

Institution: University of Sheffield
Unit of Assessment: A-03 Allied Health Professions, Dentistry, Nursing and Pharmacy
1. Unit context and structure, research and impact strategy

1.1 Overview

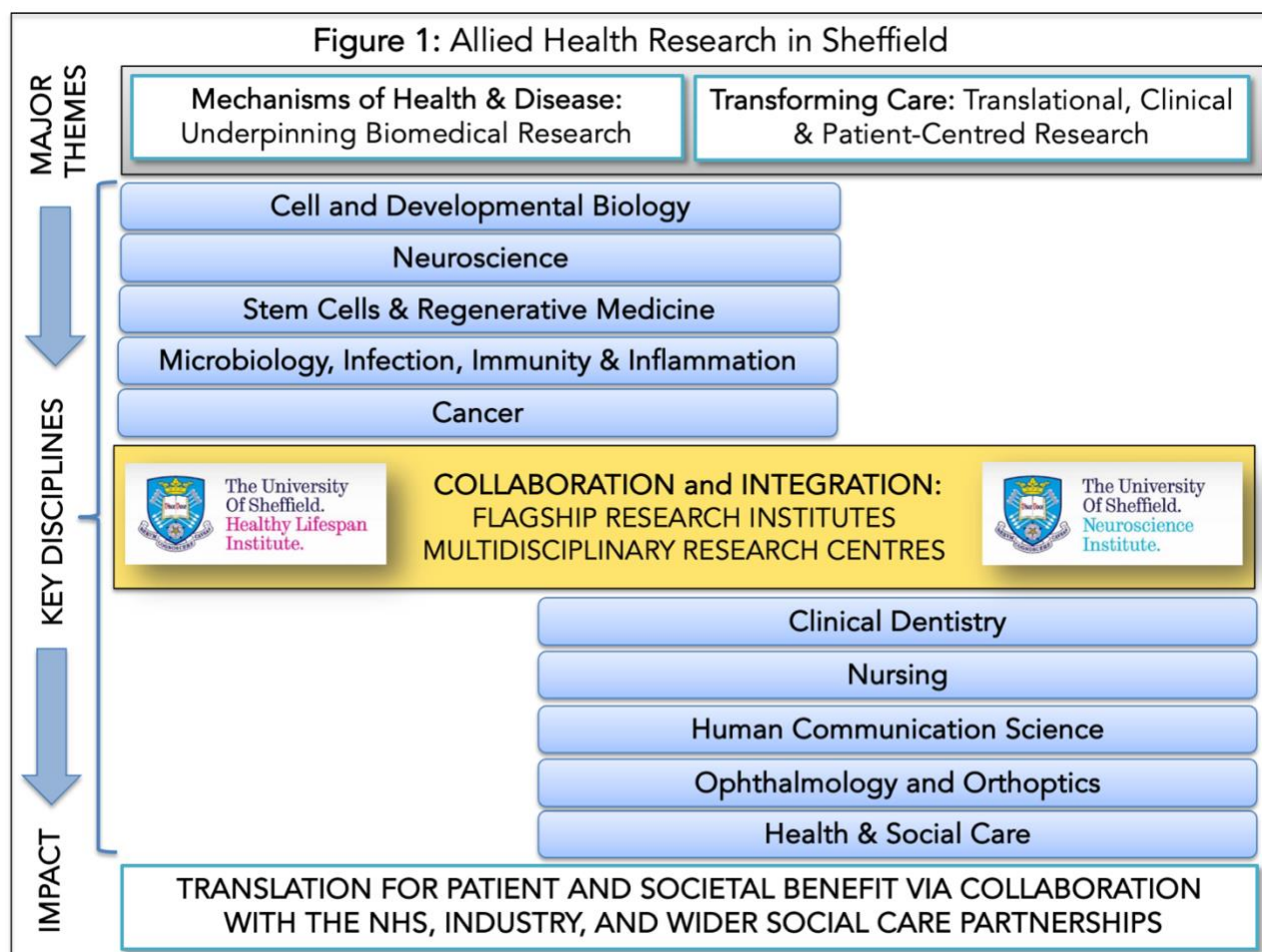
Allied Health, Dentistry and Nursing research at Sheffield makes positive contributions to human health and quality of life from birth to old age. Our strategy is driven by recognition that innovative solutions to major healthcare challenges are based on new insights gained from the integration of basic biomedical sciences with clinical or clinically related research, working in close partnership with industry and healthcare providers. Our two research themes: **Mechanisms of Health and Disease** and **Transforming Care** provide a continuum from basic biology, through translational studies to deliver improvements in clinical practices, to policies, and investigation of healthcare improvement over the life course (Section 1).

Our ambition is to fully exploit the synergies within our Allied Health community, which includes basic and clinical scientists, healthcare professionals, biomedical engineers, and social scientists, through our commitment to creating a nurturing and supportive environment for staff, thus ensuring that the skills, experience, and potential of this diverse community can be fully harnessed (Section 2). Our research is underpinned by significant investment in supporting infrastructure and facilities (Section 3). Pivotal to our mission are our collaborative links with the NHS, industry, charities, and policymakers, which means that research and impact within the unit are inherently intertwined, leading to tangible national and global impact (Section 4).

During the current assessment period, we have built upon our strong performance in REF2014:

- **Underpinning biomedical research** has significantly increased mechanistic understanding of major clinical challenges including cancer, neurodegeneration, inflammation, impaired hearing, infection, and antimicrobial resistance (Section 1.2).
- We have **advanced translations of this new knowledge into novel therapies**, for cancer (*ICS Lynparza*), nerve repair, chronic pain, irritable bowel syndrome and a first-in-man stem cell treatment for deafness (**Pipeline Impact Exemplar 1**).
- Our policy-oriented research addresses global healthcare problems resulting in significant improvements in **quality of life** (*ICS HeadsUP*, *Dental Anxiety*), and step changes in **NHS and global policy and practice** (*ICS Progas*, *Endocarditis*, *Response*, *Practitioners*).
- **Collaborations with industry** have allowed the development of healthcare devices (*ICS Zedscan*) and potential therapeutics resulting in significant economic and societal benefit, e.g. *ICS Cordella System* (>**\$100M** investment); **Pipeline Impact Exemplar 2**, *AFYX Therapeutics* (>**\$20M** investment).
- Our research awards of >**£58M** have leveraged **additional investments** of >**£80M** and additional royalties of **£63M**.
- We have **grown our PGR community** awarding 390 doctoral degrees, a 100% increase on REF2014 in a range of Allied Health Professions. The quality of our training is evidenced by a 100% 4-year submission rate in 2019.

1.2 Research themes and progress against REF2014 objectives

**A. Mechanisms of Health and Disease***Cell and developmental biology (19 PIs)*

This group seeks to understand fundamental elements of cell behaviour, working across scales from cells through to tissues and organisms. Following our REF2014 aspirations to dissect underlying mechanisms of development and adult homeostasis, we have further explored membrane trafficking in health (**Smythe**, *J Cell Biol*) and disease (**Ridger**, *Nature Comms*), signalling *in vitro* (**Erdmann**, *Nature Comms*) and *in vivo* (**van Eeden**, *Nature Comms*), adhesion and the cytoskeleton (**Winder**, *Aging Cell*).

Future strategy: To fully understand how fundamental cellular processes contribute to health and disease, we will collaborate with neuroscientists, cancer biologists, computational biologists, and psychologists, to take a truly systems level approach. We aim to exploit the availability of large sets of 'omics' data to develop novel cell biological tools to understand the dynamics of molecular and cellular events that impact on whole organism physiology, during development, adult homeostasis and ageing (e.g. **Sudbery**, *Mol Cell*).

Neuroscience (19 PIs)

Sensory neuroscientists, using both mammalian and non-mammalian animal models, combine electrophysiology and imaging techniques with computational modelling, cellular and molecular biology, behavioural analysis, and drug discovery, to investigate how specific genes, physiological processes and pathological conditions affect sensory outputs. Recent studies have identified key

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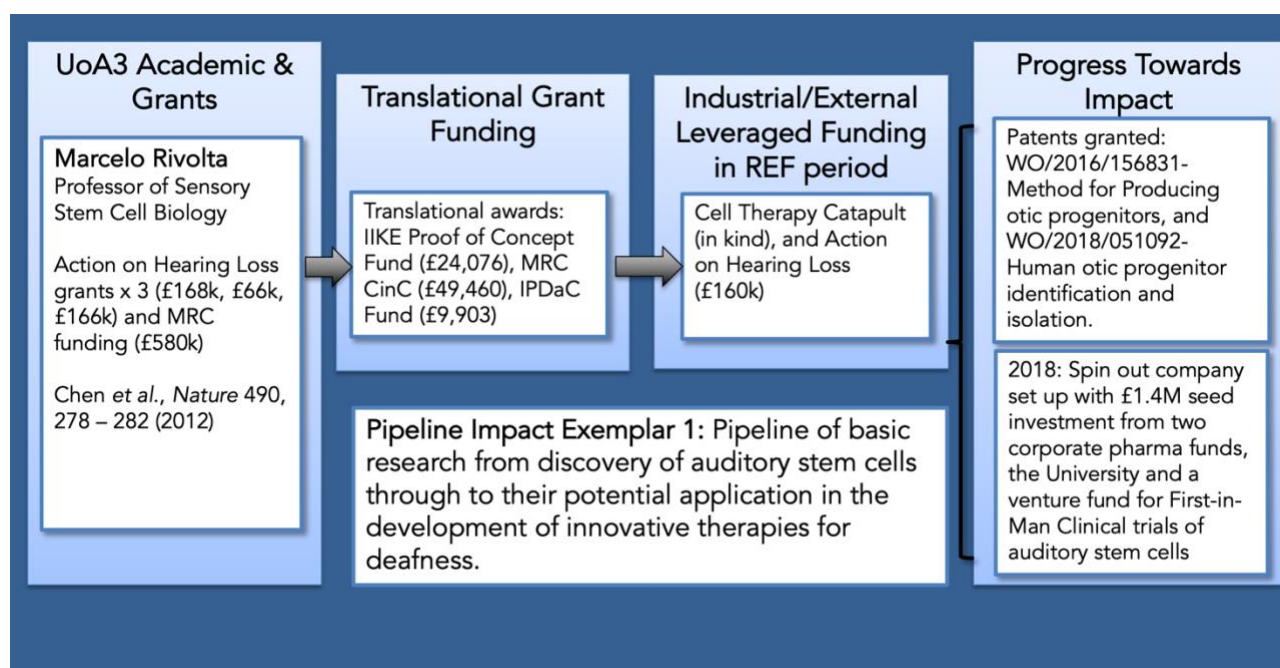
regulators of the development and function of the auditory system (**Johnson**, *Nature Comms*) as well as effective ways to repair damaged nerves (**Boissonade**, *Biomaterials*).

There is significant expertise in understanding mechanisms of neurodegeneration through studies in non-mammalian models (**Cooper-Knock**, *Cell Reports*) and induced pluripotent stem cells (**Allen**, *Brain*), thus delivering on our REF2014 aspirations. This is largely focussed in the Sheffield Institute of Translational Neuroscience (SITraN) which is **the only NIHR Biomedical Research Centre dedicated to neuroscience** (awarded £4M, 2018).

Future strategy: Our ambition is to develop the expertise needed to bridge the different modalities in brain processing of sensory inputs, including expansion of both our behavioural studies and our therapeutic pipeline for sensory-related disease. Via the flagship **Neuroscience Institute**, we will invest in facilities for high-throughput analysis (e.g. multielectrode array technology) and maximise use of our drug screening and imaging facilities (Section 3.3). We will continue to translate our fundamental understanding of mechanisms of neurodegeneration to improve prognosis, treatments (e.g. MRC Developmental Pathway Funding Stream, 2021-2024, **£3.5M**, **Mead**, collaboration with Aclipse Therapeutics), and quality of life for patients suffering from neurodegenerative disease and chronic pain.

Stem cells and regenerative medicine (10 PIs)

Research is focussed on understanding mechanisms that drive stem cell self-renewal, fate decisions and differentiation to the exploration of their application in future therapies. There is a major focus on human pluripotent stem cells (hPSC), while also including research on other adult and tissue-specific stem cell populations using animal models (**Roehl**, *Nature Comms*). In line with our REF2014 aspirations to translate our discoveries towards clinical impact, researchers are closely involved in the UK Regenerative Medicine Platform (UKRMP, Section 4.2). The group has been instrumental in developing safety protocols for preclinical use of hPSCs (**Andrews**, *Nature Comms*) and realising impact for the clinical translation of hPSCs. It developed the first clinical grade lines to be validated by the UK Stem Cell Bank, producing one of the first lines to be used in a clinical trial worldwide for age-related macular degeneration (collaboration with UCL) and, recently, has spun out **Rinri Therapeutics** (Section 4.2, **Pipeline Impact Exemplar 1**).



Unit-level environment template (REF5b)

Future strategy: hPSC-derived therapies are becoming a reality. In the future we will combine the use of organoids and organ-on chip technology (established via the MIMIC ITN, Section 2.3) with development of hPSC approaches, informed by institutional expertise in developmental biology (**Tsakiridis**, *eLife*), to develop therapies for Hirschsprung Disease (Section 3.2) as well as other spinal cord and neural crest pathologies.

Microbiology, infection, inflammation, and immunity (28 PIs)

The Florey Institute (Section 1.4) fosters interactions between basic scientists and clinicians to address the global problem of antimicrobial resistance, by understanding host-pathogen interactions and mechanisms underpinning the immune response. Through elucidating fundamental properties of bacterial structure (**Bullough**, *Nature*) and infection of mammalian cells (**Kelly**, *Nature Comms*), this group aims to translate their findings into antimicrobials to overcome problems of resistance (**Fagan**, *Science Translational Medicine*; **Stafford**, *Infection and Immunity*). Consistent with REF2014 aspirations, studies on host-pathogen interactions have had a particular focus on macrophages and neutrophils, (**Marriott**, *Amer J Resp Crit Care Med*). A further important breakthrough has been demonstrating the benefits of antibiotic prophylaxis to prevent cardiovascular disease after dental treatment, with implications for prescribing practices and guidelines in the UK and overseas (*ICS Endocarditis*).

Future strategy: The Florey Institute will be used as a platform to understand how host-pathogen responses result in changes in immunity and inflammation with the goal of reducing antibiotic usage and combatting antimicrobial resistance. Strengthening links with the Bateson Centre (Section 1.4), via Wolfson Foundation funded joint research space, is a priority to exploit expertise in non-mammalian models of infection and inflammation (**Johnston**, *PLOS Pathogens*). We will perform clinical studies using novel antimicrobials developed by our spin-out company DeFENition (Section 4.2). Immunity researchers within the flagship **Healthy Lifespan Institute** will investigate age-related immune dysfunction in interdisciplinary consortia. Our goal is to improve outcomes from infection, combat antimicrobial resistance and increase global vaccination against COVID-19 (**Collini**, *Cell Host Microbe*) and other communicable diseases.

Cancer (10 PIs)

Cancer research is focused on bone oncology and the tumour microenvironment (**Gartland**, *Nature*; **Rainero**, *Cell Reports*) and has also resulted in advances in understanding oral cancer progression (**Lambert**, *British Journal of Cancer*). Basic research is complemented by translational programmes including novel approaches for cancer treatment (**Muthana**, *Nature Comms*), drug discovery, target and biomarker identification (**Holen**, *Journal National Cancer Institute*), and use of *in vitro* and *in vivo* models that move towards human clinical studies (**Ottewell**, *Clin Cancer Research*). Our basic scientists and clinical pathologists have collaborated with industry to further develop and optimise an innovative cancer detection technology from the UK SME, Zilico Ltd. in research directed at improving cervical (*ICS ZedScan*) and oral cancer detection (SBRI Healthcare Award, **Hunter**).

Sheffield hosts one of 18 adult Cancer Research UK/Department of Health Experimental Cancer Medicine Centres (ECMC) (Scientific Lead: **Holen**) reflecting outstanding research at the translational interface. The PARP inhibitor olaparib (*ICS Lynparza*) was the second highest earning oncology drug for AstraZeneca in 2018, earning over **£63M** in royalties for the University in the census period. Sheffield is also part of the **Yorkshire Cancer Research Early Phase Trials Network**, which provides infrastructure support for oncology early phase research (clinical trials: ZOLMENO, NEPTUNE). The Yorkshire Cancer Research Catalyst for Innovation in Cancer Care and Treatment in Sheffield (YCR CONNECTS, 2020) was established to exploit infrastructure in

Unit-level environment template (REF5b)

the ECMC and imaging via POLARIS (Section 3.3), to improve cancer outcomes through early diagnosis and clinical trials in Yorkshire and, ultimately, more widely.

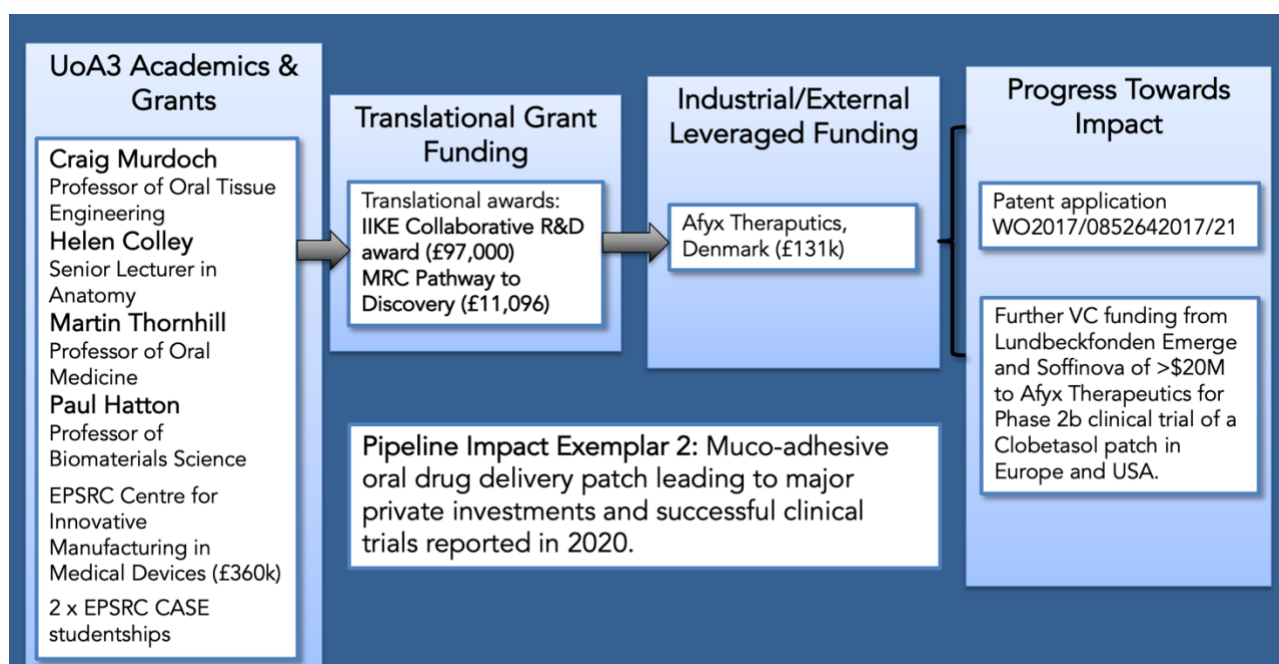
Future strategy: Through a coordinated University and Sheffield Teaching Hospitals (STH) oncology research strategy, we will undertake integrated research to inform prevention strategies, early diagnosis, and better treatments, driven by patient needs to improve patient outcomes. We will create an interdisciplinary centre with world leading scientific, clinical, and translational oncology expertise that is integrated with primary, secondary and public health care, and industry.

B. Translational, clinical, and patient-centred research

Dentistry (31 PIs)

Oral and dental research at Sheffield mirrors the wider ethos of the unit, with basic biomedical research feeding translational programmes directed at major clinical challenges, informed by patient and public engagement. Delivering on our REF2014 goals, staff collaborate with other academic groups, industry, and the NHS to develop drugs, devices, and other interventions that have the potential to make a major impact on human health. For example, EPSRC funding (MeDe Innovation, **£360k, Hatton**) enabled the engineering of mucoadhesive oral patches for management of oral diseases, including pre-malignant lesions (**Colley, Biomaterials**), resulting in venture capital investment for clinical trials (**Pipeline Impact Exemplar 2**, Section 4.2). We lead key clinical and related studies, including new ways of reducing children's dental anxiety (**ICS Dental Anxiety**), and a multicentre trial investigating melatonin as a pre-medication in children (NIHR MAGIC, **£1.64M, Deery**). Our goal of increasing interdisciplinary collaboration has resulted in a significant increase in research income compared with the previous REF period (**£6M to >£8.5M**).

Future strategy: Our research will maintain its focus on disease biology, including cancer, infection, pain, and tissue injury and degeneration. To benefit patients, especially children and young people, we will exploit synergies between our scientific, engineering, patient-centred research and clinical expertise to develop innovative modelling, detection, and advanced therapeutic interventions.



Nursing (10 Pls)

Nursing is among the top 100 nursing departments worldwide (QS World University Rankings) with research centred around the themes of: child and family health; palliative and end-of-life care; and enhancing the lives of older people. Reflecting our research strength and exemplifying our collaborative relationships which translate to patient benefit, Sheffield is the **only UK university to host a Strategic Research Alliance (SRA) with the Royal College of Nursing**, a programme of research on workforce, emerging nursing roles, and nurse education (**Ryan, Tod**). The SRA seeks to influence public policy and promote better outcomes for the population and the NHS workforce. Building on this success, Nursing was awarded (2020) the **Mesothelioma UK Research Centre (Tod, Gardiner)**, to conduct research that is of benefit to the care of people diagnosed with mesothelioma and their families. Research on relationship-centred care has led to significant enhancements in quality of life for older people (**Ryan**).

Future strategy: Collaborations with local and regional NHS Trusts are being strengthened, with plans to expand joint clinical research capacity by way of senior research appointments and the development of a shared agenda and strategy with Sheffield Management School focused on interdisciplinary research. We will continue to expand the evidence base for clinical practice in nursing; this includes user-focused translational pathways for improving patient outcomes and clinical environments.

Human Communication Sciences (HCS) and Orthoptics and Ophthalmology (OO) (17 Pls)

HCS researches speech, language, literacy and interaction, contributing to the empirical base for theory and practice in speech and language therapy, linguistics, education and the biobehavioural sciences in adults (**Herbert, Cortex**) and children (**Clegg, JCPP**). Our research is conducted in English and other languages (**Ozturk, PNAS**; **Cowell, J Mem Lang**) with specific applications to multilingual communication (**Fricke, Reading and Writing**). We have developed and tested interventions for acquired speech disabilities in adults (**Whiteside, Stroke**) and literacy difficulties in young people (**Thomson, Reading Research Quarterly**), which were conceived with strong theoretical frameworks. Speech rehabilitation using technology forms the basis for significant impact (**Cunningham, Section 4.2**). Award-winning communication clinics (Royal College of Speech and Language Therapists, Sternberg Award, **Herbert**) provide a means to support community engagement, student learning experience, and clinical and research capacity in partnerships with the NHS and Charity sectors (**Tavistock Trust for Aphasia, Sheffield NHS CCG, Parkinson's UK, Alzheimer's Society UK**).

OO is one of three UK academic units in the field of Orthoptics, researching the evidence base for clinical practice. Key areas involve psychosocial and functional impact of adult strabismus (**Arblaster, NIHR Clinical Doctoral Research Fellowship**) and visual system neuroplasticity (**Buckley, Frontiers in Psychology**). A diverse portfolio of research-driven KE involves UK and international partners. It includes: the development of cost-effective clinical guidance for vision screening across Europe (Griffiths, EU Screen, Horizon 2020,) which has shaped Public Health England's guidance on early vision screening in children; and partnership in an award-winning network developing patient pathways (Griffiths, **Arblaster**, Nystagmus UK Eye research group, **British Medical Association Award**).

Future strategy: Our research will drive advances in science, practice, and policy. Focal areas include: improving social inclusion in relation to socio-economic disadvantage and clinical conditions affecting vision and communication; applying novel linguistic and behavioural approaches to human health research; and innovating digital technology to increase access to education and rehabilitation. Strategic research alignment with Nursing will expand our capacity to

Unit-level environment template (REF5b)

better serve the health and social care needs of children and young people, and of adults in later life.

Health and social care research (11 PIs)

Health and social care research is focussed within two interdisciplinary research centres: the Centre for Assistive Technology and Connected Healthcare (**CATCH**) and Centre for Urgent and Emergency Care Research (**CURE**). **CATCH** (Director: **Hawley**) is an interdisciplinary centre, researching digital healthcare and assistive technologies which aims to develop new user-friendly technologies to enable independent living and improve healthcare for older and disabled people. CATCH encompasses a broad range of expertise including: identifying unmet clinical needs; harnessing engineering research; technology development; patient/user group evaluation; and the implementation of new technologies within health and social care.

In combination with investment of **£1M** from the University, CATCH has won substantial (**>£11M**) grants over the assessment period (Section 3.1), produced a portfolio of notable outputs (**de Witte, J Med Internet Res; Palmer, Lancet Neurology**) and collaborated with the NHS and care organisations to introduce and evaluate >20 innovative technology-supported services (Section 4.2).

CURE is the focus of research into urgent and emergency care, securing **~£10M** in funding in the current assessment period. Through close links with the Emergency Department of STH and the Yorkshire Ambulance Service locally, and emergency and urgent care services nationally, it aims to improve the delivery of care across the urgent and emergency system. Key work areas include performance metrics (*ICS Response*), waiting times and risk-adjusted mortality rates, methods for managing demand for urgent care, reducing avoidable admissions, and delivery of specialist emergency care.

Future strategy: The mission of health and social care research is to address one of the world's grand challenges: how to provide the best care for all in the context of a rapidly ageing population with rising incidence of long-term conditions, frailty, and disability? One major goal is to develop new user-friendly technologies to enable independent living and improve healthcare for older and disabled people (**Hawley, de Witte, JMIR Aging 2020**). Future plans include examining how emerging technologies (AI, robotics, IoT) and data science are likely to impact health and social care and shaping how these emerging technologies impact on health and well-being.

1.3 Enabling impact

Our strategy since REF2014 has been to maximise our impact by fully exploiting the translational potential of our two themes of ***Mechanisms of Health and Disease*** and ***Transforming Care***. Impact activities have been facilitated by the **Sheffield Healthcare Gateway** (SHG, Section 3.2) which has been supported by **>£2M** HEIF funding. SHG provides dedicated professional expertise to enable the development of relationships between academics and external collaborative partners, sustaining an environment that fosters innovation, maximises opportunities for impact and accelerates translation, often using HEIF funds for pump-priming. We have focused our investment and support for impact on three overlapping areas, which span the breadth of research within the unit and are reflected in our ICS.

- a) Through investment in, and development of, translational health-related research partnerships, we have harnessed the strengths of our **fundamental biomedical science** to develop effective anti-cancer treatment (*ICS Lynparza*). Substantial University support has led to the first-in-man stem cell therapy for hearing (**Pipeline Impact Exemplar 1** and

Section 4.2) and improved management of trigeminal nerve pain (**Boissonade, Atkins**), where Sheffield is the main tertiary referral centre for trigeminal nerve injury, performing 95% of repair surgeries in the UK in the assessment period. Facilitated by SHG, we maximize exploitation of IP and establishment of University spinouts (Section 4.2).

- b) To **significantly improve patient experience** we build on our extensive links with the **NHS** to ensure the achievement of impact for our clinical and clinically related disciplines. The University and STH have a joint research office and a joint research hub for the **Transforming Care** theme. NHS clinician scientists (**Cooper-Knock, Swift, Rothman**) carry out basic research in labs, informed by their clinical practice, leading to the development of health technologies (*ICS Cordella System*), improving cancer detection (*ICS Zedscan*), providing physical support for those suffering from neurological disease (*ICS Heads UP*); and psychological interventions: reducing anxiety in children about dental visits (*ICS Dental anxiety*).
- c) To ensure that our health and social care research can be effectively translated into **policy changes**, we have developed a comprehensive **Programme of Parliamentary** engagement through links with the UK Parliament Knowledge Exchange Unit, e.g. the launch of research findings from the Recovering Quality of Life (ReQoL) research programme. The recruitment of Lord Willis to act as Chair of the Collaboration for Leadership in Applied Health Research and Care, Yorkshire and Humber (**CLAHRC YH**, Section 4.2) provides a further focus to raise the profile of our research in Parliament. Staff in this theme (e.g. **Hawley**) also work part-time within the NHS. There are over 40 Patient and Public Involvement (PPI) groups in STH, which allow reciprocal exchange of expertise and experience between researchers, patients and families. This has resulted in step changes in NHS policy for ambulance response times (*ICS, Response*), paramedic training (*ICS, Practitioners*), use of prophylactic antibiotics to prevent endocarditis (*ICS Endocarditis*), and nutritional support and the use of gastrostomy in patients with motor neurone disease (*ICS Progas*).

Future impact strategy

Recognising that impact is likely to be stronger when co-produced, we will continue to build upon, and sustain our interactions with key stakeholders and partnerships to ensure research is relevant to identified priorities, leveraging appropriate investment and research support as required. We currently have an extensive impact pipeline (**Impact Pipeline Exemplars 1-4**; Section 4.2 and 4.3) and ongoing projects likely to lead to significant impact include: **Cork**, building on his REF2014 ICS, on skin emollients to establish international guidelines for skin treatments from birth (**Cork, Lancet**); **Gardiner** developing policy with Public Health England and National End of Life Intelligence Network to enhance palliative care; development of antimicrobial bone graft substitutes, supported by HEIF-funded collaborative R&D awards, (**Miller**, patent WO2020044028A1) where the global costs for device associated osteomyelitis is estimated as **>\$1.6B** in 2020 alone; increased patient access to the IBS drug, alosetron, (**Grundy**), which has resulted in significant patient benefit as well as pharmaceutical industry profitability. The IBS treatment market is projected to reach **\$1.6B** by 2026. Repurposing methotrexate, a rheumatoid arthritis drug, to treat myeloproliferative leukaemia, opens the possibility for it to be sold cheaply in low- and middle-income countries (LMICs) (**Zeidler**). **Bass** is collaborating with Smith and Nephew to develop non-invasive ultrasound devices to treat chronic wounds (**Bass, J Invest Dermatol**), a current NHS burden of **~£3B** per year. Further examples of our industrial and societal impact pipeline are described in Section 4.

Unit-level environment template (REF5b)

1.4 Support for interdisciplinary research

In recognition of the scale of research required to understand the complexities of health across the life-course, the challenges of an ageing population and how this is integrated with brain function, the interdisciplinary **University Flagship Institutes of Neuroscience and Healthy Lifespan** (Figure 1) were established with projected investment of **£13.7M** over 5 years. These provide overarching umbrellas within which collaborations and synergies between research themes are being realised. Researchers in the areas of stem cells, cell and developmental biology, cancer and inflammation collaborate with neuroscientists to tackle the enormous challenge of treating degenerative, sensory, and developmental neurological disorders (**Cunliffe**, *Epilesia*; **Grierson**, **Hautbergue**, *EMBO J*). The Healthy Lifespan Institute provides a focus for the breadth of our research aimed at improving quality of life from birth to old age, encompassing our themes of Nursing, Health and Social Care research, Human Communication Sciences as well as cellular mechanisms of ageing (**Foster**, *Lancet Psychiatry*; **Ryan**, *Health Services and Delivery*).

More specialist interdisciplinary research is driven by a variety of research centres that are devoted to key biomedical challenges. These in turn have overlapping research interests, e.g. members of the **Florey Institute** (Section 1.2), in addressing mechanisms of inflammation resolution, collaborate closely with researchers in the **Bateson Centre** to use non-mammalian models of disease (**Furley**, *JCI*). Collaborations between staff in the **Sheffield Institute for Nucleic Acids**, and the **Florey institute** underpin our spin-out company **DeFENition** (Section 4.2).

In silico modelling and mechanobiology are increasingly yielding new insights and opportunities for improvement in healthcare. The Institute for *in silico* Medicine (**INSIGNEO**) is Europe's largest research institute dedicated to the development, validation, and use of biomedical modelling, imaging and informatics in healthcare. INSIGNEO comprises >150 staff across the University, attracting **£54M** of research income in a partnership that aims to generate a framework for computer modelling of mechanical, physical, and biochemical functions in man (**Serbanovic-Canic**, *Circulation Research*; **Lawford**, *JACC Cardiovascular Imaging*). Future collaborations between unit staff and INSIGNEO include increasing critical mass to establish Sheffield as a recognised hub in understanding mechanopatho-mechanisms and the development of novel therapies. This interdisciplinary endeavour will build on international networks of biophysicists established by the Biopol and MIMIC ITNs (Section 2.3).

The University Flagship Institutes and centres act as hubs, promoting collaborations through vibrant seminar series and retreats and acting as foci for recruitment (Section 2.1, IRFs). Our postgraduate researchers (PGRs) are exposed to the value and execution of interdisciplinary research through our PhD programmes which bridge fundamental biomedical science, clinical and patient-oriented research (Section 2.3). Almost all staff are actively involved with these institutes and centres, including several with senior roles (**Bellantuono**: co-Director of the Healthy Lifespan Institute, Hawley: Director of CATCH, **Collini**: Clinical Lead for the Florey Institute, **Smythe**: Director of Centre for Membrane Interactions and Dynamics (CMIAD); **Narracott**: Director of Operations at INSIGNEO).

1.5 Progress towards an open research environment

We embrace open science approaches to research, and see these as key to raising and maintaining standards of research integrity across the sector as well as in our own environment. We are part of the UK Reproducibility Network and a Research Practice Lead has been appointed to develop the processes and platforms we use in research, including study design, data collection, storage and sharing, analysis, interpretation and integration of research findings, and publishing

Unit-level environment template (REF5b)

and dissemination (**REF5a**). There is an active ECR-led Reproducibility group, which meets regularly to explore open science and its challenges.

Within the unit we are moving to a system of electronic lab notebooks and all raw data are stored securely on mirrored storage for 10 years in line with journal and UKRI requirements.

To ensure maximum discoverability of our research, we aim to put all outputs in White Rose Research Online, our shared repository with Leeds and York (green route). The 2,832 outputs deposited over this assessment period were downloaded over 277,000 times. This is our preferred route, ensuring equity in publishing opportunities regardless of available funding; we also publish outputs in fully OA journals or hybrid where required for funder compliance. In addition, staff increasingly submit papers to preprint services such as medRxiv or bioRxiv to ensure timely dissemination of research findings.

We regularly host seminars and workshops on open data and sharing practices. Where possible data are shared in national data centres or repositories, e.g. mass spectrometry data in the [PRIDE/ProteomeXchange repository](#). We also encourage data deposits in the University's data repository (ORDA), which enables research data to be preserved, discovered, and accessed.

Accessible databases

Research within the NHS can lead to significant cultural changes within the organisation itself, including potential impacts on workforce, skills and knowledge, service delivery, patient and carer experience, as well as economic benefits. To capture and share these 'ripple' effects, **VICTOR** (Visible ImpaCT Of Research, **Cooke**) was launched by CLAHRC YH as a tool to demonstrate the impact of delivering research. VICTOR can be accessed [online](#), was already accessed by ~200 UK organisations by August 2019, and is being used in Australia and Denmark. The *Addressing Capacity in Organisations to do Research Network* (ACORN) organisations have included the VICTOR tool as part of their annual planning to promote the benefits of research at executive level and into the community, e.g. provision of easy access to information regarding ambulance response times (*ICS Response*), which can be used more widely to inform policy. Support is currently being sought from NIHR to fund an interactive VICTOR tool, which will further extend its reach.

NIHR-funded **CUREd** is a unique research database, containing over 15 million patient episodes, collated from a number of service providers in the Yorkshire and Humber region (2011-2017). This allows analysis of patient demand as well as the flow of patients through the system. Data are available on request to external researchers focusing on urgent and emergency care within the UK.

Clinical trials data

In accordance with current guidelines, we ensure that any research involving patients that is considered a trial, is registered in a suitably accessible database. Many of our larger research projects (MAGIC, **Deery**; BRIGHT, **Marshman**), managed by NIHR-funded Clinical Trials Research Units, have study specific websites and/or Twitter accounts, which also help with the recruitment of participants and disseminating study outcomes. It is our policy to publish the findings of clinical trials that do not result in positive effects of the tested intervention e.g. **Marshman**, **Deery**, FICTION, PMID: 32340074.

Unit-level environment template (REF5b)

1.6 Promoting a culture of research integrity

We promote a respectful, egalitarian, and supportive environment where open discussion and constructive criticism of experimental approaches and findings are actively encouraged. Ensuring trust and confidence in the methods used and the findings of our research is fundamental to our reputation. We expect high professional standards from our research staff and ensure that the training and development opportunities that we offer facilitate this. Awareness and implementation of research governance is organised within departments, with appropriate academic leadership, integrated with the central University systems and interfacing with colleagues in STH. The unit builds on the outstanding support of the University for research integrity (**REF5a**) e.g. in line with institutional policy every PGR has to undertake a **mandatory ethics module** and provide a **research data management plan**. Ethics modules cover topics such as the legislative limitations and ethical implications in human interventional research and biomedical science, including considering real-world scenarios. In the Postgraduate Research Experience Survey, 94% of students agreed that their understanding of research integrity had improved, evidencing the success of this approach.

Research requiring research governance is automatically flagged at costing/ application stage. Post-award, funds are released only when appropriate Home Office licences and ethics governance are agreed and in place. STH's Clinical Research & Innovation Office is responsible for research involving human patient samples. Ethical approval applications for human interventional studies and clinical trials are supported by our Research Ethics team. A flow chart tool helps researchers identify the appropriate governance requirements for each study. Human volunteer studies not requiring NHS approval, require ethical approval from our Research Ethics Committee, chaired by an academic who sits on the University Research Governance sub-committee. Towards the **study end** the ethics office flags the biorepository and the investigator with reminders on sample storage requirements (destroy, extend, transfer) governed by the agreed ethics. We perform an **annual audit** of all projects to confirm that all **samples are held in accordance with the Human Tissue Act** or under active ethics approval. All PGRs detail ethics proposals within their data management plan. We view maintaining strong integrity as essential to conducting impactful research that is transparent and reproducible.

Research using hPSCs falls under the regulatory framework of the UK Stem Cell steering committee. Derivation of stem cell lines requires HFEA licences. Sheffield has been at the forefront of establishing due diligence, enabling derived cell lines to be used in clinical studies (PMID: 29553577). Human tissue storage is either under licence or held within the Sheffield BioRepository in accordance with the Human Tissue Act. PGR students are trained in GMP policies and good practice.

2. People

People are our most valuable resource and our unit is a collegial and supportive place to work. We promote an environment where all can flourish and realise their ambitions, with equal opportunities for recognition, reward, and progression for all staff whatever their career stage or role. Our goal of excellent underpinning research to drive translation and impact requires a strategy that recruits for diversity, in individuals, career stage, disciplines and approaches, and recognises a very wide range of contributions. For administrative purposes, e.g. teaching, staff are affiliated with several departments in two faculties, however membership of research centres and institutes allows narrow disciplinary barriers to be dissolved.

Unit-level environment template (REF5b)

2.1 Staffing and recruitment policy

Staff profile and succession planning

Our overall demographic is illustrated in Table 1. We recognise the importance of an appropriate balance of early career colleagues, together with those moving towards research leadership, as well as existing leaders, and this is reflected in the distribution over early, mid-career and senior academic positions. This enables effective succession planning, which is also enabled by appointing deputies to shadow leadership roles, allowing more junior staff to gain experience. It is noteworthy that 72 staff (46%) in the unit are female. There are 149 staff who have open-ended contracts (125 full-time, 24 part-time), and 28 with clinical contracts. We are returning all our Category A Eligible staff.

Table 1a. Category A staff profiles

Total	Female	Male	BAME	Promotions
155	72 (46.5%)	83 (53.5%)	13 (8.4%)	73

Table 1b: Grade profiles within the unit

Lecturer and equivalent	Senior lecturer and equivalent	Professorial
36	64	55

Independent research fellows (IRFs)

We continue to focus on attracting future leaders to our clusters of research strength (e.g. **Swift, Rothman**: Inflammation; **Cooper-Knock**: Neuroscience; **Gardiner**: Palliative care; **Tsakiridis**: Stem Cell Biology). Our strategy is not only to attract, but also to nurture IRFs with the highest potential to achieve excellence. We thus mentor prospective candidates from their initial applications through to setting up their independent research teams. As IRFs establish themselves, we provide a supportive environment. Since 2018, the Faculty of Science has guaranteed progression to an open-ended contract for all IRFs with fellowships longer than three years, subject to the candidate meeting new lecturer probation requirements. A fully-funded PhD studentship is also provided for each IRF to help develop their independent research programme. This is also common practice within the Faculty of Medicine, Dentistry and Health. Because IRFs are attracted to particular research centres, they join existing research groupings where they have access to shared equipment as well as joining cognate group meetings to gain constructive feedback from staff with complementary expertise. Administrative and teaching loads are kept low and intellectual and pastoral support is provided by allocation of an experienced academic mentor. IRFs are thus allowed to fully dedicate themselves to establishing their nascent research groups and the success of this approach is evidenced by their significant publications as independent researchers (e.g. **Tsakiridis**, *eLife*; **Swift**, *Am J Crit Care Med*; **Rothman**, *JACC Cardiovasc Interv*; **Cooper-Knock**, *Cell Reports*).

Our strategy of attracting and supporting the next generation of research leaders is further evidenced by the success of **Gardiner** (with **Tod**) in winning substantial funding (£480K), to establish the first Mesothelioma UK Research Centre. She is also instrumental in establishing national and international policy ([Government response to end of life care](#)) on the delivery of palliative care for a range of conditions. **Rothman** has been instrumental in developing devices that have had significant patient, as well as commercial benefit (*ICS Cordella system*; **Pipeline Impact Exemplar 3**). **Tsakiridis** has been awarded EU funding (€530K) for emerging technologies

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and MRC funding (£1.2M), jointly with Great Ormond Street Institute of Child Health, to develop therapies for Hirschsprung disease. **Cooper-Knock** was awarded an MRC/MRC Lady Edith Wolfson Clinical Research Training Fellowship to pursue PhD studies, prior to his Wellcome Career Development award and is now an NIHR Clinical Lecturer. We will continue to recruit future leaders to areas of existing and developing research strength and we are currently supporting candidates who are submitting applications investigating mechanobiology and hearing.

During the assessment period we have strengthened existing research themes through strategic appointments to more senior positions. **Condiffe** was appointed as Professor of Respiratory Medicine, further strengthening our infection and inflammation core. **Mustapha** relocated from Stanford, funded by a non-clinical MRC Senior Fellowship, to understand congenital and age-related hearing impairment, thus further enhancing our sensory neuroscience research.

2.2 Staff development policy

Academic departments within the unit provide **all** staff (professional services and academic, temporary and permanent) with a tailored induction on arrival, and staff are subsequently mentored through an annual Staff Review and Development Scheme (SRDS). This is an important opportunity for individuals to reflect on their work of the previous year, including the most and least satisfying aspects, as well as to consider their career aspirations and how best to achieve them. Although not used as a metric, SRDS is integral in preparing staff for promotion, working with a designated mentor. This means that staff are able to build a portfolio of achievements that align with both organisational and personal goals, and this enables them to maximise opportunities for reward and recognition, including promotion following the Academic Career Pathway Framework (**ACP, REF5a**). Impact activities are recognised and rewarded through ACP (e.g. promotion of **Miller, Murdoch, Pacey** and **Whiteside** to personal chairs).

Early career researchers (ECRs)

A dedicated ECR committee, (**Miller**, Chair), composed of departmental ECRs, ECR academic champions as well as human resources representatives, aims to ensure we provide the best support and environment to enable our ECRs to exploit opportunities for personal and career development. The ECR committee inputs directly into the strategic design of a wide-ranging programme of training (**Think Ahead**) and mentoring to equip ECRs with a broad range of specialised and generic skills. This not only allows ECRs to develop and flourish in their current roles, i.e. produce high quality research outputs, but also contributes to future career aspirations within or outside academia. To ensure we achieve our aims, and in line with the 2019 'Concordat to support the career development of researchers', the ECR committee Chair sits on the Faculty Research and Innovation Committee. This has led to better representation at both departmental and faculty level and ensures input into relevant institutional policies. Regular meetings between the ECR Champions have led to clarity around their responsibilities during the recent COVID-related disruption. In response to requests from ECRs, we have initiated dual SRDS reviewers, normally the line manager, and another staff member who ensures that ECR professional development is prioritised alongside research projects. University policy is for fixed term researchers to have 1 day/month equivalent for professional development, exceeding the recommendation of the Concordat.

"**Think Ahead**" is a specific ECR staff development programme coordinated by a dedicated member of the professional services team, which aims to highlight employment opportunities and professional and career development. This programme is a comprehensive blend of training workshops, career mentoring, and selected work-based opportunities. The scheme encourages researchers to develop plans to support their career trajectory through access to tailored

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development activities. For example, an undergraduate research experience scheme enables ECRs, with the support of a senior academic, to develop skills as primary supervisors for funded summer student projects. **Cooke**, as Professor of Capacity Building, facilitates the development of non-medical clinical research careers. An annual Faculty of Medicine, Dentistry and Health prize recognises the outstanding contributions that postdoctoral research staff make and rewards excellence in any of the four categories: Research, Teaching, Leadership and Wider Participation. Less formal mechanisms also contribute to ECR development, including a number of relevant postdoctoral researcher societies, e.g. Researchers in STEM. These are run by ECRs who organise seminars and events that contribute to cohesion and well-being among these communities. This integrated approach to managing ECRs work and welfare is considered key to maximising career development opportunities, including transition to academic, clinical, or industrial settings.

Onward destinations for our ECRs include academia with 16 appointments to lecturer or senior lecturer in diverse Allied Health Research settings (e.g. Hollinger, Clinical Educator for NHS Highland, and Lecturer, Scotland; Atapattu-Bakmeewewa, Human Communications, Sri Lanka; Gupta, Dentistry, Aberdeen; Lodge, Respiratory Medicine Clinical Lecturer, Imperial College), IRFs (McGovern, Sir Henry Dale Fellowship) and more than 40 appointments as postdoctoral researchers; roles as NHS analysts (NICE, CRUK Biomarkers), in biomedical charities, industrial roles in R&D and management (e.g. Covance, Janssen, Boehringer Mannheim, Afyx Therapeutics), medical writing and communication, and politics.

Through **CURE** we have collaborated with Health Education England to improve paramedic recruitment, retention, and clinical development. One of the first paramedics (Miles) to be awarded an NIHR AHP clinical research fellowship is based in CURE.

Specialised technical support

Our strategy to maintain our first-class research facilities (Section 3.3) is to recruit and retain highly qualified senior experimental officers (SEOs) and technicians. Sheffield launched the first National Technician Development Centre for University technicians in 2017 and is a signatory to the Technician Commitment, pledging to ensure visibility, career development, recognition, sustainability and evaluation of the impact of technical roles. The value of this approach is exemplified within the unit. This cohort of staff is responsible not only for the maintenance of equipment but also for training of staff and students in state-of-the-art technologies. Importantly, they ensure that the latest developments are implemented. In turn this provides significant opportunities for staff development. Robinson was initially appointed as an SEO for the Wolfson Light Microscopy Facility and, through ongoing career development, has been promoted to Facility Manager, line managing two SEOs and contributing to intellectual as well as technical elements of microscopy (e.g. PMID:32340074). Baxendale (Zebrafish screening unit) has contributed to several publications (Section 3.3). Acosta-Martin, (BiOMICs) quantitated the contribution of our research facilities to Masters training as part of her own Masters degree.

Dedicated research time

The University offers study leave for academic staff with the opportunity to seek dedicated time to further an area of research. There will be renewed emphasis on the benefits of study leave in the next REF period to encourage staff to develop avenues which will have long-term benefits for their research programme. This will be achieved by co-operative management of teaching, and application for schemes such as Leverhulme Research Fellowships (**Smythe**, 2020/21).

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Our work allocation model has been developed during this assessment period to allow us to allocate and protect a specific proportion of academic time for research and related impact activities, as well as recognising the importance of time (5-10%) for external activities that contribute to professional standing.

2.3 Postgraduate research

We train both clinical and non-clinical PGRs and our community has grown significantly with a 100% increase in doctoral degrees awarded since 2014. It is a diverse community of UK (51%), EU (4.1%) and non-EU international students (44.9%). Our **submission rate** reached **100%** in 2019.

Strategy and recruitment

We recruit PGR students on the basis of excellence at undergraduate and postgraduate level, with particular emphasis placed upon research experience and motivation. Our aim is to equip students to become excellent researchers, with the potential to excel both in academic and non-academic careers, and to be able to engage fully with end-users (from industry to policymakers), thus ensuring they maximise their potential. As our submission rates have improved, facilitated by key monitoring milestones at 12 and 36 months, we are now focused on ensuring that PGRs have a realistic expectation of submitting their theses within their funded period, as working without funding has such a detrimental effect on mental health. We have undertaken a full review of the essential skills and competencies required to achieve a PhD to ensure that PGRs manage the amount of development they wish to undertake but also to ensure they do not over-commit. To do this we complement subject-specific training in the context of a broader Doctoral Development Programme, which identifies existing skills and offers potential to develop new skills by having a tailored training needs analysis, agreed upon by student and supervisor. Students can access a wide range of University courses in skills such as statistics, computer coding as well as master classes in microscopy, mass spectrometry and bioinformatics. PGRs have many opportunities to present their data as oral and written presentations to departmental and research centre groupings. This provides excellent opportunities for constructive criticism and pastoral support if required. They are also actively encouraged to attend national and international meetings where they have been successful in winning prizes (Section 4.4).

The success of our training is reflected in significant PGR contribution to our research output (e.g. 19% papers submitted to the unit have PGRs as authors, including first authorship on ground-breaking studies: Webster, *EMBO J*; Greenald, *PNAS*; Kirk, *Science Translational Medicine*; Bardsley, *Biomaterials*; Dehghani-Tafti, *Nucleic Acids Research a and b*; Maib, *JCB*; Rayagiri, *Nature Comms*; Frith, *eLife*; Allison *Nature Comms*; Sharma, *Nature Comms*; Pasquina-Lamonche, *Nature*). Beaurivage (PMID: 31726729) was awarded paper of the year. Stavish was first and corresponding author (*Nature Comms*, PMID:33020476).

We actively support those students who wish to remain in research to launch their independent careers. Examples include Frey (Fulbright Scholarship, University of South Florida), Frith (Sir Henry Wellcome Fellowship, Francis Crick Institute), Stooke-Vaughan (Otis Williams Fellowship, University of Santa Barbara). Many of our basic science PGRs remain in research taking postdoctoral positions in the UK as well as worldwide, including institutions such as Harvard and Stanford. Other career destinations include positions in industry, government departments, e.g. DEFRA, clinical trials management, allied health disciplines including nursing and patient care.

Building an awareness of impact is integral to our postgraduate programmes. From the beginning students are expected to write and maintain statements highlighting the impact of their research.

Unit-level environment template (REF5b)

Students have opportunities during Professional Internships for PhD students (**PIPS**, **BBSRC DTP** Section 2.3) to explore how they can use their expertise in a wider professional context (e.g. Natural England Evidence Services). In addition to those students who are funded by CASE collaborative awards with industry, students often choose to carry out their PIPs in industry (e.g. Taylor, now employed by Janssen Pharmaceuticals). Studentship programmes such as the MIMIC ITN-ETD and the HEFCE-funded Catalyst Industrial Placement Award scheme (Ferreira with Eli Lilly, resulting in Boissonade, *Mol Pain*) allowed students to spend significant time in an industrial context. Students are actively encouraged to participate in schemes such as the BBSRC Biotechnology Young Entrepreneurs Scheme (Section 4.4).

Funding and capacity building

A variety of studentship programmes reflect our research themes and commitment to interdisciplinary research. Staff within **Transforming Care** can access funding from the **Clinical Doctoral Nurses and Allied Health Professionals (CARDiNAL)** network (NIHR) which is a network of universities and NHS Trusts that provides the opportunity for fully qualified nurses to pursue postgraduate studies while continuing with clinical work. The **Nursing SRA** supports the development of clinical research careers through studentships and scholarships. The **Wellcome 4ward Northern Clinical Academy** (in partnership with Manchester, Leeds, Newcastle, Francis Crick Institute) aims to train the next generation of clinician scientists through funding 25 clinical fellows (4 awarded to the unit). To fully exploit this pipeline, additional bursaries are available to enable newly qualified clinician researchers make the all-important transition to successful postdoctoral research careers. **Arblaster** was supported by an **NIHR Doctoral Fellowship** to pursue PhD studies as a staff candidate. **MRC Discovery Medicine North (Furley: co-lead)**, in partnership with Leeds, Newcastle and Liverpool, aims to deliver training in stratified medicine, focusing on the best treatment for every patient. The **EPSRC-funded White Rose Doctoral Training Centre in Tissue Engineering and Regenerative Medicine** (Sheffield Lead: **Hatton**), **Centre for Innovative Manufacturing in Medical Devices** and **CDT in Polymers and Soft Matter** (Unit lead: **Hatton**) all provide opportunities for interdisciplinary studentships focussing on development of therapeutic devices while the **BBSRC Mechanistic Biology White Rose DTP** (in partnership with Leeds and York) trains basic science PGRs in interdisciplinary approaches to understanding the organisation of molecules, cells and tissues that are fundamental to **Mechanisms of Health and Disease**. The UKRI programmes have received substantial University investment (>£2M), as well as the appointment of **Ortega** to build capacity in tissue engineering. In line with our REF2014 aspirations we have more than **doubled** (4 to 11) the number of CASE studentships. Recognising the contribution of the PGR community, the University also funded a significant number of studentships (>£1.5M) during the assessment period, notably 18 to the Florey Institute.

Internship scheme

As part of our commitment to sustainability in impact awareness, we have used the OnCampUS PGR/T impact internships to work with researchers to identify, develop and track impact. The scheme has expanded significantly since its inception, building from 1 intern in 2016 to >350 by 2020, and the unit has been awarded 4 interns from each cohort. Many of the students are recruited from the Master's in Public Research programme which, having a high proportion of international students, builds capacity not only in the UK but worldwide.

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2.4 Equality, diversity, and inclusion

Within the unit, we recognise the importance of an inclusive, diverse, and high-performing culture which leads to richer, more creative and innovative research. Our EDI strategy is based on adapting our recruitment, support, and development mechanisms to ensure we can fully harness diverse talents and perspectives to advance our research themes. In this assessment period we have embedded this strategy into our operational organisation in the unit, creating departmental EDI Directors who have *ex officio* roles on departmental executive committees and promotions review panels. We now ensure that **EDI is considered in all decision-making processes**. EDI shapes our recruitment strategy with a shift to job descriptions reflecting the requirements of the role, debiasing job advert language, unconscious bias training for all recruitment panels, addition of positive cases encouraging candidates with diverse backgrounds to apply, and independent scoring of candidates against the essential criteria of the job.

The University is a signatory of the San Francisco Declaration on Research Assessment (DORA) in recognition that assessing outputs according to journal-based metrics particularly disadvantages early career, female and BAME researchers. We are committed to responsible research assessment, ensuring that objectives are proportionate for part-time and other equality impacts.

Addressing gender equality

The University holds an Athena SWAN Silver award and ~90% of unit staff are associated with departments that have been awarded either Silver or Bronze awards. Each department has a Gender Pay Gap target. We recognise that practical support is required to further our EDI agenda. Of particular value is the Women Academic Returners' Programme (WARP) scheme where funding up to **£10k** is available to provide additional support for women (ECR and academic) if needed, during a period of parental leave or upon return to work. This helps to minimise the impact of extended leave on research activities. WARP was used by **Rainero** (CRUK Career Establishment Award), **Miller** (promoted to personal chair), **Spencer** (*IJLCD*, 2017) and **Fricke**. It is University policy that staff on parental leave are entitled to up to 10 keep-in-touch (KIT) days, allowing them to maintain contact with their research groups, e.g. by attending research retreats or seminars, or to hold discussions about grant and paper writing with collaborators within, and beyond, the University. To maximise use of these days, researchers within the unit can also access the **Whyte payment** to contribute to childcare expenses during one KIT per leave. The Dame Pamela Shaw Awards give students and staff the opportunity to apply for small awards aligned with the goals of Athena SWAN, including bursaries of up to **£1k** for conference attendance or projects to develop and explore equality issues. Dedicated rooms for infant feeding have been specifically refurbished within easy reach of laboratories and offices to facilitate nursing mothers returning to work. The terms and conditions for staff moving between University and Hospital posts have been harmonised.

Our proactive engagement with support for EDI is evidenced by our equal gender balance and by women holding senior positions: **Mawson** was the only Allied Health Professional to direct an NIHR CLAHRC; **Bellantuono** is Co-Director of the Healthy Lifespan Institute; **Holen** is Director of ECMC, **Smythe** is Director of CMIAD, **Daly** is PGR Director. Over 57% of our current PhD students are female.

Support for LGBTQ+ staff

Sheffield's commitment to eliminating discrimination and promoting diversity includes strong and active support for our LGBTQ+ staff and students, as evidenced by being included on the Stonewall Top 100 Employers list in 2020 for the seventh year running (ranked 11th). This

Unit-level environment template (REF5b)

achievement is testament to the importance that the University places on LGBTQ+ inclusion and frames our own efforts in the unit.

Support for neurodiversity

We have actively taken steps to support neurodiverse staff through technological and mentoring support, prioritising tasks that make the most of their inherent strengths, facilitating and encouraging flexible working arrangements and adjustments to workspace or encouraging homeworking where possible.

Support for disabled staff

Disabled staff and PGRs are supported via the University Disabled Network. Within the unit, there is provision for disability leave, a form of reasonable adjustment to enable disabled staff to be absent from work in certain circumstances, for example to undergo treatment, assessment or rehabilitation as part of managing their disability and maintaining their fitness/health and well-being at work. We have protocols in place, where feasible, to ensure access to equipment (e.g. remote access to microscopes) for people of all abilities.

Support for BAME staff

By creating a diverse and inclusive community, we aim to address the clear discrepancies in career progression between Black, Asian and minority ethnic (BAME) and White researchers. We have a race equality action plan with targeted actions around positive recruitment of IRFs. **Ali** is a member of the BAME Staff Network Committee, set up to address the needs, priorities, and concerns of staff from diverse non-White groups. All staff on boards and committees undertake implicit bias and addressing diversity training. We aim to improve diversity from the ground-up, building and progressing BAME talent from PGR and ECR stages using BAME mentoring and support networks, with senior academics as advocates.

To provide good role models, we take practical steps to increase diversity in our external seminar programmes and encourage staff to invite female researchers and members of BAME communities to present seminars. Our seminar programmes include recognised academic experts in the field of inclusion (*Apampa*, Birmingham, *Tiwari*, Colorado) as well as experts in EDI in research (*Tracey*, Wellcome Trust).

Preparation for the REF2021 submission

The University has a Code of Practice for REF2021 submission that stipulates processes to ensure EDI which was adhered to in preparing this submission. All members of our REF Committee undertook REF-specific EDI training, including material on recognising and countering implicit bias. Our REF team is representative in gender and as inclusive as possible, with peer review of outputs undertaken by staff with a breadth of expertise. Following our Code of Practice, outputs were selected on the basis of ranked quality. Where outputs were assessed as being of equal quality, we considered protected characteristics, both in output selections and in deciding author attributions for co-authored outputs. The University has undertaken equality impact assessment of our output scoring and attribution, and on our independent researcher decision-making, and found no evidence of bias.

The institutional process for disclosing equality-related circumstances was highlighted to staff to ensure awareness of the support available. Clear policy statements ensure there will be no detriment to staff either in their independent researcher status or in the number of their outputs submitted. REF status is not used during recruitment, review, or promotion.

3. Income, infrastructure and facilities

3.1 Research funding and strategies for generating research income

Our aim has been to grow our external research income to support our strategy of underpinning excellence and its translation to patient benefit. Within the assessment period, researchers within the unit have successfully secured new research awards > **£75M** as PIs, of which **~£56M** comes from grants greater than £100k. The mean funding is **~£0.51M** per FTE. Notably 50 PIs obtained funding in excess of **£0.5M**, reflecting the strength and breadth across all of our research and ensuring that our success is not dependent on a small number of individuals. The breadth of our research is also reflected in our funding portfolio, which includes UKRI (MRC, EPSRC, ESRC, BBSRC and Innovate UK), NIHR, charities (Wellcome Trust, Royal Society, CR-UK and BHF), central UK government as well as commercial and industrial sources. This diversity of sources ensures resilience and demonstrates our agility in winning funding in an increasingly challenging landscape. Members of the unit have successfully led large consortium grants including: **Mawson** (NIHR CLAHRC YH, **£10M**); **Andrews** (UKRMP Pluripotent Stem Cell Platform, **£25M**); **Ryan and Tod** (SRA with the Royal College of Nursing, **£1.4M**); **Erdmann** (MIMIC and BIOPOL EU ITN networks, **€3.9M**), **Hoggard and Griffiths** (POLARIS MRC, **£3.2M**); **Fagan** (Wellcome Collaborative grant **£1.2M**); **Deery** (NIHR MAGIC clinical trial, **£1.64M**); **Hawley** (Telehealth and Care Technologies, **£1.2M**).

Grant capture

Our strategy is to provide support for grant capture at all stages, including recognition of EDI as a priority, resulting in a high proportion of successful grants being led by women. Staff can outline ideas for both developing and more mature projects at grant workshops attended by colleagues within research themes who provide constructive feedback. Internal peer review on draft applications is carried out for all UKRI grants with at least two independent reviewers providing feedback in time for pre-submission revisions. Peer review is also widely used for grants to other funding agencies. For fellowship applications, specific support is provided by University Research Services who co-ordinate mock interviews with academics who have served on fellowship committees. Evidence for the success of the approach is that within the assessment period, we have obtained several prestigious fellowships (MRC Non-Clinical Senior Fellowship (**Mustapha**), Wellcome Clinical Career Development Fellowships (**Swift, Rothman, Cooper-Knock**), Royal Society Fellowship (**Johnson**), and BHF Intermediate Fellowship (**Serbanovic-Canic**)).

Enabling sustained success

Our well-developed mentoring system and support for staff (Section 2.1) ensures that all newly appointed lecturers since 2014 have successfully secured grant funding. Several of our recently appointed staff have subsequently won substantial funding, e.g. **Fagan** won further UKRI (MRC and BBSRC) project grants as well as co-ordinating a Wellcome Collaborative award. Existing Royal Society IRF, **Johnson**, successfully secured his renewal. Building on an Academy of Science Springboard Award, **Rainero** was awarded a CR-UK Career Establishment Award.

Alignment with national funding agencies

Our strategic priorities align with those of UKRI and major UK charities. **Andrews** and **Barbaric** have had key roles in leading the UK Regenerative Medicine Platform (UKRMP) (Sections 1.2 and 4.1). **Condliffe, Parker, Bullough, Prince** and **Marriott** are all part of the SHIELD consortium

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which received **£3.5M** to combat antimicrobial resistance by boosting immune responses (Bewley, *Am J Respir Crit Care Med.*, Section 4.1). **Condliffe** is part of the COG-UK Consortium (**£20M** from government, NHS, PHE, UKRI) to sequence the UK SARS-CoV-2 virus. **Monk**, with **Partridge**, has a GCRF award (£675K) to explore membrane microdomains as a target for antimicrobial drug discovery.

Research funding generating impact

Fagan co-ordinated a Wellcome Trust Collaborative (**£1.2M**) award to study the antibiotic resistance of *Clostridioides difficile* using cutting-edge structural biology and infection modelling. Following a successful collaboration with AvidBiotics (Kirk, *Science Translational Medicine*), **Fagan** is developing a new relationship with Summit Technologies to understand the mechanisms of action of novel antibiotics targeting *Clostridioides difficile*. **Bullough** (PI) and **Fagan** (collaboration with **AvidBiotics**) received BBSRC funding (**£579k**) to investigate the structural interactions between engineered bacteriocins and explore their potential as non-antibiotic anti-microbial agents. Since its foundation (2016), DeFENition (**Sayers**) has awarded research contracts (>**£720k**) to the University. **Sayers** (co-I) received MRC DPFS funding (**£2.6M**) to develop novel treatments for acromegaly (collaboration with **Asterion**, Sheffield spin-out company established 2000). University spin-out company DeFENition (Section 4.2) arose following MRC CinC funding (Section 3.2) exploiting genome integrity studies (**Sayers**, *Nat Structural Mol Biol*). This triggered Bill&Melinda Gates Foundation funding (**\$463k**) to tackle TB and malaria.

Boissonade (collaboration with Nottingham) leads a programme funded by Eli Lilly, Versus Arthritis, and BBSRC (**£1.3M** in the assessment period), providing proof-of-concept that a specific chemokine axis provides a novel target for analgesic development. **Davletov** has developed a long sought-after, highly sensitive cell-based assay for tetanus. The Sheffield-patented technology has been developed with grant and industrial research funding, and is now a commercial opportunity which is attracting significant interest from end users including vaccine regulators (e.g. **MHRA** **NIBSC**) and companies (e.g. **Merck**).

Together with co-investigators in Cambridge and Holland, **Condliffe** holds an MRC MICA programme grant with **GSK** involving a clinical trial (Coulter, *J Allerg Clin Immun*). Innovate UK and Coeliac UK are funding **Kurien** to work with **Cievert Ltd** (Gateshead) to improve detection and treatment of coeliac disease. Examples of industrial contract research include the Skin Barrier Facility (**Cork**) and the Skeletal Lab (**Bellantuono**).

3.2 Organisational infrastructure supporting research and impact

Identification and exploitation of potential impact:

The Sheffield Healthcare Gateway (Section 1.3) establishes healthcare partnerships and collaborations between academic researchers within the unit and service providers as well as pharmaceutical, clinical, life science and biomedical companies. SHG provides a single point of contact to promote and support knowledge exchange and commercialisation. It employs three dedicated business managers who identify, signpost, and assist with internal and external translational funding schemes (e.g. MRC Confidence in Concept (CinC), MRC DPFS, NIHR i4i), developing the route to market, including licencing and spin-out formation (Section 4.2), coordinating contracts, and liaising with other key professional services including costing and intellectual property, as well as media and public relations. During the assessment period, PIs within the unit have engaged in research collaborations with industrial partners, including CASE studentships with AstraZeneca, GSK, Eli Lilly, Afyx Therapeutics and Sosei Heptares, while 27 PIs

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have benefited from knowledge exchange funding from HEIF. Patenting has always been strongly encouraged and there have been over 92 patent applications filed in all territories. Support is provided to develop and manage translational funding schemes such as MRC MICA (Condliffe with GSK).

MRC Confidence in Concept (CinC) funding: The University has secured 8 successive rounds of MRC CinC funding (since 2015 in collaboration with STH and Sheffield Children's NHS Foundation Trusts as well as Sheffield Hallam University) with a cumulative total >£3.1M to support early-stage translational research. CinC funding has resulted in >£26M follow-on funding of which £16.9M has been secured either by the academic or partners for further development of the translational concept (**Impact Pipeline Exemplars**, Section 4.2), and >£9M to further develop underpinning science (e.g. **Boissonade; Barbaric**).

3.3 Infrastructure

Our strategy in the current assessment period has been to continue to maintain and develop our world-class research facilities, because of their importance in underpinning excellent research.

Imaging infrastructure

Imaging across scales is key for much of our research. Biomedical scientists study interactions within individual cells, between cells within tissues, and between tissues within organisms and, importantly, the dynamics of these interactions. Clinical scientists use MRI imaging in diagnosis of respiratory disease, cancer, and neurodegeneration. In recognition of the importance of state-of-the-art imaging, the University established the **Imagine, Imaging Life** initiative, and invested approximately £10M in studentships and equipment to develop advanced microscopy to gain new insight into life and disease.

The Wolfson Light Microscopy Facility (LMF) (Academic lead, **Smythe**) is a key pillar of the Imagine initiative. It is a multi-user microscopy facility that houses the latest commercial microscopes. During this assessment period it added a light sheet microscope (BBSRC Alert2014, PI: **Whitfield**), as well as an AiryScan microscope (Royal Society and University) to its existing suite of standard confocal, TIRF, wide field and super resolution microscopes. The light sheet microscope has been particularly useful for imaging ear development in zebrafish (**Whitfield, Elife**), while the AiryScan has been used to understand mechanisms of bone loss (**Hunter, Faseb Journal**).

Visualisation of cellular and molecular events that are below the diffraction limit of light is also key to understanding conditions such as cancer, neurodegeneration, and antibiotic resistance. Delivering on our REF2014 aspirations, the University invested in the **Cryo-Electron Microscopy Facility** (Academic Lead: **Bullough**). Key University, UKRI and Wellcome investments (~£4M) allowed the installation of state-of-the-art equipment and computational facilities for CryoEM. Central to this has been the installation of an FEI Arctica cryo-electron microscope, which enables determination of the three-dimensional structure of molecules in cells. This investment has allowed the detailed structure of the cell walls of *Staphylococcus aureus* and *Bacillus subtilis* (**Bullough, Nature**), which are the target of many antibiotics, as well as components of the motility apparatus of *Campylobacter jejuni*, which is the major cause of food poisoning worldwide (**Kelly, Nature Comms**).

The unit has an established tradition in clinical imaging via **POLARIS**. Sheffield acts as a national centre for pulmonary MR imaging, functionally assessing 25% of adults with hypertension in the UK for lung disease using hyperpolarised gas and proton lung MRI. During the assessment period,

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POLARIS received major capital investment from the MRC (£7.5M). Facilities include 5 polarisers, a radio frequency lab dedicated to building new technology scanners and a pulmonary function test lab to couple functional breath testing to imaging. Technological research is facilitated by image-based computational models of lung structure and function (**Norquay, Thorax**). Reducing nuclear medicine scans reduces radiation risk and invasive catheter procedures for patients. A collaboration with the German DZL consortium has led to participation in **CHANGE-MRI**, a Phase III multi-centre diagnostic trial to demonstrate that functional lung MRI can replace ventilation-perfusion scans in a diagnostic strategy for patients with suspected Chronic thromboembolic pulmonary hypertension (CTEPH). If successful, this is likely to lead to a European guideline change for CTEPH screening.

Recently the University provided matched funding of £2M to match £2M raised by donations and alumni to install a new MRI-PET scanner to enhance our clinical research capabilities. The scanner will be used by scientists and clinicians at our NIHR Biomedical Research Centre, dedicated to translating neuroscience research for chronic neurological disorders. In the long term we aim to fully integrate our MRI and PET anatomical and functional imaging techniques through development of hardware via Polaris.

Mass spectrometry

Biological mass spectrometry is performed in the BiOMICs facility (Deputy Director: **Collins**) and allows the identification of protein binding partners as well as established (**Collins, Cell Reports**) and novel post-translational modifications (**Collins, EMBO Reports**). Our capability in metabolomics has been enhanced through a **BBSRC Alert** award to purchase a mobile GC-MS system whose use has included metabolic profiling in precancerous lesions and HPV resistance (PMID:28508693). Demonstrating the scope of the facility, a collaboration with **Croda International** funds a technician to investigate shampoo damage to hair.

Bioinformatics

At the end of the last REF period the University invested £0.5M in a jointly funded high-throughput next-generation sequencing facility for diagnostic and research projects and also set up a bioinformatics hub to provide essential expertise for analysis and modelling of the data generated by these and other screening facilities within the University. The Hub has now developed into two branches: (i) a Bioinformatics Core, staffed by two SEOs, provides advice and training to biomedical scientists and public health workers within the unit on experimental design, high-throughput next-generation sequencing (NGS) analysis, clinical bioinformatics services and microarray analysis; (ii) a partnership between the University and the Sheffield Children's NHS Foundation Trust consisting of independent research groups who have been recruited because of their expertise in different aspects of computational biology (e.g. **Sudbery**) who synergise with our biomedical (PMID:32592946) and clinical research (PMID:28454844).

Non-mammalian models of disease

Sheffield has an established tradition for the use of non-mammalian organisms, especially zebrafish, as models of disease. Our zebrafish facility is one of the largest and best equipped in Europe, housing a globally important collection of mutant and transgenic lines. The aquaria house >112,000 fish, and are complemented by a comprehensive genotyping service, microinjection rooms, cryogenic storage, a behavioural analysis suite and a small molecule screening unit with high-content imaging and robotics for liquid handling. A new database has been installed and philanthropic investment has supported the upgrade of behavioural analysis equipment and software. Funded zebrafish projects during the assessment period include a community wide

Unit-level environment template (REF5b)

CRISPRi resource (BBSRC, **van Eeden**). Output highlights include studies on inflammation (**Furley, JCI**) and regeneration (**Roehl, Nat Comms**). As a University we have signed the Concordat on Openness in understanding animal research and are at the forefront of implementation of the 3Rs.

Screening facilities

The Sheffield Zebrafish Screening Unit performs a wide range of *in vivo* drug screening assays in zebrafish embryos. Since 2014, the facility has responded to a shift in drug discovery research towards phenotypic screening in *in vivo* systems because of success in producing 'first-in-class' drugs. Screens have identified potential anticonvulsants (**Cunliffe, Epilepsia**); regulators of androgen signalling (PMID: 31919453, **van Eeden**), pituitary function (**Watt, Human Molecular Genetics**). External collaborations include screens to prevent hair cell death (University of Sussex PMID: 29263311; Baxendale, **Whitfield**); with UCL on Usher Syndrome (PMID:31998945, Baxendale) and there are ongoing collaborations with ICR, KCL, and Manchester. **Whitfield** collaborates with Sosei Heptares (BBSRC NPIF and EPSRC PhD studentship), seeking novel GPCR targets (Diamantopoulou, *eLife*). Screens in the siRNA Screening Facility have identified novel pathways involved in cytoplasmic drug delivery (BBSRC CASE studentship with AstraZeneca, **Smythe**).

Sustainability of research facilities

Our facilities have appointed academic leads supported by management committees that include representatives of user groups. The leads ensure that facilities remain state-of-the-art by co-ordinating and enabling appropriate multiuser equipment bids (e.g. BBSRC Alert) This led to awards of **£1.29M** supported with matched funding from the University (**~£2M**) during the assessment period. Our facilities run on established business models allowing them to be self-funding to cover maintenance and personnel costs. This ensures that our equipment is always fully operational and is supported by highly trained SEOs and technicians who provide specialised training which in turn enables us to expand our capability. In the Wolfson LMF, for example, in addition to the LMF manager we have employed two part-time SEOs who provide specialised support for light-sheet and super-resolution microscopy.

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

4.1 Research Collaborations, Networks and Partnerships

Collaborating with and contributing to society form an integral part of our vision. The global issues addressed by our research: **Mechanisms of Health and Disease** and **Transforming Care**, can only be tackled through interdisciplinary approaches, coupled with national and international collaboration. Our strategy is first and foremost to create an environment for excellent research, then to ensure that our researchers have the time and support needed to develop appropriate collaborations.

International collaboration

We have a number of mechanisms to support researchers at all career stages, and our institutional frameworks underpin this. For example, the **ACP** rewards and recognises international collaboration resulting in excellent research or impact. We provide funds and organisational support for:

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- Staff visits and exchanges, examples include: **Winder**: Mexico, Germany, and USA (*Aging Cell*); **Johnson**: Italy (PMID:31846752); **Murdoch**: Poland (PMID: 27777406, 32681704); **Thomson**: Norway (*Reading and Writing*) and Canada (SSHRC Partnership Grant 2020, CA\$2.5M).
- Early career colleagues receive support and mentorship to access Marie Curie schemes: Palanca (**Dall'Ara**, PMID:28457604); and these have led to new collaborations for more senior colleagues Gentile (**Hatton**, PMID:28169513); De Felice (**Boissonade**), Radhakrishnan (**Hunter**, PMID: 29980182, 29416610), and Zafred, (**Sayers**).
- Seminar programmes and conference attendance.

As evidence of our international collaboration, some 50% of our outputs have international co-authors.

The following exemplars illustrate participation in national/international networks, which have been initiated during the assessment period:

- **Narracott** is providing research leadership to build capacity in Krakow via an EU and Polish government funded project (New Methods in Computational Diagnostics and Personalised Therapy to deliver *in silico* products and services).
- **Gardiner** works with partners in Canada and Africa with funding from the Winston Churchill Memorial Trust to advance our understanding of international approaches to palliative care.
- **Erdmann** and **Smythe** have collaborated with EU partners on an EU Industrial doctorate programme advancing work on organs-on-chips for high throughput drug screening.

The unit has benefited from opportunities arising from institutionally funded initiatives and networks:

- The Worldwide Universities Network has provided a springboard for work with Ghana (**Thompson**) and the US (**Rutter**: *The phonetics of dysarthria: studies in production and perception*. Equinox)
- Institutional Global Challenges Research Fund competition enabled new collaborations benefiting our understanding of the global south and allowing us to provide funding to support their participation. Examples include:
 - **Ortega** (India) worked with LVPEI Prasad and successfully improved synthetic membranes, a step in the process for developing a new low-cost corneal blindness treatment which is viable in LMICs.
 - **Cunliffe** (Ghana) is testing natural compounds as anti-convulsants.
 - **Stafford** (US) secured funding of \$165,000 from the National Institute of Dental and Craniofacial Research (NIDCR) scheme for a collaborative PhD studentship.

Reflecting our two research themes, we both lead and participate in significant national networks and collaborations:

Mechanisms of Health and Disease

- **Andrews** and **Barbaric** are key partners with Cambridge, Edinburgh, and Imperial in the UK Regenerative Medicine Platform. Andrews was Director in the first phase (£25M UKRI funding 2013-18) and the unit is a partner in the second phase (£17M, 2018-23).
- **Juusola** collaborated with Sussex and QMUL with EPSRC funding to investigate reverse engineering biological systems to develop improved robots. This research underpins a University spin-out company Opteran Technologies, which secured £2.1M venture capital investment to develop low-cost silicon robot brains which mimic insect behaviour.
- **Cunliffe** is part of a BBSRC/ESRC funded EpiStressNet network, including Glasgow, Bristol, Imperial College and Leicester which takes an intradisciplinary biosocial systems approach to understanding epigenetic embedding of social stress responses.

Transforming Care

- **Hatton, Miller, and Ortega** secured £6M from EPSRC with Leeds, Bradford, Newcastle, Nottingham, and Cambridge to undertake biomedical manufacturing research.
- **Deery and Marshmann** secured £2M with Dundee and Aberdeen to undertake a clinical trial to improve treatment for children with Pulpitis.
- **Palmer**, with Manchester and Glasgow, (£1.5M HTA NIHR) evaluated self-managed computer-based speech and language therapy post stroke in 20 UK NHS speech and language therapy departments.

4.2 Relationships with key research users, beneficiaries, and audiences

Our ambition is to enhance quality of life for all ages and to improve disease treatments and diagnostics. To ensure that our research delivers appropriate impact we actively engage with the NHS, DHSC, industry and other key stakeholders including the public.

Collaborations with the NHS

Perhaps our most strategic relationship is with the NHS. In order to ensure that our research impacts positively on patients, we have a threefold approach.

Investment in excellent clinician scientists: **Bishop** is the only Professor of Paediatric Bone Disease in the UK and leads the largest paediatric metabolic bone disease unit in Europe. His research translates into better treatments for childhood bone fragility and he has transformed patient fracture prediction by developing the FRAX tool, which is now used routinely in 64 countries worldwide.

Securing funding for commissioned research: **CURE** has had a substantial NHS policy impact through work on ambulance performance measurement and standards (PGfAR PHoEBE project and NHS England Ambulance Response Programme). Two current NIHR funded studies in progress are developing pre-hospital assessment or triage tools to help paramedics identify patients with major trauma (MaTTS) and sepsis (PHEWS).

Strategic investment in regional networks: an exemplar of this approach is the Collaboration for Leadership in Applied Health Research and Care Yorkshire and Humber (**CLAHRC YH**, Director: **Mawson**). Established in 2014 it aimed to perform high quality applied research and evidence-based implementation to improve the health and wealth of Yorkshire and Humber. From an initial

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investment of **£10M** from NIHR, CLAHRC YH realised **£14.6M** in matched funds along with an additional contribution of **£2.6M** from industry which resulted in the generation of **>£74M** of external income in the period to 2019. Funding supported a diverse range of projects including establishment of smoke-free mental health services, palliative care through collaboration with **Sensory Technologies** (see below) and expansion in the range of diseases screened in new-borns (collaboration with **Great Ormond Street Hospital**). Projects supported through CLAHRC YH have had international reach with new-born screening implemented in **Bangladesh** while in **Bangalore** local women have been enabled to use a mobile diagnostic and screening toolkit to screen for diseases in some of India's poorest urban areas. The legacy of CLAHRC YH has provided the foundation for ongoing partnerships through the NIHR Applied Research Collaboration alongside NIHR MedTech Co-operative Devices for Dignity.

These approaches have enabled us to respond swiftly to the COVID-19 pandemic. Rapid commissioning of two studies in CURE have assessed outcomes of patients with suspected COVID-19 admitted to emergency departments (**PRIEST** study) and who called NHS111 or the 999 emergency ambulance service (**Prehospital PRIEST**).

In 2020 we won contracts from DHSC to supply recombinant SARS-CoV-2 Nucleocapsid antigen for development of new, high-throughput COVID-diagnostics tests as alternatives to PCR for potential NHS deployment.

Collaborations with industry

Collaborations with industry are vital both in co-creation of research questions and in ensuring research results have impact. Unit staff collaborate with companies ranging from large multinationals (e.g. GSK, Afyx Therapeutics, Pfizer) through to SMEs, including businesses in the Sheffield City Region and the North. **Pipeline Impact Exemplar 1-3** indicate how the infrastructure described in Section 3.2 has facilitated collaborators between researchers within the unit with industrial partners, leading to substantial translational impact.

CATCH collaborations with industry have led to development of a range of assistive technologies:

- Research with HMA Digital (**Hawley**) developed three health apps targeted at older people and people with dementia.
- NIHR funding and collaboration with Therapy Box (**Cunningham, Hawley**) created a post-stroke rehabilitation app with IP being licensed to the company to underpin the technology.
- Work with Sensory Systems Technologies led to investment of **£1.1M** into end-of-life technologies enabling community-based care providers to deliver palliative care under the online supervision of specialist palliative care clinicians.
- Funding (**£970k**) from Innovate UK and Department of Health, and collaboration with Therapy Box (**Hawley**), led to a unique communication aid app for people with severe disabilities and moderate to severe dysarthria.

Spin-out companies

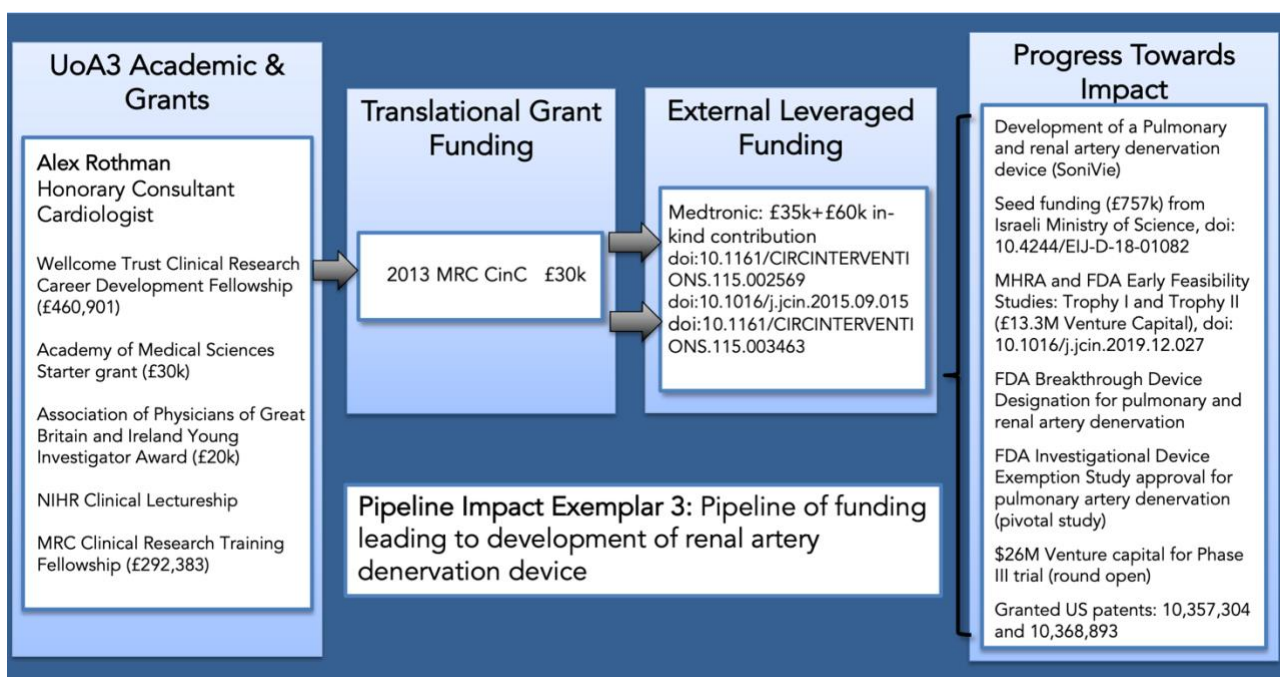
Our spin-out companies are an excellent route to develop therapies and to transform care. They also provide research funding back into the unit to continue research: a truly symbiotic relationship. Exemplars during the period within our two themes include:

Mechanisms of Health and Disease

- **Davletov** collaborated with the National Center for Advancing Translational Sciences and Maximov at the Scripps Research Institute, to found Neuresta; a significant US government grant has ensured regulatory support and leveraged private investment into non-addictive treatments for neuropathic pain.
- **Mead** founded Keapstone Therapeutics with co-investment of **£2.6M** from Parkinson's UK and the University to enable exploitation of a novel chemical series which aims to treat Parkinson's and motor neurone disease.
- **Sayers** secured **£1.4M** venture capital funding, together with SBRI and Innovate funds of **£600k** for DeFENition which develops inhibitors of Flap endonuclease in Gram negative bacteria.

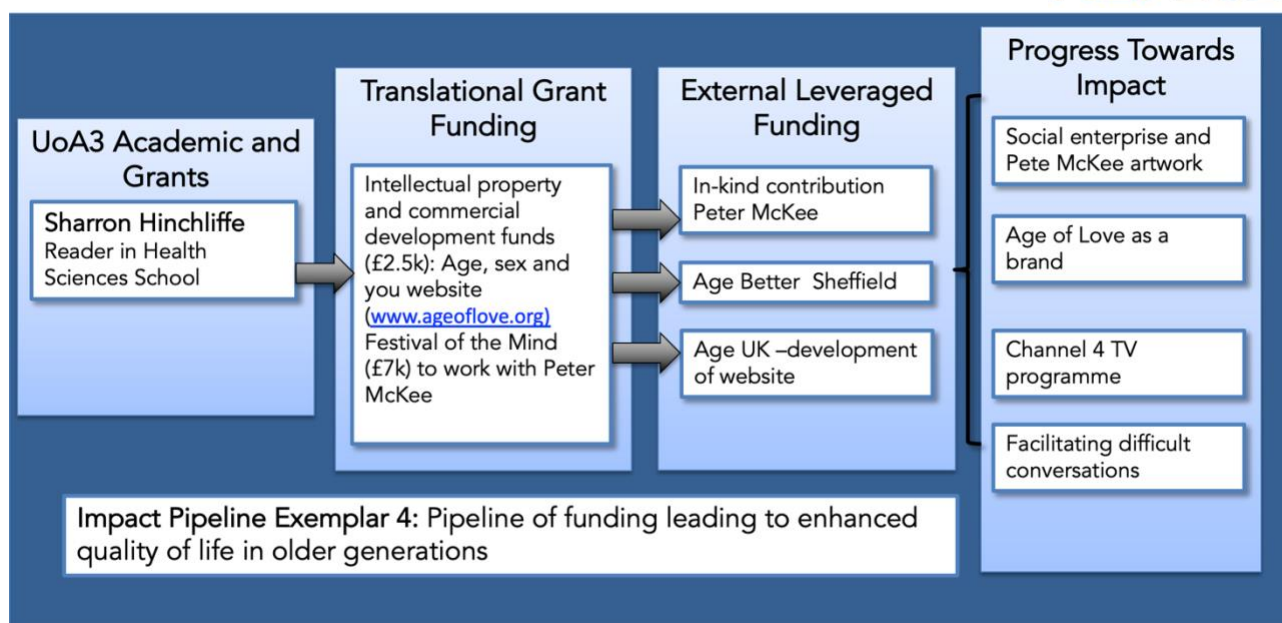
Transforming Care

- **Rothman** has collaborated closely with SoniVie, a start-up with initial investment of **\$11M** to develop pulmonary artery denervation technology (**Pipeline Impact Exemplar 3**).

**4.3 Wider societal impact**

We engage with a broad audience with the aim of creating wider societal impact.

Dedicated support is available for researchers wishing to exploit their intellectual property through social enterprises. **Hinchliff**, working with local artist Pete McKee, has set up a new social enterprise “Age of Love” to support older people in their relationships. This has facilitated conversations that were considered difficult. The idea has been adapted by Channel 4 for their ‘dementia café’ series. **Pipeline Impact Exemplar 4** illustrates how institutional funding from the Higher Education Innovation Fund (HEIF) enabled the development of this impact.



Ali received institutional investment from our IP Development fund, and the Burdett Trust, to work with Focus Games. This led to development of a board game for domestic abuse support workers (<https://www.dvgame.co.uk/>) which is now on sale and has been endorsed by 'Safe Lives' and Police Scotland. This led to a course 'Supporting Victims of Domestic Violence' on FutureLearn.com, which was ranked in the top 35 such online learning resources across the globe in 2020 and has enrolled over 10,000 students.

Stakeholder engagement promoting policy

We identify appropriate stakeholders to ensure that our research is translated into tangible patient benefit. **Gardiner** and **Seymour** (Emeritus) have engaged with policymakers including Public Health England to improve advanced palliative care (ACP) planning following a commission from the European Association for Palliative Care, the leading European advocacy organisation for palliative care with membership from 52 countries worldwide. The work resulted in an international 'White Paper' defining optimal APC, providing a consensus framework and facilitating greater understanding and adoption of APC across Europe, North America and which is now underway in Asia. **Seymour** was a member of the expert panel of the Canadian 'Palliative Care Matters' Consensus, an initiative that promotes debate and informs policy initiatives. This led to the commission of research about how best to raise public awareness of PC which subsequently informed the Canadian PCM consensus statement on PC which has been widely adopted across Canada and contributed to a federal private member's bill committing to the adoption of "a framework on palliative care in Canada".

Enderby is a technical expert on the WHO Rehabilitation 2030 program to develop rehabilitation guidelines and harmonise services. **de Witte** is co-editor of the flagship report on emerging technologies and their potential for the field of assistive technology that the World Intellectual Property Organisations (UN) is developing. He is also a member of the editorial team for the Global Report that WHO is developing.

Public engagement

Recognising the importance of public engagement and dissemination of research and research principles, staff within the unit make regular contributions to local, UK and international events, including Festival of the Mind, which have attracted more than 400K people in recent years

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(<https://www.sheffield.ac.uk/pre/public-engagement>), Discovery Night, Science Week, Pint of Science, Researchers Night, Sheffield International Documentary Festival (DocFest) and the literary festival 'Off the Shelf'.

Pacey is extending his work set out in a REF2014 case study, as a writer for BioNews and Trustee of the Progress Educational Trust (PET). He has appeared in 1,306 English Language media articles within the assessment period with an estimated audience of ~2 billion. He regularly appears on news and documentary programmes on major networks such as the BBC.

Gardiner (2019) broadcast an interview on US National Public Radio on loneliness among older people.

Mustapha participated in an exhibition on hearing and deafness at the MRC Festival. Due to positive feedback, an invitation to present 'The Senses' (MRC Festival 2020) online followed.

International Clinical Trials Day is an annual event in Sheffield city centre, which demonstrates a 'mock' clinical trial, demonstrating how clinical trials are conducted.

Staff at all levels participate in visits to local schools, motivated to increase public understanding of research and also widen participation of less advantaged children in Higher Education. For example, **Hautbergue** presents "Our Amazing Brain" interactive lecture series to local schools (>100 children each year). Staff perform hands-on experiments during Science Week, as well as during Pint of Science, and the MRC Festival of Medical Research.

4.4 Contribution to the sustainability of the discipline

The institutional framework for recruitment and promotion recognises academic citizenship as a core part of our endeavour. As such, unit staff contribute to the sustainability of their disciplines both in leadership and contributor roles.

Societies and professional bodies

Unit staff make significant contributions to their professional communities through membership of relevant societies, professional bodies, and institutions. This includes leadership roles within these organisations. Exemplars include:

- Founding member of the Association of Biomedical Andrologists and Chair of the British Fertility Society (**Pacey**)
- Vice-President for Science and Research at the Royal College of Paediatrics and Child Health (**Bishop**)
- Chair of the Oral Microbiology & Immunology Group of the British Society for Oral & Dental Research (**Stafford**)
- Director of research and development for the Royal College for Speech and Language Therapists (**Palmer**)
- Chair of the Biomedical Materials Division Institute of Materials, Minerals and Mining (**Hatton**)
- Chair of the Dental Schools Council (**Deery**).
- **Enderby** is president of the International Association of Communication Sciences and Disorders.

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Support for journals

During the assessment period, staff were members of editorial boards of over 80 peer-reviewed journals which cover the full range of subjects that are relevant to the unit (Figure 2).

Editors-in-Chief

Editorial Board Members



Figure 2: Examples of journals where unit staff play leading roles

Invited Presentations

Researchers gave >250 keynote lectures including **Rothman** (Royal College of Physicians Quincentenary Lecture, 2018), **Condcliffe** (Royal Society of Medicine 2017), **Prince** (British Thoracic Society 2016 meeting), **Bishop** (Slemenda Award lecture at the International Conference on Children's Bone Health meeting 2019), **Gardiner** (5th International Conference of Advance Care Planning and End of Life Care), **Hinchliffe** (21st Congress of the European Society for Sexual Medicine, Slovenia).

Services to funding bodies

Unit staff serve or, have served, on grant awarding panels for a wide range of UK and international sponsors.



Figure 3: Examples of national and international funding agencies where unit staff serve on panels

Related evidence of esteem and standing

Staff also serve on over 50 advisory boards in the region, UK, and overseas. These include:

- President of the Global Alliance of Assistive Technology Organisations (**de Witte**).
- Director of International Stem Cell Initiative 2004 - 2017; member of steering committee 2017 onwards (**Andrews**).
- Chair of the Steering Group for the UK National External Quality Assurance Scheme for Andrology (**Pacey**).
- Chair of the European Association for Palliative Care taskforce on financial costs of caring (**Gardiner**).
- Membership of Scientific Advisory Boards including charities (**Holen**: Breast Cancer Campaign/Breast Cancer Now; **Winder**, Duchenne UK), research centres (**Davletov**, Izmir Biomedical Centre, Turkey; **Hatton**, Versus Arthritis Centre for Tissue Engineering), international, national and regional bodies (**Hinchliff**: World Association of Sexual Health, **Rivolta**: Stem Cell Program for the Cell & Gene Therapy Catapult; **Hatton**: Yorkshire & Humberside Medilink; **Allen**, South Yorkshire Motor Disorders Research Advisory Group).

Honours and awards

The high esteem and contributions of members of the unit has been reflected by the award of a wide range of national and international awards. Exemplars include:

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- In recognition of its contribution to improving the lives of patients suffering from neurodegenerative diseases, SITraN was awarded the **Queens Anniversary Prize for Innovation in Neuroscience** (2019).
- **Rodd** received an MBE (2020) for services to children's dentistry. **Enderby** (Emeritus) received an OBE (2018) for outstanding contributions to speech and language therapy. **Pacey** received an MBE for services to reproductive medicine (2016).
- **Di Giovine** was awarded the Sir James Black Award for Contributions to Drug Discovery (British Pharmacological Society) in 2016 (jointly with Duff and Nuki).
- Lifetime achievement award (2014) from International Journal of Palliative Care Nursing and Macmillan Cancer Support (**Seymour**)
- Royal College of Speech and Language Therapists Sternberg Award (**Palmer**, 2014; **Herbert**, 2015)
- Outstanding Achievement Award from Lung Cancer Nursing UK (**Tod**, 2019)
- Mary Seacole Leadership Award by RCN 2016 and the Emerging Researcher Award by Sigma 2017 (**Ali**).
- David L Turpin Award for Evidence-based Research (**Benson**, 2018)
- Samuel Charles Miller Award of the American Academy for Oral Medicine (**Thornhill**)
- Charles Tomes Lectureship, Royal College of Surgeons of England (**Rodd**, 2016/17)
- Distinguished Scientist Award for Behavioural, Epidemiologic and Health Services Research by IADR (**Baker**, 2018)
- IADR Giddon Award for Behavioural, Epidemiologic and Health Services Research (**Baker**, 2016).
- Alan Wilson Memorial Lecture Award of the UK Society for Biomaterials (**Hatton**, 2019)
- European Network for Cure of ALS (ENCALS) Young Investigator Award (**Cooper-Knock**)
- Julie Wallace Award by the Nutrition Society (**Kurien**, 2016)
- **Hautbergue** is an elected fellow of the Royal Society of Biology.

We offer tailored support to ECRs and PGRs and the quality and impact of their research has been recognised by numerous poster prizes and awards. These include INSPIRE, the International Association for Dental Research, and the Royal Society of Medicine, Colyer Prize 2020. MIMIC students were finalists in the BBSRC BioYes competition, winning Best Intellectual Property Strategy prize (2018). Harrison won the British Society for Dental Research 'President's Prize' for her work on osteomyelitis where she is also named on a patent. Emerson won the Ghent University Researcher Award for Best Conference Proceedings Paper (2017) from the *European Society for the Cognitive Sciences of Music*. Kindell won the Award for Outstanding Paper of 2015: Emerald Literati Network Awards for Excellence.

Conclusion

We represent a highly effective research community, dedicated to improving human health and well-being throughout the population. Our basic biomedical science provides key insights into

Unit-level environment template (REF5b)

health and disease where it frequently underpins translation into new therapies and devices. Our patient- and public-orientated research results in significant improvements in treatments, practices and policies that have a positive impact on quality of life. The impacts from the research and related professional activities of our staff extend far beyond academia, with development of new medical devices, drugs, surgical techniques, industrial innovation, and increased competitiveness. Building on our twin pillars of ***Mechanisms of Health and Disease*** and ***Transforming Care***, we look forward with confidence to continuing our collaborations with key stakeholders, including the NHS and industry, forming interdisciplinary partnerships to tackle the most pressing healthcare challenges and to improve quality of life across society.