Institution: University of Reading

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

1. Unit context and structure, research and impact strategy

Over this REF period, we have refocussed our Unit's research strategy to enable **translation of our fundamental research into therapies and treatments**. Building on our strengths in Pharmacy, Biomedical Sciences and Biomedical Engineering, we have harnessed synergies to further our research and applications in areas ranging from understanding disease pathophysiology though to medicine usage and optimisation, augmented with technological interventions to support healthcare. We have established a **strategic venture** with NHS partners whilst growing and deepening **industry collaborations**. Our work is underpinned by a **transformation** of our internal structures, together with significant investment in **facilities and infrastructure**.

1.1 Context and structure

As set out in the Institutional Environment Statement (IES), during this period the University changed the way in which it organises, manages and leads its research. Research is now coordinated around four Research Themes, each comprising Research Divisions which broadly map to academic units. Each Theme is led by a Research Dean, who provides leadership in the broad remit of the Theme, facilitates internal interactions and interdisciplinary collaborations across divisions and Themes, and provides support and mentoring for other research leaders in the Theme. Research Divisions have a Research Division Leader (RDL) and an Impact Lead (IL) who provide leadership and management of research and impact for the division. RDLs meet regularly with the Research Dean to discuss future plans, needs and opportunities for cross-Theme and cross-University opportunities.

Our UoA3 submission returns staff from two Research Divisions, **Biomedical Sciences and Biomedical Engineering (BSBE**), part of the School of Biological Sciences (SBS), and **Pharmacy**, part of the School of Chemistry, Food and Pharmacy (SCFP), together with one staff member from the School of Psychology and Clinical Language Sciences. We are organised into six, multidisciplinary research clusters corresponding to our priority areas for research.

Our research is inherently multi- and interdisciplinary, and it is strengthened by interactions and collaborations with our Interdisciplinary Research Centres:

- **Institute for Cardiovascular & Metabolic Research (ICMR),** bringing together scientists from a wide range of research fields to work to understand the development of cardiovascular diseases, and associated obesity-related metabolic diseases.
- **Centre for Integrative Neuroscience (CINN**), which focuses on the physiological and psychological mechanisms that underpin complex behaviour, targeting typical and atypical development across the life span, including obesity, ageing and cognitive decline.
- **Institute for Food, Nutrition and Health (IFNH),** bringing together the University of Reading's world-leading expertise in agriculture, food, nutrition, health and the environment to understand how improvements in food production, processing and nutrition can help deliver better diets and health.

Figure 1 below provides a summary of our research environment.

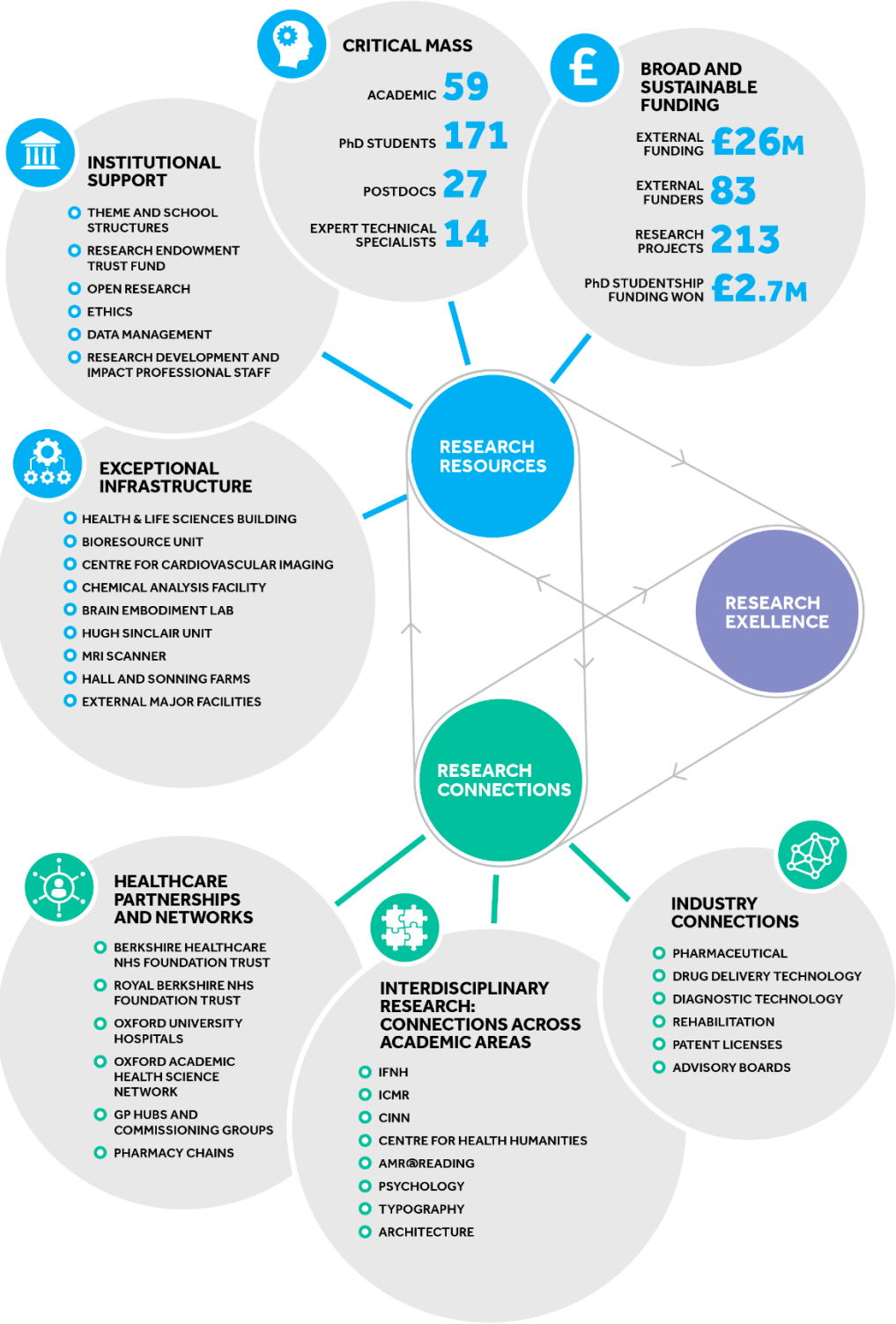


Figure 1. A summary of the research environment within our Unit

1.2 Research & Impact Strategy

In REF 2014, we returned our Pharmacy research to UoA 3 (Allied Health Professions, Dentistry, Nursing and Pharmacy), all our research in SBS (Biomedical Sciences and Ecology and Evolutionary Biology) to UoA 5 and our Biomedical Engineering research to UoA 13 (Electrical and Electronic Engineering). In 2015, building from areas of strength in our previous submission and in line with wider University ambitions, we took the strategic decision to refocus our activities towards clinical research and its translation into practice.

In this context, the stated aim for this UoA is to drive synergy between our pharmacy, biomedical, computational and engineering sciences, reinforcing collaborations to enhance our capacity to address health and clinical challenges both nationally and internationally in critical human diseases and allied-health profession fields. To achieve this aim, we set ourselves the following strategic objectives:

- To develop long term partnerships with the NHS to deliver clinical and pre-clinical research,
- To achieve and sustain critical mass in identified key areas of research and impact,
- To upgrade our research infrastructure to match our ambitions in clinical research and its translation,
- To increase the impact of our research through strengthened engagement with non-academic partners, end users and policy makers.

The sections below demonstrate how we have achieved these objectives.

1.2.1 To develop long term partnerships with the NHS to deliver clinical and pre-clinical research.
We have transformed our collaborations with our local community and mental health Berkshire Healthcare NHS Foundation Trust (BHFT) and the acute Royal Berkshire NHS Foundation Trust (RBFT). In 2014, the University of Reading (UoR) and these two trusts jointly established the Thames Valley Clinical Trials Unit (TVCTU) to support trial design and management, QA and data analysis. Building on this venture, a Joint Academic Board (JAB) between UoR and RBFT was established, to specifically drive joint research, education and commercialisation opportunities. Funded by both the RBFT and UoR (**£1.15M over 3 years**), this scheme has provided £292K to pump prime 12 collaborative projects in our Unit (20 academics and 19 clinicians). Additional new clinical links have been established through the introduction of our Physician Associate programmes and the launch of a UoR accreditation scheme for RBFT specialisms as 'University Departments' (e.g. Cardiology, Emergency Medicine and Radiology), recognising research and teaching collaborations alongside clinical excellence. Building on this and our strengthened links with RBFT, TVCTU expertise will be reorganised into a Joint Research Office to expand translation of our collaborative research.

1.2.2 To achieve and sustain critical mass in key areas of research and impact.
We achieved this objective through two key mechanisms. Firstly, we successfully established six research clusters mapping to our areas of strength and with potential to grow. These clusters act as a focal point for interactions and collaborations between researchers working under each area and provide a nurturing environment for Early Career Researchers (ECR), post-doctoral research assistants (PDRAs) and doctoral students to thrive. Reflecting our interdisciplinarity, researchers often work across several clusters.

Secondly, we increased capacity and expertise in our research clusters through recruitment of 20 new staff at different career stages, with a significant proportion being ECR at the time of appointment. Over the period, they have established and developed their independent research groups, and many have already secured significant funding (see Section 2). New expertise introduced through these appointments includes animal models (Zebra fish and *C. elegans*) of neurological and cardiovascular disorders; neurophysiology of dementia; neuroendocrinology; epigenetics of obesity; longevity and stress control; pain mechanisms; inflammatory signalling pathways; alcohol addiction; macromolecular drug delivery; and enhanced capability in molecular modelling of biological and pharmaceutical materials. Establishing Biomedical Engineering within our unit introduced new capacity to develop technologies for early diagnosis, to restore neurological functions and improve quality of life for patients including older adults, and expertise in 3D neural cell culture technology.

Our research clusters, their composition and key achievements are:

Neurological disorders research cluster
[*Bithell, Cottrell, Dallas, Delivopoulos, Horwood, Harwin, Hayashi, Maiaru, McCrindle, McNeish, Nasuto, Sherratt, Stephens, Tamagnini, Vasudevan, Widera, Zheng, Lewis (to Dec/2019*)]

Research spans fundamental, interdisciplinary research through to therapeutic interventions and is underpinned by **>£5.2M** funding over the REF2021 period. Key areas of focus include development of cannabis-derived compounds to treat epilepsy, research in Parkinson's disease (PD) and Alzheimer's disease (AD), motor neurone disease and issues related to child eye focusing problems, through to developing technologies to improve outcomes for patients with neurological disorders.

Examples of our success in these areas include our award-winning (Sir James Black award for Contributions to Drug Discovery 2019) pre-clinical development of the cannabis-derived compound, cannabidiol (CBD) for epilepsy. Our work led to clinical trials, approval and launch of CBD as the medicine Epidiolex/Epidyolex by GW Pharmaceuticals in the US and EU, for combating difficult-to-treat childhood epilepsies (an Impact Case). Our research also provided understanding of neurovascular coupling in the epileptogenic cortices of rats with chronic focal epilepsy, suggesting a new approach to improve the localisation accuracy of irritative zones and seizure-onset zones (BBSRC, £411K).

Important contributions within PD include characterisation of a key therapeutic target - synuclein-mediated modification of ion channel function (£328K, MRC). For AD, we revealed the need for treatments that address the loss and instability of synapses (Alzheimer's Research and Alzheimer's Society; ~£400K). Our research also contributed high impact publications on neurogenesis and motor neurone disease through epigenetic regulation effects. Our 3D culturing of neural progenitor cells and astrocytes differentiation methodology has established *in vitro* neural networks for evaluating stroke and neuroinflammation treatments.

Our Rosetree Trust and MRC funded (together ~£640K) Pain Mechanisms research has enhanced understanding of synthetic botulinum derivatives as alternatives to addictive opioids for chronic pain relief. Our research into child eye focusing problems (Vision Lab) has led to new understanding impacting clinical practice in paediatric ophthalmology, orthoptics and optometry (an Impact Case).

Our collaborative EPSRC-funded (£509K) Brain Computer Interface research identifies therapies for depression. In partnership with Evolv, we developed technologies for rehabilitation of stroke and dementia patients (NIHR funded), which are included in Evolv's next commercial release of VirtualRehab into hospitals and for home-based rehabilitation (Impact Case). We support stroke and dementia patients through our Innovate UK funded development of driver devices (£190K) and 'smart' garments (£225K), and through our Leverhulme Trust funded (£253K) development of 3D learning in a haptic environment. Our research on wearable technologies to assist patients with neurodegenerative disorders has been supported through a large Interdisciplinary Research Centre EPSRC grant (SPHERE, 2013-2019, £11.5M; £1M for UoR).

Cardiovascular and metabolic disease research cluster
[Boateng, Clerk, Gibbins, Hughes, Hwang, Jones-C, Kevei, Leake, McGuffin, McNeish, Pollitt, Sellayah, Vaiyapuri, Li (to 2020)]

With **£9.9M** awarded since 2014, this cluster focusses on multi-disciplinary approaches to improve understanding of cardiovascular and metabolic disease development, prevention and treatment. The work of this group is further enhanced by the close collaboration with the ICMR and enabled by the cutting edge Centre for Cardiovascular Imaging (Section 3)

Major progress includes our discovery of new mechanisms of regulation of platelet function leading to a new drug-discovery programme for novel anti-thrombosis treatments, protected in a patent which has been licensed to Quercis Pharma AG (Switzerland). We have driven advances in template-based protein modelling (BBSRC, £732K) including successes in the global Critical

Assessment of Structure Prediction competition and the Continuous Automated Model Evaluation project. This expertise has enabled design of new anti-thrombotic peptides targeting novel gap junctions on platelets. Research of this group also illustrated how low-density lipoprotein is oxidised in lysosomes resulting in atherosclerotic plaque formation. Subsequent BHF-funded research (£183K) developed a new therapeutic approach that substantially reduced atherosclerotic plaque burden in mice. We also discovered how endogenous anti-microbial peptides cause thrombosis, thrombocytopenia and haemorrhage during infection and inflammation.

Translational studies to explore intergenerational effects of maternal obesity using rodent models (MRC, £417K) revealed new epigenetic effects associated with long-term consequences for cardiovascular and metabolic disease risk in offspring. Our research provided insight on how dietary components influence disease development and on responses to drugs used to prevent cardiovascular disease. Using knowledge of the impact of diet on cardiovascular and metabolic health, we developed a new app-based platform for personalised nutrition. This was showcased in the University's 2019 Fairbrother Lecture.

Important progress has been made using machine learning and mathematical modelling to understand the relationship between platelet function and regulation, supported by a BHF Programme Grant (£1.4M, renewed in 2020 with a further £1.4M). These population and clinical studies led to new technologies that allow precision medicine approaches for more effective treatment or prevention of cardiovascular disease. Multidisciplinary approaches are also central to the European Joint Doctorate Programme (£738K; TAPAS) that we devised to establish and integrate a range of systems-biology approaches to target receptor function to prevent thrombotic disease.

Our research has clarified how drugs such as ibrutinib (used in non-Hodgkin lymphoma) cause severe bleeding side effects, and how this may be alleviated, and that PIM kinase inhibitors modulate thromboxane receptor trafficking, providing the anti-thrombotic benefits of aspirin but without increased bleeding.

Molecules and Tools for Health research cluster
[Allman, Al-Obaidi, Bowen, Brazier, Edwards, Greco, Green, Hall, Hart, Kabova, Khutoryanskiy, Osborn, Shankland, Williams]

Our research ranges from fundamental science that underpins our understanding of biological targets, design of translational tools and analytical technology for diagnostics, to drug design, novel delivery systems and treatments. Grant income of **£2.8M** from diverse sources supports the work of this group, which has also secured over **£1.7M** of UK and International major facilities time.

Clinical translation of diagnostics has progressed through developments in microcapillary technology, leading to commercial clinical infection diagnostic products (e.g., for dengue fever) supported by industrial and innovation funding of >£2M to the spinout Capillary Film Technology Ltd. We enhanced the capabilities of terahertz spectroscopy for new applications in imaging and detection, both within the medical field and more widely. Our nucleic acid structural studies have led to significant success in binding of ruthenium complexes to DNA and probing the biological role of unusual DNA structures. This was facilitated by BBSRC funding (£580K) and strategic investments in a new X-ray diffractometer (£440K, UoR) and crystallisation robot (£50K, EPSRC).

Our novel research for **drug delivery** to the eye, lungs and to/through the skin is a major strength. Our delivery technologies for both small and macromolecule drugs use physical (e.g., microneedles and nanoparticulates), thermodynamic (e.g., supersaturation and salt selection) and polymeric (e.g., co-polymers, polymer-drug conjugates) approaches in work funded by the BBSRC, EPSRC, Royal Academy of Engineering, British Council, industry, EU and overseas governments (£850K). We work closely with the ISIS Neutron and Muon Source to develop

biological lipid-membrane models to investigate molecular interactions with membranes to understand antimicrobial peptide action.

We strategically recruited to strengthen our carbohydrate chemistry and glycobiology expertise, complementing our multi-disciplinary programmes funded by UKRI and industry that are developing more rapid methods for detecting clinically important bacteria. We invested in research on crystal structure determination from powders, with a new academic appointment and, supported by C4X Discovery Ltd (£250K), further developed powder diffraction software, *DASH*, leading to significant impact in the pharmaceutical industry (Impact Case).

Medicine usage and prescribing behaviours research cluster
[Dhital, Donyai, Hollywood, Lim, Patel-N, Vaiyapuri]

This group's research responds to the government's plans for tackling the rising cost of medicines, estimated at £19.9bn in 2018/19 in England alone, and for preventing antimicrobial resistance (AMR). Our research has delineated the contribution of pharmacists to the General Practice sector, by creating key performance indicators and measuring stakeholder feedback, working with Clinical Commissioning Groups and stakeholders nationwide. In 2017 this work was showcased at the Centre for Pharmacy Postgraduate Education as well as the Houses of Parliament. Our research informed the revalidation of the ~80,000 pharmacy professionals in Great Britain (from 2018) by the General Pharmaceutical Council through use of continuing professional development.

Our definitions of health professional competences to prevent AMR, have been acknowledged in government policy as evidenced in the 'Tackling antimicrobial resistance' government's five-year plan 2019-2024, and have been adopted for health professional training. Our links with BHFT (including joint-appointment teacher practitioners in pharmacy) and nationally, have led us to explore medication usage in dementia and psychosis, winning funding from the Wellcome Trust, Alzheimer's Society and Janssen Cilag Ltd, and recognition from the College of Mental Health Pharmacy, thus contributing to patient safety.

Our research on reducing medicines wastage has created in-depth understanding of the psychology of drug holidays and medication re-use, the latter facilitating interdisciplinary collaboration with our Biomedical Engineering colleagues. Our quality improvement research (funded by the British Society of Interventional Radiology) explored quality of life in interventional radiology. Other health service projects examined misuse of substances within the community settings (NIHR £2.1M, 5 years), insulin services within the hospital settings, and medication reviews (Pharmacy Research UK, Leverhulme Fellowship).

Our research in rural India revealed that snakebite incidence is >10 times higher than reported, and that lack of public awareness is the key factor driving snakebite-induced deaths and disabilities. Our resulting snakebite public awareness campaign was highly successful in reducing snakebite-induced deaths and disability (an Impact Case). Communication design was also central in a collaboration with our Typography department, School of Architecture and the Day Lewis Pharmacy chain which attracted funding from the AHRC (~£200K) to develop persuasive spaces to reduce AMR, and a resulting international collaboration creating impact in Rwanda (GCRF funded).

Ageing and Associated Degenerative Disease research cluster.
[Dash, Foster, Hadijloucas, Holderbaum, Kevei, Knight, Patel-K, Darbre (to 2017)]

Our collaborative research seeks to further understand the cell-signalling mechanisms governing physiological process of important degenerative pathological conditions (ageing, cancer, infertility, muscular decline). Over the REF period, we have received **£3.5M** in external funding to support the research of this group.

Our research capacity has been enhanced by new capability in *C. elegans* as an experimental model through recruitment of a colleague with expertise in ubiquitylation-dependent signalling pathways of ageing. A second ex-vivo model (the bovine ovary) has driven understanding of the causes of infertility by excess androgen production, funded by BBSRC (£371K). This resulted in the discovery that the molecule inhibin alpha increases androgen production, relevant to patients with polycystic ovary syndrome, one of the leading causes of infertility. We established new industry partnerships that increased delivery of therapeutic antisense oligomers to muscle, brain and heart for various genetic diseases, in particular for Duchenne muscular dystrophy, attracting significant funding (Harrisons Fund; £544K; GW Pharma £357K; Duchenne UK £243K; Sutura Therapeutics £168K). Our Sutura Therapeutics funded research resulted in a patent for stitched peptides for increased drug delivery efficiency and our GW Pharma funded research resulted in a patent for the use of cannabinoids to treat Duchenne muscular dystrophy. A collaboration between our tissue engineers and developmental biologists demonstrated that myogenesis using acellular matrices is an effective therapeutic approach for muscle injury. Regeneration research enabled characterisation of ovine neural crest derived stem cells as progenitors for osteogenic and adipogenic cells, suggesting that these can be used as models to assess efficacy of transplantation.

Our research into the evolution of cancer cells using mathematical modelling and imaging (£291K) showed that resource competition promotes expansion. Our Breast Cancer UK funded research also revealed that parabens and bisphenols in health care products increase breast cancer proliferation by upregulating the enzyme aromatase.

Infectious Disease and Health research cluster
[Andrews, Clarke, Cottrell, Edwards, Jones-I, MacIntyre, Osborn, Watson, Widera]

Our well-funded (**£4.3M**) research focuses on bacterial and viral mediators of disease with the goal of furthering understanding, treatment and control of ill health arising from infectious agents. We have progressed towards commercialisation of novel vaccines by developing an improved synthetic vaccine against several serotypes of the Foot & Mouth Disease virus (vaccine licenced to MSD Animal Health). This Wellcome-funded interdisciplinary research exploits our expertise in insect cell expression technology, is collaborative with the Pirbright Institute and Oxford University, and aims to develop vaccines for low-and-middle-income countries. Progress has also been made towards developing an effective bovine TB vaccine with direct implications for the WHO's End TB Strategy. Our BBSRC/Clasado-funded interdisciplinary work with Food & Nutritional Sciences on protein engineering of industrial enzymes is improving the biotechnological production of prebiotics to support gut health. We are driving BBSRC-funded interdisciplinary research on the impact of dietary iron on the gut microbiota and health and have advanced understanding how *Staphylococcus aureus* and *Campylobacter jejuni* colonise the gut. We developed a low-cost, miniaturized antibiotic resistance testing device using fluoropolymer microcapillary film and used gut models to rationally design live bacterial vaccine formulations. In addition, we have synthesised a set of novel α- and β-linked triclosan glycosides that display enhanced antibacterial properties compared with triclosan. Our research also revealed how lipopolysaccharides from different bacterial species elicit reciprocal inflammatory cell-signalling responses.

1.2.3 To upgrade our research infrastructure to match our ambitions in clinical research and its translation.
We have received major investment to expand and upgrade research facilities to enable increased volume and quality of our clinical and translation research. A full account of our investments is in Section 3, but key developments include:

- A new £55M state-of-the-art Health & Life Sciences Building with extensive new laboratories and research space.
- Relocation of the cutting-edge Centre for Cardiovascular Imaging to purpose-built laboratories within the new Health & Life Sciences building.
- A new BioResource Unit providing animal experimental facilities.

- Upgrade and enhancement of the Chemical Analysis Facility instruments, including new electron and atomic force microscopy, NMR and mass spectrometry equipment.
- Investment of over £2.5M in new equipment across different laboratories.
- Upgrades to our clinical research and teaching facilities including simulation equipment.

1.2.4 To increase the impact of our research through strengthened engagement with non-academic partners, end users and policy makers.
Most of our research develops health-related impacts by identifying new disease targets, drug treatments and rehabilitation therapies, and by engaging end users from patients to clinicians, and influencing policy makers in the UK and overseas. Impact Leads work with a dedicated impact team to support staff to identify and develop impact from inception of their projects, including support to:

- Grow and deepen interactions with non-academic partnerships, for example, our interactions with national and international pharmaceutical companies, as well as our work with NHS Trusts.
- Identify opportunities for co-design and co-creation of research with end users (industry, clinicians and/or patients).
- Increase engagement with national and international policy makers.
- Grow capacity through workshops and tailored training.

Enhanced support is provided by a 5-member dedicated central Impact Team with designated managers aligned to each Theme/and Research Division, and support of the University's Knowledge Transfer Centre co-located in our Unit, providing an avenue for external business collaborations. The University's Building Outstanding Impact Support Programme (BOISP) provided funding of over £100K to underpin the development of 18 impact projects at all stages, of which five are included in this submission. The University recently welcomed Bill Kilgallon as a Royal Society Entrepreneur in Residence who is working with multiple Unit staff to assist with commercialisation of research.

1.3 Open Research and Research Integrity
We proactively implement the University's **Open Research** strategy (see IES) which nourishes the culture and practice of transparency and reproducibility. Our research data is openly hosted, for example in the Protein Data Bank and GeneBank, and in preprint servers. Staff are encouraged to use preprint servers (e.g., bioRxiv), open journal submission systems and open peer review, and we generate open software for bioinformatics (e.g., in Structure Prediction). As University exemplars, our researchers were members of an internal judging panel for the University Open Research Awards competition, where two projects from the Unit were submitted ("Maximising the utility of existing protein-protein interaction data" and "Protein structure and function prediction servers at the University of Reading"). Using Open-Source hardware and software, we are building low cost-solutions for healthcare through our Biomedical Technology Lab. This work is featured as one of the University's Open Research Case studies. We are currently appointing Open Research Champions across all our Research Divisions to further embed and deliver the objectives outlined in our institutional Open Research Action Plan.

We have high levels of Open Access publications throughout this REF cycle, with Gold Open Access encouraged and funded (40% of all outputs Gold Open Access). Robust data management polices (planning, managing and sharing) are integral to our research practices which include use of REDCap (Research Electronic Data Capture) for secure and GDPR compliant management of participant data.

We are committed to undertaking our research ethically and with the highest standards of integrity, ensuring that the University's Code of Good Practice in Research is followed by all. The School-level Ethics Committee, chaired by the Head of School, reviews all relevant research projects. The Head of School is responsible for identifying projects using human subjects, human samples (however obtained) or human personal data and ensuring they are assessed by the University's Ethics Committee and NHS Ethics Committees as appropriate. Investigators and

staff undertake their research under the provisions of the Human Tissue Act 2004 and the Mental Capacity Act 2005. We apply the University's Animal Research Policy, and have been exemplary in openness regarding our animal work; as signatories to the Concordat on Openness on Animal Research in the UK and we were recognised by Understanding Animal Research, which shortlisted our pages in the category 'Website or Use of New Media Award'.

1.4 Future strategic aims and goals for research and impact

Our **overarching future aim** is to further **enhance our clinical links** to expand advances in patient care; increase translation of our research into clinical practice; and improve our access to medical facilities and expertise to strengthen our research/impact capacity. We retain the ambition to establish a **Medical School at Reading** and have a Medical School Development Board in partnership with the Royal Berkshire NHS Foundation Trust, the Berkshire Healthcare NHS Foundation Trust, Frimley NHS Foundation Trust and local GP hubs and networks.

Exploiting synergies in the University, and those with academic and non-academic partners, we will:

- continue to increase the interdisciplinarity of our research by expanding collaborations and partnerships within and beyond our Unit to bring our research from bench to patient,
- exploit biological targets identified through our fundamental pathophysiology research to design, test and introduce novel therapeutic strategies. This will be supported by our continued engagement with external commercial partners, and growing partnership with local NHS Trusts, and includes testing and refinement of our proof-of-concept discoveries in diagnostics and drug delivery systems,
- extend our neurological disorders research on haptic and robotic teleoperation technologies to support patients, and on newly emerging approaches e.g., novel autoantibodies,
- develop behavioural as well as technological interventions to reduce drug wastage, optimise prescribing and mitigate AMR,
- continue progress towards vaccine commercialisation, microbial diagnosis and translation of our novel antibacterial approaches.

2. People

Our research staff and students are at the heart of our thriving research community. Our diverse and inclusive environment attracts, supports, develops and rewards excellent researchers in their careers and in progressing our research goals, with equality and diversity at the forefront. We have built a strong, diverse team of research staff across our strategic priorities, developed existing staff towards senior positions, and expanded our research capacity, including through recruitment of dedicated teaching staff. As such, we have firm and sustainable foundations to realise our research aims.

2.1 Staffing Strategy

Our staffing strategy has two complementary aims: to build on our existing strengths and national and international priority areas (including neurological disorders, ageing, cardiovascular disease and clinical translation research); and to further build, develop and exploit critical mass in biomedical engineering.

Since REF 2014 we have made 20 academic Teaching & Research and Research Intensive appointments including new lecturers and Research Fellows (including two Marie Curie Research Fellows) across Pharmacy and BSBE. Thirteen Category A staff included in this submission have been appointed as part of this drive, with 2 FTE appointed to each of the Infectious Disease and Ageing and Associated Degenerative Disease research clusters, and 3 FTE appointed to each of the remaining four research clusters. These appointments have added expertise and new capabilities as described in section 1. We have additionally recruited a net total of two permanent Teaching Fellows, four Graduate Teaching Assistants and one Teaching-focussed lecturer, who have supported an increase in our research capacity.

2.2 Staff support & development

We are committed to develop all members of our research community, from PhD students to professors, and fully recognise the importance of a nurturing research environment in achieving our research and impact goals. Our approach is strongly guided by values from the **Technician Commitment** through to the **Researcher Development Concordat** and from Institutional and managerial levels to each individual. This approach has contributed to increased research income and doctoral awards/FTE in the assessment period.

Development and retention of staff employed within the Unit is a priority, with a focus on developing research leadership. Staff are provided with a range of support and development opportunities, available through a central UoRLearn platform that enables them to record their Continuous Professional Development (CPD). Undertaking CPD is required within our Personal Titles promotions process.

New academic appointees are assigned a mentor to provide individual support separate to their line manager. Appropriate mentoring guidance documents and training are provided, with specific and enhanced Department and School processes developed by us in this assessment period. ECRs have a 3-year probation period and, through discussion with line managers, are provided with clear expectations and agree probation targets aligned with our promotion criteria. ECRs are afforded a reduced teaching and administrative load during probation to help build research momentum, and start-up funds and/or a fully funded PhD student are provided to help establish their research independence. ECRs are supported through specific internal funding opportunities and given academic and research professional support for external ECR-specific funding schemes, for example the mentoring provided to **Pollitt** in winning an AMS Springboard grant (£99K). All our ECRs successfully passed probation within 3 years, and several have subsequently also been promoted to Associate Professor, evidencing effective and continued support, and successful career development.

University funding supports the development of ECRs and PDRAs. Cases can be made through the Research Dean for pump priming funds, whilst equipment is funded through the Research Endowment Trust Fund (RETF) and via the University Research Infrastructure Fund through open competitions. Internal awards of >£1.2M have been made to our ECRs and PDRAs since 2014, for example funds for a virtual reality system to enable parallel rodent behavioural and brain activity assessment (~£50K), new imaging capability (~£250K), a crystallisation robot (£50K) and several pilot projects to build local clinical research links. The positive impact of this supportive environment is reflected by external research funding successes for our 17 ECR new arrivals in the REF period, with **£2.85M** awarded in total as PI. ECRs and PDRAs can also apply for funding to cover travel to conferences via the University Travel Fund.

Our ECR and PDRA community is a vibrant one. Colleagues in Pharmacy have established an Early Career Forum – as part of the wider school (SCFP). This is largely run by PGRs/PDRAs who organise regular events and meetings.

All academic staff produce annual Personal Research Plans (PRP) which are discussed with their RDL and are focused on staff goals and ambitions for their research over the medium term (5-year rolling). Through these plans, each individual can inform and influence Research Division (and consequently Research Theme and University) planning, helping identify common themes and individual needs that can be addressed through research structures and support mechanisms. PRPs also inform the annual Performance and Development Review (PDR), which is carried out by line managers. PDRs provide an opportunity to reflect on staff's performance, career progression plans and development needs in a holistic manner. The PDR process is informed by workload models and/or work profiles; these have been developed and regularly revised throughout the assessment period at senior-management level (including relevant D&I committees), to ensure they best reflect the diversity of our staff.

Academic staff have various opportunities to apply for sabbatical periods (typically 6 months) and criteria for sabbatical award include fit with our research strategy and development

opportunities; four sabbaticals have been awarded in the assessment period. Since REF 2014, three staff have also been awarded University Fellowships providing a period of relief from teaching duties to focus on publishing high-impact research articles. Additionally, our academic staff hold individual staff development accounts which can be used flexibly e.g., for training, conference attendance or pump-priming research.

All staff have access to a wide range of training and development opportunities led by the University's Centre for Quality, Support and Development (for Teaching and Learning, including teaching qualifications that lead to HEA membership) and People Development (for non-Teaching and Learning training and development). Within the Unit, we offer further, tailored support for our research-active staff, primarily led by our RDLs who themselves receive support and training through regular Community-of-Practice meetings. We provide grant-writing workshops, which have been attended by >40 researchers from PGRs to professors and also run a monthly grant review scheme ('Research NOSH'), to disseminate our latest research ideas and findings, and receive support and feedback on grant applications. Multiple interdisciplinary projects - including collaborations with ECRs - have resulted from these initiatives, for example, on neuroprotection in neuronal systems (Nandini /Nasuto /Delivopoulos /Tamagnini), supported by an EPSRC DTP PhD studentship and CINN internal funding. We also host a commercial grant-writing training session (Scriptoria) specifically tailored for PDRAs. A further highly successful inclusion and networking venture is our 'Coffee Connect' project in which >70 BSBE staff and research students engage in monthly one-to-one coffee meetings. Other specific activities are organised to develop our strategic and national research priority areas, such as the University-wide workshop on Healthy Ageing (February 2019) organised by one of our Unit's RDLs, which involved staff from more than 10 Schools plus two RCUK staff and led to three new collaborative projects subsequently funded by internal pilot-funding schemes.

All staff, including PDRAs, are invited to contribute to relevant Departmental, School and Research Division staff meetings, and committees have staff membership across all levels ensuring input and feedback to all staff and students. The University Rewards Committee considers cases for additional increments for staff on grade 6 and cases for research intensive staff (including PDRAs) to move from grade 6 to grade 7 (lecturer equivalent) by meeting the criteria of sustained excellence; many are underpinned by permanent contracts. We also have a scheme for awarding lump sums and vouchers to reward one-off activities of note. Our ECRs, PDRAs and PGRs also benefit from contribution to our extensive outreach and public engagement activities (see below). In the current REF period, a '**Director of Postdoctoral Researchers**' and associated committee (that includes all relevant PDRAs) was introduced within the UoA providing our PDRAs with increased opportunity to develop and contribute as young researchers.

Our Unit has a track record of developing staff into leadership roles. During this period, a former PVC (Teaching & Learning)/DVC and the Research Dean for Agriculture, Food and Health were drawn from our UoA (as was a Teaching and Learning Dean). Staff in our Unit also sit on key University Research committees and boards including the University Board for Research and Innovation (**Williams**), the Committee for Research Infrastructure (**Williams, Gibbins**), and the University Committee for Research Impact, Partnerships and Engagement (**Williams, McCrindle**). **Edwards** leads a new cross-disciplinary AMR@Reading group (focusing on antimicrobial resistance) and **Gibbins** is Director of our Institute for Cardiovascular and Metabolic Research. Research leadership roles within the UoA are appointed through open competition, and all staff, irrespective of career stage, are invited to apply. We welcome job-share applications and this approach led to the first University appointment of joint Research Division Leaders in Pharmacy. Several ECRs have been appointed into leadership roles over the period, such as our D&I lead and Director of PGR; support and mentoring is provided in these cases. Leadership roles are generally cycled every 3-5 years, enhancing career development opportunities and providing fresh perspectives. Thus, processes that support succession planning are well embedded within our Research Divisions driving a strong culture of leadership ambition and achievement.

Our multidisciplinary research is further strengthened through extensive links with academia, industry and the public sector (detailed in Section 4), supported by the University's Knowledge Transfer Centre (KTC). We have two biotechnology companies based within our UoA and one further embedded researcher sharing use of research facilities, engaging in knowledge exchange and joint research projects (Saretius, Microgen, Folium). We facilitate interaction with industry through partial appointments and/or secondments. Five of our Category A staff have been recruited fully or partly into industry or the NHS over the REF period.

Our working practices adapted rapidly to the Covid-19 pandemic, ensuring impact on our researchers was mitigated. Examples of measures introduced include: working from home where possible with comprehensive IT support provided; meetings, seminars and events converted to on-line formats (often recorded); provision of comprehensive Covid-19 safety guidance and training for those returning to campus; extension of financial support for university-funded PhD students whose research programmes were disrupted; and allocation of UKRI costed extensions.

2.3 Support for Research Students

Our vibrant, diverse PGR community currently includes **171 PhD** students representing at least **38 nationalities**, summarised in Figure 2.1.

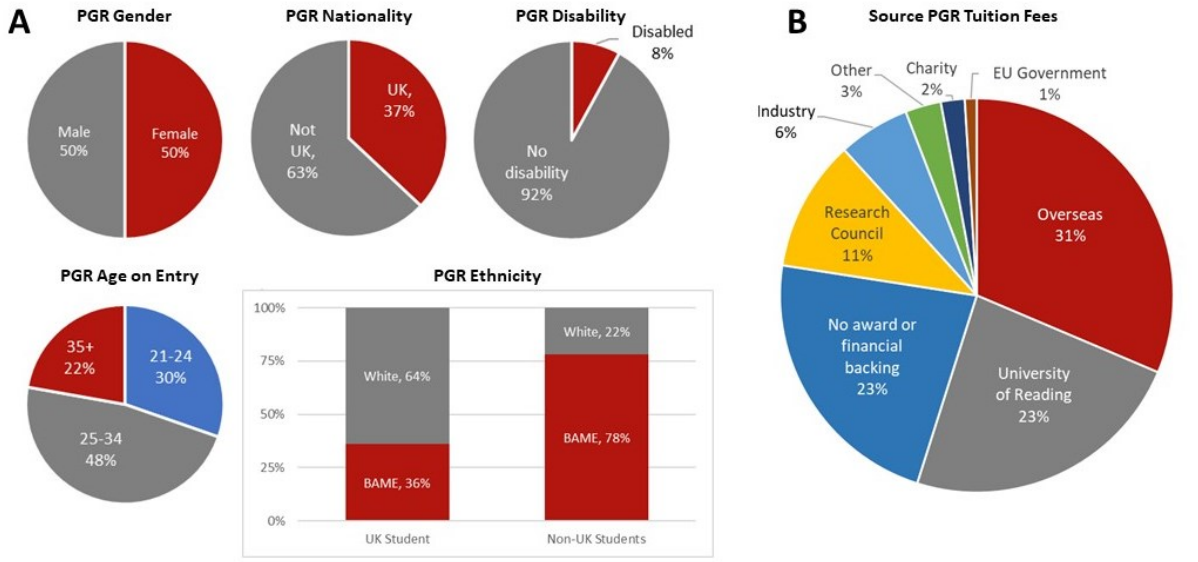


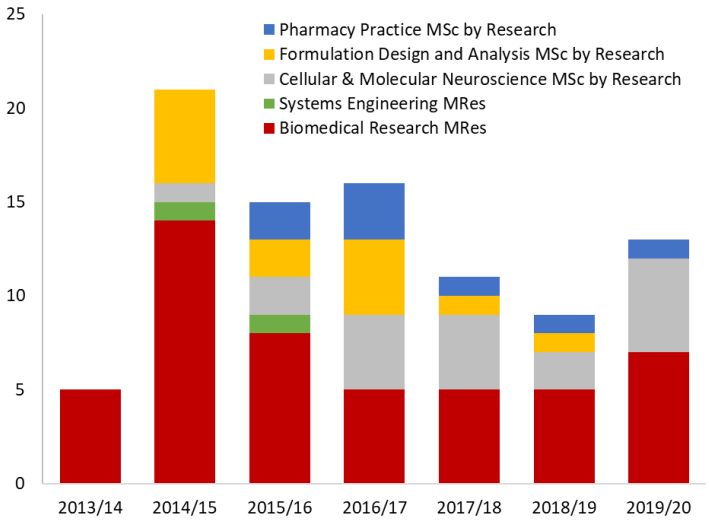
Figure 2.1. A:2019/20 PhD student cohort characteristics and B. Sources of tuition fees 2014/15-2019/20

We offer flexible modes of PhD study to cater for a range of circumstances, with opportunities widely advertised. PhDs have been supported by multiple funding sources with major contributions from overseas funders (31%), the University (23%), RCUK (11%) and our industrial partners (6%). A total of **48 competitively funded studentships** have been awarded to a value of **£2.7M** from EPSRC, BBSRC, MRC, the Marie-Curie ITN funded DTP (€4M, €820K to UoR; 5 students to UoA3) and Horizon 2020. In addition, we benefit from a new Reading-led Food BioSystems BBSRC-Doctoral Training Partnership (DTP) (£12M) initiated in 2020 (6 partner universities), funding >130 studentships over 5 years with 3 awarded to UoA3 this year. Many PGRs have also been co-funded by the University and industrial partners including Pfizer, GW Pharma, MedPharm and UCB.

The Graduate School provides a central hub for all PhD students, delivering the Reading Researcher Development Programme (RRDP). Our PhD students complete at least 11 research and professional skills (generic and subject-specific) training modules over a 3-year programme, selected from >100 options. Of note, D&I training was recently added to the RRDP because of work by one of our UoA's D&I committees. PGRs can also engage in a Leadership Programme

and the SPRINT Women's Development Programme. Our PhD students can engage in undergraduate practical classes as paid demonstrators via the innovative University Campus Jobs scheme. Excellent opportunities for research supervisory experience are also offered through our Undergraduate Research Opportunities Programme, where PhD's and PDRA's can supervise undergraduate students working on pilot or existing projects in the UoA.

PhD students receive focused, tailored research support in our UoA, beginning with departmental inductions on joining. Our students are provided with at least two supervisors with whom regular meetings take place as well as an independent monitoring committee consisting of at least two other academics. A Training and Learning Needs Analysis identifies developmental requirements at the outset and each PhD student and project is monitored at regular intervals to ensure appropriate training, supervision and progress, with opportunities to address any issues. Students are organised locally into specialist research groups that meet regularly to present research progress and review relevant journal articles. PGRs are strongly encouraged to attend research seminar programmes and join relevant scientific societies, for which many of our Category A staff act as official local representatives. Local and University funds are available to support PGR conference attendance and to provide financial support to those with caring responsibilities or caring needs, and conference presentations are part of our monitoring process. We hold annual PhD symposia, which provide forums for students to present and celebrate their research to their Department/School and invited industrial partners; they also participate in the University-wide Doctoral Research Conference organised by the Graduate School, providing a wider perspective of research across different fields of study.



We also operate a range of MSc by Research programmes within our UoA with 104 enrolments over the REF period (Fig. 2.2).

Integral to our diverse research community, we highly value our PhD researchers who frequently present at national/international conferences, publish their findings, and received both internal and external prizes and recognition such as the Fairbrother Lecture (2014) on cannabis treatments for epilepsy.

Figure 2.2. MRes/MSc by Research students during the REF period.

2.4 Equality & Diversity

Practices and policies across our UoA adhere to our values and culture of promoting equality, diversity, inclusion and wellbeing for all, mirroring those of the wider University (see IES). The Wellbeing, Inclusion, Diversity and Equality (WIDE, based in SCFP) and Diversity, Inclusion and Wellbeing (IDW, based in SBS) Committees work to address EDI issues and embed solutions in all our working practices. In addition to seminars and events, they undertake regular surveys to understand the changing needs of our staff and ensure these are addressed in policies and processes. Both committees are active in University-wide networks, including Women@Reading, Staff Disability (co-chaired by a member of this Unit), LGBT+ Ally Network, BAME, Parent & Family, and Cultural Diversity Group. Both School-based committees have brought about change in local practices and policies. Institution-level Communities of Practice enable sharing of good practice across the University. Our committees and school leadership regularly engage with the University's Dean for Diversity & Inclusion, who drives institutional policies. Senior colleagues in the Unit provide University wide mentorship for diverse development schemes such as the Aurora Women's Leadership Development Programme and Stellar HE.

During this period, we have enhanced our appointments processes to ensure they are diverse and inclusive. Appointment panels are gender diverse and, where possible, ethnically diverse. We ensure that recruitment adverts emphasise our commitment to equality and diversity, and we promote our flexible approach to working arrangements. We are members of WISE, supporting gender balance in STEM, and regularly advertise through their networks. All UoA3 staff have completed mandatory Diversity & Inclusion training, and appointment panels are required to have completed specific tailored training for D&I together with unconscious bias and responsible use of metrics.

Our work on gender balance has resulted in both our Schools of Biological Sciences and Chemistry, Food and Pharmacy securing Athena SWAN Silver Awards. During this REF period, 55% of newly recruited Category A staff were female. We support women's development via the Springboard Women's Development Programme and Aurora Women's Leadership Development Programme, which have been completed by 8 and 5 staff, respectively, in this assessment period. The numbers of female staff in senior grades have increased to 33% at Associate Professor and 41% at Professor level, largely the result of staff promotion and our support towards staff development.

BAME staff representation currently exceeds the University-wide target of 14% of Grade 7+ academic staff. We won funding from the University D&I Fund to support several local initiatives including workshops to promote careers of our BAME students and to address the BAME attainment gap within the higher education sector. A well-attended pilot D&I 'away day' for staff to raise awareness, provide training and promote discussion of a range of D&I-related issues has subsequently been adopted by other departments.

We fully support part-time and flexible working patterns, with ~14% of our Cat A staff holding part-time contracts at all grades. Workload and promotion criteria are appropriately adjusted to support part-time staff or, for example, those with caring responsibilities. These challenges are regularly discussed in D&I committees to ensure other specific actions are put in place. As an example, core working hours were introduced for all formal School/Division meetings and key seminar programmes, and events are scheduled on alternating days where possible to maximise attendance. We also strongly support role-sharing to expand opportunities for career development; one of our RDL roles is currently job-shared. Fixed-term research staff are fully integrated into our research community which has led to 14 PDRAs being awarded competitive Lectureships within the assessment period within our UoA or at other Institutions.

In line with the University's REF 2021 Code of Practice, all key staff involved in preparation of our UoA3 submission completed REF-specific D&I and unconscious and implicit bias training. The UoA core team also includes one of our two D&I Leads. Our selection process has been based on quality, as determined by our self and peer review assessment system, run in line with the University-wide systems. Where metrics have been used to aid selection, these have been used following the principles of the University policy on Responsible Use of Metrics and the provisions of the Code of Practice. We reflected on the outcomes of the University's interim Equality Impact Assessment (2020) and bias analysis (2021), which identified no statistically significant differences for protected characteristics in our selection.

3. Income, infrastructure and facilities

3.1 Income

Over the current REF period our research income (spend) was **~£26M** (**£68K/FTE/year**) from a variety of sources as shown in Figures 3.1 and 3.2 below.

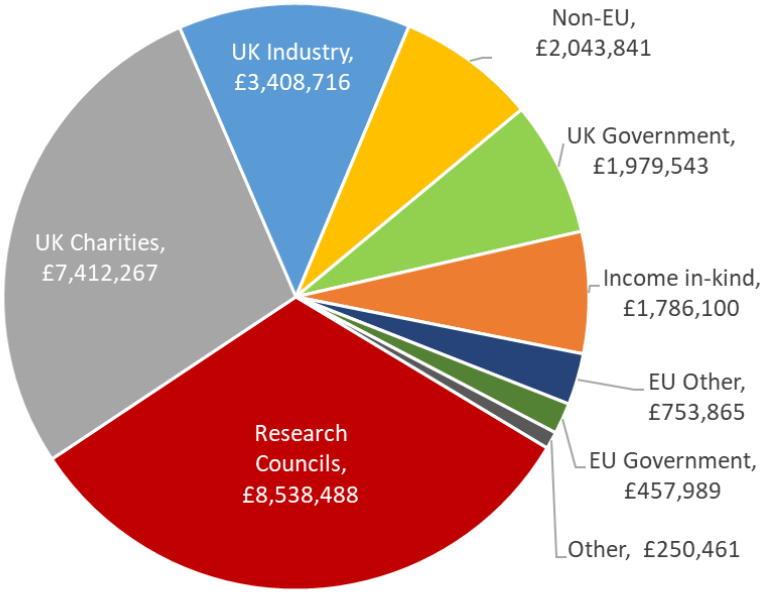


Figure 3.1. Research income (spend) into UoA3 over the current REF cycle

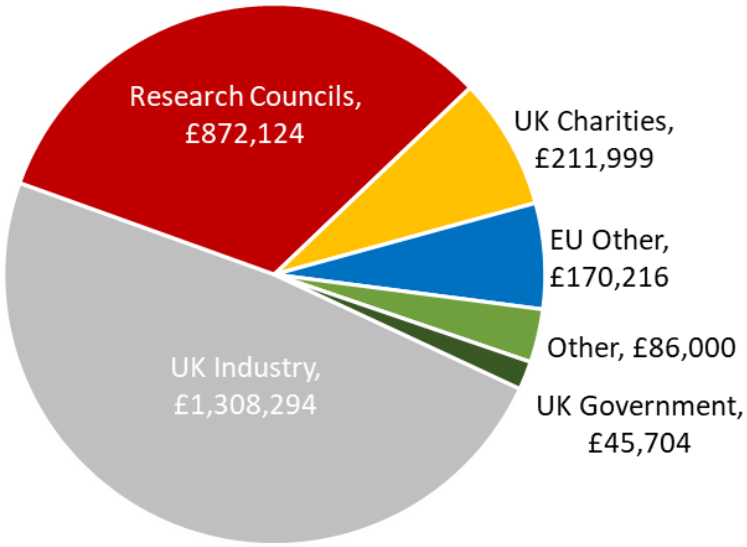


Figure 3.2. Funding won for PhD studentships over the current REF cycle

The research awards funded **213** discrete projects (excluding PhD projects) and this sustained level of income ensures that we will meet our future research and impact strategy. Importantly, we have expanded our sources of income, now won from **83** different funders, with particular focus on NIHR, MRC, charities and industrial partners to support our ambition for greater clinical translation of research as demonstrated below.

Our national and international collaborations with the **pharmaceutical industry** have resulted in income of **£3.4M**. This has included awards from, amongst others, GW Pharma, Janssen-Cilag, Merck Sharp & Dohme, Pfizer, Shire Pharmaceuticals, UCB Pharma, and Zogenix International. Other sources of income include those arising from collaborations with industry having interests in **health and well-being** in varied sectors, for example Atomic Weapons Establishment, Clasado, Mondelez Global, ImmunoSep.

We have also secured major funding (**~ £10M**) from diverse UK Government and Research Councils sources, including AHRC, BBSRC, the British Council, DEFRA, EPSRC, Innovate UK, **MRC, NIHR**, the Royal Society and the Technology Strategy Board.

We benefit from strong support from **UK Charities** (**£7.4M**), including Academy of Medical Sciences, Alzheimer's Research UK, Breast Cancer UK, British Heart Foundation, Duchenne UK, Harrisons Fund, Leverhulme Trust, Parkinsons UK, Physiological Society and Wellcome Trust. We have won awards from various EU funding sources **(~ £1.2M**) such as Deutsche Forschungsgemeinschaft, EIT Food KIC and Horizon 2020. Additionally, our research exploits UKRI and international research facilities (research income-in-kind of **£1.7M**) such as Diamond Light Source, ISIS Neutron and Muon Source, and MRC Harwell.

3.2 Infrastructure and Facilities

During this period, we received major investments in equipment, facilities and infrastructure, further demonstrating the University's ambitions in health-related research.

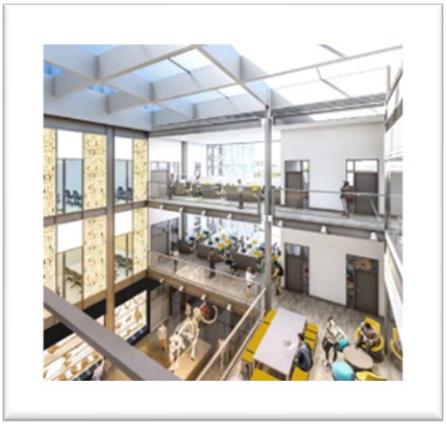


Figure 3.3. Health & Life Sciences Building

A new 4 storeys **£55M Health & Life Sciences Building** was completed in 2020 (5,020m^2 housing ~250 staff and research students; Figure 3.3). This state-of-the-art facility incorporates the *Cardiovascular* and *Infectious Disease research clusters*. The ground floor provides substantial, flexible teaching laboratory (320 students) and preparation space together with networking space (café and zoological museum) within a central atrium. The first and second floors provide extensive shared laboratory and write up space for **150 researchers and 30 PIs** with new fully equipped microbiology containment laboratories for work with pathogens, 4 tissue culture suites, 6 controlled environment rooms, inbuilt Nordic -80 freezer systems, Human Tissue storage facilities and a crystallisation room. The **£2.5M** cutting edge **Centre for Cardiovascular Imaging** has relocated to purpose-built laboratories within this new building; its intravital confocal microscopy, high speed confocal and super-resolution microscopy have recently been expanded through further investment.

The third floor houses our new **BioResource Unit** providing animal experimental facilities, under the ARMIS animal management system. The new BRU (905 m^2; capacity for 250 rats, 1800 mice and 100 tanks for newly introduced zebra fish) was designed through extensive consultation to allow flexible use and high-level biosecurity, health and safety. All rodent strains housed in the new unit have been re-derivatised to ensure that they are pathogen free (**£120K**). Four large animal holding rooms are available for rodents, rabbits and zebrafish, including immunocompromised strains, fitted with the latest animal-cage facilities (**£100K**). Twelve procedure rooms allow use of large equipment (such as ultrasound imaging) and extended animal holding, thus increasing flexibility. Surgical suites and recovery rooms facilitate modern aseptic techniques; a dedicated necropsy room is available for tissue recovery. A quarantine room is also available, and design ensures sterilisation of individual rooms. Also available are 2-photon microscopy and sophisticated intravital microscopy. These new facilities, and particularly the high levels of biosecurity and extensive surgical facilities, will enable us to expand our collaborations with biotechnology and clinical research organisations and support rapid translation of our research findings.

The Hopkins building is jointly occupied by Pharmacy and BSBE and has seen investments in multielectrode arrays, incubators, centrifuges and a t-Scan freezer monitoring system. The *Molecules & Tools research cluster* occupies the **Chemistry & Pharmacy building,** with facilities for synthetic organic chemistry, physical chemistry and chemical analysis and a

dedicated glass blowing facility. The group uses the co-located **£4.5M Chemical Analysis Facility** (CAF), a University research platform, operated by dedicated technical staff (7.2 FTE). It provides four NMR spectrometers, five mass spectrometers, X-ray facilities for single crystal, powders and small angle scattering, vibrational spectroscopy, thermal analysis (e.g., TGA, DSC, ITC) and extensive electron microscopy facilities. New investments since 2014 include cryo-TEM with Vitrobot preparation unit (£550K), a Light Isotope Ratio Mass Spectrometer (£300K), an NMR console upgrade (£75k) and a recent order for an atomic force microscope (£150K). A new single-crystal X-ray diffractometer (£439K) is extensively used and managed by our pharmaceutical materials experts.

Biomedical engineering uses specialist facilities in our **Polly Vacher building** which provides access to the **Brain Embodiment Lab**, with cell culture facilities, two new 3D printers, and computing, electronic and engineering facilities. Joint occupation of the buildings with our computer scientists and shared facilities provides further opportunities for interdisciplinary research. The *Medicines Usage and Prescribing cluster* is central within the School of Pharmacy and benefits from ready access to interview rooms equipped with video and audio recording and simulation facilities. The buildings housing all the research groupings are closely co-located in the University "Health" building zone, to which some local NHS Trust services will shortly relocate, enabling ready interaction and sharing of resources.

Our research has benefitted from additional specific strategic investments of **~£2.0M in new research equipment** over the current REF period. Notable examples include: Octet biosensor, (£105K); two Accuri C6 cytometers (£165K); 5 AKTA protein purification systems (~£150K); Nordic -80°C system (£500K) and Innova microbiological incubators (£150K). We also rely on other key research facilities at the University, including the Hugh Sinclair Unit for human nutrition intervention studies; Hall and Sonning farms (llama nanobody production, piglet experimental facilities); the MRI Scanner and EEG facility in CINN and *in-vitro* gut models in Food and Nutritional Sciences (gut microbiota research). Externally, we are also partners in the EPSRC-funded (£4.5M) 'Young' consortium of 12 leading Universities, for Materials and Molecular Modelling (MMM Hub Tier 2), a world-class **high-performance computer** (~23,000 cores) which supports research across our Unit.

In addition to the internal financial investment in infrastructure, we benefit from access to a range of funding to support research, including:

- The **University Strategic Fund**: which invested £575K, matched by RBFT, to establish the Joint Academic Board; £292K was awarded to our Unit to pump prime 12 collaborative projects.
- UoR's **Research Endowment Trust Fund**: which makes available £1.2M per annum to support research. This fund is accessible via several competitive schemes to which all staff can apply.
- **Research Infrastructure Fund**: over £1.5M allocated to the Unit as described above.
- **Research Impact** support funds: allocated through the BOISP programme as described in Section 1.

Our research is expertly supported by a team of highly qualified technicians, working with our technical services function. Dedicated technical specialists manage CAF (7.2 FTE) and the BRU (7.0 FTE) platforms. An additional 40 FTEs provide teaching and research support across all our laboratories, including stores, health and safety, and running specialist facilities such as our tablet making suite and microbiological facilities.

The University invested significantly in expanding professional support capacity. As a result, we benefit from a range of staff in the professional services who work closely with colleagues in the UoA in developing grant applications and impact. Research Development Managers are highly qualified and provide specialised input to our proposals, supporting from the early inception stages, whereby they can offer advice on the focus for the proposals to fit with specific funding calls, through to review and costing support. They regularly provide briefings and presentations for staff and liaise with ECRs to provide tailored support and facilitate workshops and events for

idea generation in response to large external initiatives and, in doing so, support internal collaborations and interdisciplinarity.

In addition, we receive support from a dedicated impact team, the KTC, contracts officers and Research Communications. The KTC facilitates interactions with industrial partners. The impact team provide invaluable support for building capacity for impact through workshops and training and developing impact case studies. For example, this has included training on the Business Model Canvas in partnership with the Oxford Academic Health Sciences Network to establish a viable prototype for personalised nutrition support for use during cardiac rehabilitation.

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

Our UoA has continued to make powerful contributions to shape local, national and international research landscapes. We have fostered significant collaborations, benefitting interdependent research networks, the economy and society, both within the UK and amongst our collaborators' home bases. The vast majority of our research is collaborative, with external healthcare, academic and industry organisations, including very significant international activity. These contributions extend beyond our Impact Cases and incorporate diverse communities.
We contribute fully to the wider research base, and influence research policy and public-facing strategies; such activities further extend to our successful outreach activities locally and nationally.

4.1 Collaborations, Networks and Partnerships

We work with diverse local, national and international networks, as reflected by the large number of collaborative publications; Table 4.1 shows our major output collaborators. In this REF period, we have published over 850 papers in international, peer-reviewed journals and conference proceedings (including Nature, Science and Cell) of which 46% include international co-authors from 69 nations (Figure 4.1). Our submission includes 62 papers co-authored with industrial collaborators from 25 different companies.

Institution	Co-authored publications	Total citations	Total co-authors	FWCI
University College London	55	3112	147	3.58
University of Oxford	50	3459	99	3.55
Kings College London	46	2971	64	2.99
CNRS	27	3469	143	7.39
Marine Biological Association	27	876	22	3.71
Imperial College London	26	2629	49	4.14
University of Manchester	24	2638	32	4.69
Diamond Light Source	24	354	19	1.2
University of Birmingham	23	2948	52	5.09

Table 4.1. Top collaborating institutions for UoA3 from 2014-2020. From 802 outputs in Scopus (10,911 citations, average FWCI of 1.47)

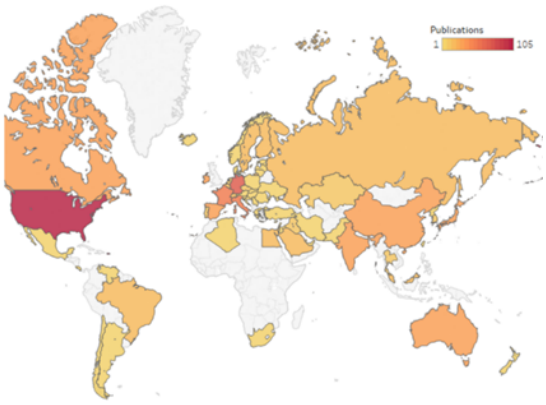


Figure 4.1. UoA3 International collaborations by publication.

NHS collaborations. We have extensive collaborations with health care services and providers. At a local level, collaborators include our Joint Academic Board partnership with RBFT, and work with BHFT, and Oxford University Hospitals. For example, our Celgene-funded (£580K) study on haemostatic function in multiple myeloma supports work in the Oxford Haemophilia and Thrombosis Centre. We also work closely with the University Department of Cardiology at RBFT on a £1.4M BHF programme grant developing new precision medicine approaches to prevent thrombosis. The Unit provides strategic leadership for the University's collaborative JAB partnership; Williams co-chairs with the Trusts Chief Medical Officer.

Beyond the region, we work with Stanmore Hospital developing a functional electrical stimulation system for bone health maintenance in spinal cord injury supported by EPSRC (£894K). We also

collaborate with the University of York on a NIHR Programme Grant (£2M) project entitled 'Highlighting Alcohol use in Medication Appointments'.

Industrial collaborations. We work extensively with industrial collaborators to co-design research aimed at meeting health needs, for example with Evolv in developing a Microsoft Kinect based game for home-based speech and language rehabilitation of stroke and dementia patients (Impact Case). Our industrial links are strengthened by visiting professors from companies including Arena, Bristol-Myers Squibb, MedPharm and GW Pharma, and by industrial representation on our strategic advisory boards which guide and inform our research strategy. Our interactions with industry enhance the impact of our outputs - during the REF period our 62 academic-corporate collaborative publications achieved an average FWC impact of 3.88.

International collaborations. Major international collaborations include our BHF £298K funded programme on modelling platelet function with Lomonosov Moscow State University and the €3.9M European Joint Doctoral Programme on Atherothrombosis in collaboration with three EU (Maastricht, Wurzburg and Santiago de Campostela) and one UK (Birmingham) universities, the ISAS research institute (Dortmund) and the German company Alacris Theranostics. We collaborate with 12 biotechnology companies and academic institutes across Europe on the EU-funded (€10M, €387K to UoR) ImmunoSep project which is trialling a "theranostic" approach to personalised immunotherapy for sepsis.

We also collaborate significantly with overseas partners on PhD studentships and MSc programmes, often supported via government and university schemes which seek to obtain the best research training for their students. Such overseas collaborations include Bangladesh, China, Egypt, France, Iraq, Jordan, Kuwait, Malaysia, Oman, Saudi Arabia, Thailand and Turkey.

Our international collaborative activities include hosting prestigious overseas academic visitors as part of grant-funded research. Examples include Dominic Behan founder of Arena Pharmaceuticals (USA), Prof Toshiyuki Kondo, Prof Ryo Yoshida, Prof Sadao Kawamura and Professor Sumiko Mochida (Japan).

4.2 Impact of our collaborations, networks and partnerships

Our collaborations have generated considerable impact, including many examples beyond our 5 Impact Cases and those described above. **Healthcare** impact examples include our work with the Primary Care Pharmacy Association at a Centre for Pharmacy Postgraduate Education (CPPE) conference to create videos which are now used in training sessions for general practice pharmacists. Impact examples with **regulatory bodies** and **industry** include: with the National Institute for Biological Standards and Controls (NIBSC) and the Medicines and Healthcare products Regulatory Agency (MHRA) on publication on the standardization of research procedures in dementia research (AlzSM project); with Celgene on the increased thrombosis risk in myeloma patients treated with immunomodulatory drugs; and with Arena Pharmaceuticals on the impact of drugs affecting arterial hypertension leading to new compounds licenced to United Therapeutics.

4.3 Leadership and contribution to the discipline and research base

UoA3 staff make strong contributions to their professional societies; in particular, all our Pharmacist staff are registered with the GPhC and many are members of the Royal Pharmaceutical Society. Staff are members of societies such as the Academy of Pharmaceutical Sciences, Biochemical Society, British Pharmacological Society, British Psychological Society, Royal Society of Chemistry and the UK Physiological Society. Multiple staff hold Fellowships of the Academy of Pharmaceutical Science, American Heart Association, British Pharmacological Society, Institute of Electrical and Electronics Engineers, Institute of Engineering and Technology, Royal Society of Biology, Royal Society of Chemistry, Royal Society of Medicine, Royal Pharmaceutical Society and the UK Physiological Society. Other professional healthcare contributions include membership of the Standard Setting Panel for GPhC Registration

Assessment, roles within the Pharmacy Schools Council and Committee Membership of the Royal Society for Public Health: Arts, Health and Wellbeing Special Interest Group.

We also make major policy-making contributions to **scientific societies** through our staff taking leadership positions such as Chair of the Platelet Society, Chair of IEEE Sensors UK and Ireland, Chair of IEEE Masabu Ibuka Medal Committee, Chair of the IEEE Consumer Electronics Society Fellow Evaluation Committee and Vice-President for Policy & Public Engagement for British Pharmacological Society (BPS). We also serve on the Facility Access Panel for the ISIS STFC neutron facility, including acting as Chair. We also have representatives on **Editorial Boards for over 40 different journals** in the field.

Our researchers are members of over **50** boards, committees and scientific advisory panels for RCUK, charities and industries involved in funding Unit-related research. In **healthcare**, these include the NIHR James Lind Alliance, Priority Setting Partnership awards panel and the Royal Pharmaceutical Society Health Services Research and Pharmacy Practice Committee. For **RCUK**, such contributions include to BBSRC, MRC and EPSRC grant panels. For **major charities**, committee representation includes Heart Research UK (Chair), the Royal Society Newton Panel, Wellcome Trust Peer Review College, Ataxia UK, MS Society, Parkinson's UK, Alzheimer's Society, Alzheimer's Research UK, DEBRA International, and British Heart Foundation.

Additionally, our researchers undertake multiple **research consultancy roles for industry**. Examples of companies thus supported include: Animalcare Ltd; DragonFly CBD; Foley & Lardner LLP; Hogan Lovells International LLP; MedtechtoMarket; Pfizer; Reading Scientific Services Ltd; and RusBio Ventures LLC.

Our global research base contribution is indicated by members hold **visiting titles overseas**. These include Honorary titles at Kazan State Medical University (Russia); Trichy SRM Medical College Hospital; Bharathidasan University Constituency College; Alagappa University (all India).

4.4 Societal Impact of the Unit: outreach and public understanding to benefit society.
An integral part of our research ethos is our commitment to communicating and engaging with a diverse range of audiences. Thus, we have organised and hosted many events both on campus and in the local community which have been attended by thousands of participants.

Our **local engagement** activities span the UoA3 research base from British Heart Foundation to Alzheimer's Research UK sponsored events. We are regular contributors to the University's Public Lecture Series presenting our research in an accessible format. Our outreach events have been supported by competitive awards such as two Physiological Society Outreach Grants supporting highly successful outreach events such as Science Slams. Our commitment to Outreach and Engagement is illustrated by our establishment of the Reading Pint of Science festival from 2018, as organised by UoA3 ECRs and PDRA's, in which many of our researchers have presented their research, and the success of our Heart Health MOOC (~60,000 enrolments).

We also participate in **national engagement events**, including the highly successful Science Lates at the Science Museum involving several hundred general public participants and an ARUK-supported Christmas lecture on dementia. Our **international outreach** contributions include a TED talk and YouTube videos about dementia research.

We routinely engage with the **media**, through our local Press Office and the national Science Media Centre. This has led to follow up articles and a global recognition for UoA3 staff. For example, we were involved in extensive coverage of the Novichok exposure via UK BBC World Service, Reuters and Financial Times. The Unit has also been involved in the coverage (BBC Berkshire, ITV, The Times) of cannabis-based medicines. Other examples include our contribution to a Guardian article on use of Google's DeepMind to predict 3D shapes of proteins,

an interview by the BBC on cardiovascular studies, a Royal Institute Christmas Lecture, a History Channel TV interview, the BBC Radio 4 Frontiers programme "Build me a brain" and a Guardian article, "Mind-blowing music: Tinie Tempah's brain scan". To provide up to date opinion and expert insight UoA3 staff have authored over 40 pieces in The Conversation, an independent source of news and views. The Unit has also made significant outreach responses to the COVID-19 crisis; see 4.8. **Digital media** are routinely used to promote our scientific research, for example a dedicated YouTube channel promoting our polymer science and drug delivery research. In addition, we operate an Instagram channel promoting the use of technology to address biomedical problems. Other social media platforms used include numerous Twitter accounts, webpages and blogs.

UoA3 staff also contributed to UoR's campaign to promote openness on responsible use of animals as part of the new national animal concordat. This included a BBC Radio Berkshire interview which resulted in an **Understanding Animal Research Openness Award** (1.3) on our use of llamas to produce antibodies. Our animal-concordat-linked Twitter campaign was picked up by wider media, including the Sunday Times.

4.5 Academic engagement and uptake: communicating our research.
We have continued to show leadership through the organisation and delivery of numerous research conferences/workshops, at national and global levels. Eleven conferences/workshops have been organised at Reading by Unit-members including the major Health Services Research and Pharmacy Practice 2016 annual conference (over 100 delegates), the European Platelet Summer School (in 2014 and 2017; over 100 delegates each) and the Alzheimer's Research UK Network Dementia Research conference in 2019, attended by 79 delegates.

Over 30 conferences/symposia sessions were organised by us. Notable **international meetings** include: A Newton funded Researcher Links Workshop on 'Understanding and Advancing Therapies for CNS Disorders' with a follow-up conference in Santa Catarina, Brazil (over 140 delegates); the Third and Fourth International Congress on Advances in Intelligent Systems and Computing (Ukraine); and annual International Conferences on Artificial Intelligence and Soft Computing (2014-2019). Organisation roles for notable **national meetings** include: RehabWeek, 2017 (over 1000 delegates) the Eurohaptics 2016 meeting; the 12th Royal Society of Chemistry Nucleic Acids Forum (over 100 delegates); the European Workshop on Cannabinoid Research 2017; the Pharmacology 2018 and 2019 meetings; the 12th International Symposium on Resistance Arteries 2017; and the Royal Pharmaceutical Society annual science/research conferences since 2014.
We have delivered well over 100 invited, keynote lectures at high-profile academic conferences within the discipline since 2014.

4.6 Policy and public engagement and uptake: benefit to society
Publications by UoA3 staff have **influenced healthcare policy** in the UK and globally. Examples include **Dhita**l, who advised WHO (see 4.8) and was part of the James Lind Alliance, Evaluation, Trials and Studies steering group that advises NIHR on research priorities for alcohol-related liver disease. Dhital was also part of the expert steering group who advised the London Alcohol Misuse Prevention group and Alcohol Concern. **Vaiyapuri's** work on snake bites is detailed in an Impact Case study.

UoA3 members have presented evidence in Parliament to guide UK **government policy**. Research by **Sherratt** was cited in the Parliamentary Office of Science and Technology document "Preparing for a changing world" in their Science, Communication and Behaviour section. Sherratt was also an Invited Member of the Chinese government's Foreign Experts Programme. **McNeish** liaises with government representatives in his role as British Pharmacological Society Vice-President for Policy & Public Engagement; such activity includes representation at Royal Society of Biology parliamentary links days from 2016-19.

4.7 Awards and Prizes: markers of esteem

Key examples include: **Harwin, Sherratt** and **Holderbaum** as part of the EPSRC Sphere team were World Technology Award Winner 2016 in the "Organisation: Health and Medicine Category" by the World Technology Network; **Lewis** was awarded the Physiological Society Bayliss-Starling Prize in 2018; **Stephens and Whalley**, were awarded the 2019 Sir James Black Award for Contributions to Drug Discovery by the British Pharmacological Society - this work was shortlisted for the Guardian University Awards 2020 for Research Impact; **Stephens**' research on producing antibodies in different species won an Openness award at the annual Understanding Animal Research awards in 2019; and **Vaiyapuri** was awarded a Royal Society Leverhulme Trust Senior Research Fellowship in 2020.

4.8 Responsiveness to national and international priorities

Examples include advising **NATO** on research priorities via 3 lectures at their Advanced Study Institute; and contribution to the Expert Advisory Group for the **WHO** to develop and review an online alcohol brief intervention training manual, adopted for use in primary care.

As a health-related Unit, much recent activity has focussed on **responses to the COVID-19 pandemic**. We have increased public understanding of infection risk, disease testing and potential treatments via numerous national and international written articles, interviews and videos. Moreover, we are making strong contributions to vaccines and anti-viral therapies, with ongoing discussions with clinicians on the basis of disease, the value of therapeutic options, and the design of clinical studies. Examples include:

- **Jones-I and Clarke** gave extensive expert opinion and advice on COVID-19 via the Science Media Centre and other platforms.
- **McGuffin** contributed 3D models of the virus via the CASP Commons 2020 programme.
- **Edwards** provided expert opinion to multiple outlets including The Conversation, ITV and a BBC Science Focus on the governments COVID-19 testing strategy, testing technology and the use of PPE.
- **Donyai** explained the science behind potential drug therapies for COVID-19 in The Conversation and use of ibuprofen with COVID-19 on the BBC, broadly quoted in the press.
- **Vaiyapuri** examined evidence that blood type A raises susceptibility to COVID-19 in The Conversation and was quoted extensively in, for example, USA Today, Politifact and Medical News Today.
- **McNeish** contributed to The Conversation, reproduced on ForeignAffairs.nz, on the pharmacology of potential COVID-19 treatments and raised risk of high blood pressure medicines for COVID-19.
- **Stephens** co-ordinated llama antibody work in 2 separate projects with Owens (Oxford) and Kjaer (Francis Crick Institute) to discover novel, specialised 'nanobodies' to fight COVID-19. This work was widely featured e.g., in The Conversation, the I-newspaper, BBC South and BBC Five Live.
- **Gibbins** (with Imperial College London) explored whether enhanced platelet function in severe COVID-19 infection was associated with clots in the lungs in an intervention drugs trial; and with colleagues in Amsterdam and London, Gibbins and Jones-I investigated whether 'pathogenic' early antibody responses underly abnormal clotting in COVID-19.