expert Working Group - Dunn-Walters; *BBSRC Committee A* Johnston; *BBSRC Committees B and C* Locker; *ESRC Peer Review College and Science and Research Advisory Committee Down Syndrome Education International* - Farran; *ESRC Peer Review College and Chair, NIHR South East Coast Regional Advisory Committee, RfPB* - Fife-Schaw; *NIHR South East Coast Regional Advisory Committee, RfPB* - C Jones; *NIHR Health Services and Delivery Research Programme Board* - Maben; *Horserace Betting Levy Board Veterinary Advisory Committee* – Proudman and Steinbach; *Humanimal Trust, Animal and Plant Health Agency, Food Standards Agency, NHS AMR diagnostics, Royal College of Pathologists* - La Ragione; *Tignum Executive Performance Scientific Committee (USA) and Steering Group, the Forces in Mind Trust Mental Health Research Programme, London* – Cropley; *Research Committee Autism Spectrum Database UK, Executive Committee Society for the Study of Behavioural Phenotypes, Co-Chair Scientific and Clinical Advisory Team of Cornelia de Lange Syndrome Foundation (UK and Ireland) and Secretary to this Foundation* - Moss; *Trustee, Sir Jules Thorn Trust - Russell-Jones; Coeliac UK Research Assessment Panel* - Grassby; *BBSRC/NERC-CONICET Joint Awards for AMR in the Environment (UK/Argentina) and 3R Panel Swedish Research Council* – Chambers; *Tenovus Care Psychosocial Advisory Committee and Population Research Committee Cancer Research UK* – Whitaker; *Pet Plan Charitable Trust Scientific Committee* – Rusbridge.

Thirteen colleagues have won **fellowships and awards**: Our team led by Lanham-New won the Queen's Anniversary Prize for teaching and research in food and nutrition (2017). Lanham-New won the British Nutrition Foundation Prize (2018). Gibson is a Fellow of the American Academy of Nursing and the recipient of a Lifetime Achievement Award from the International Society for Paediatric Oncology; Ogden is a Fellow of the Academy of Social Sciences; Wolfensohn and Rusbridge are Fellows of the Royal College of Veterinary Surgeons (RCVS); La Ragione was awarded Honorary Associate of RCVS. Three of our colleagues have held Wolfson Merit Awards: Dijk, Gerber and D Skene. D Skene was Elected President of the European Biological Rhythms Society. Gallagher and Maben are Fellows of the Faculty of Nursing and Midwifery of the Royal College of Surgeons in Ireland (RCSI). Whitaker won the International Psycho-Oncology Society (IPOS) Hiroomi Kawano New Investigator Award (2015) and was elected Fellow of the British Psychological Society (BPS; 2017). S Archer was the recipient of the Veterinary Record Impact Award (2016).

Editorships: During the REF period, we have served on numerous editorial boards. Examples include: Beste; Gerber; Griffin (2); Hart; Horton; Cohen Kadosh; Locker; Maluquer de Motes; Proudman; Farran; Silvanto; Askew; D Skene. Furthermore, we have contributed senior editorial and co-editorial expertise to at least 18 journals: *PLoS ONE* - Gerber, who has also been Guest Editor for *PLoS Biology, PLoS Genetics, Biomolecules, FEBS Letters; Frontiers in Immunology* - Dunn-Walters; *FEMS Microbiology Reviews* - Blackbourn; *FEMS Microbe and Frontiers in Microbiology* - Maluquer de Motes; *European Journal of Nutrition* - Griffin; *Nutrition Society Textbook Series (Blackwell)* - Lanham-New; *Brain and Cognition* - Patton; *Journal of Behavioural Sciences* - Fife-Schaw; *Veterinary Microbiology and Journal of Medical Microbiology* - La Ragione; *Social and Personality Psychology Compass and Oxford Online Encyclopaedia of the History of Psychology* – Hegarty; *Nursing Ethics* - Gallagher.

In summary, during the REF period we have forged our research environment around delivering a 'One Health' vision and have grown our capacity and capability to realise our agenda that addresses a core societal challenge: that of improving the quality of life of the ageing population. By focussing on our excellence and talent in our six Research Themes and collaborating proactively without either geographic or discipline boundaries locally, nationally and internationally, our research is improving the health of people, the environment and animals.