Institution: University of Portsmouth (UoP)

Unit of Assessment: A3 – Allied Health Professions, Dentistry, Nursing and Pharmacy

1 Unit context and structure, research and impact strategy

1.1 Unit context and structure

This submission comprises 42 staff (40.1 FTE, 12F:30M) drawn from the Schools of Biological Sciences (SBS: 13 FTE), Pharmacy and Biomedical Sciences (PHBM: 22.6 FTE) as well as cognate researchers (4.5 FTE) associated with the University 'Health and Wellbeing' Thematic Area (REF5a, paragraph (p.) 9), to which the Unit makes a leading contribution.

All staff are members of the Institute of Biomedical and Biomolecular Sciences (IBBS) whose research is characterised by its breadth and capability to address important questions on multiple levels. This is enabled through four synergistic research groups (Group Leads underlined):

- **Molecular biophysics** (*Callaghan*, *Bemmer*, *Draheim*, *Koenig*, *Kolstoe*, *Lichtenstein*, *McGeehan*, *Pickford*, *Zahn*) study biological processes in terms of the structure and function of biomolecules and their interactions.
- **Genetic basis of disease** (*Dietrich*, *Guille*, *Górecki*, *Lloyd*, *Myers*, *Robson, Scarlett*, *Schubert*, *Sharpe*, *Thorne*) examine the role of genes in early development and in the onset and progression of diseases, and develop and apply gene-editing technology in model organisms.
- **Biomaterials and drug delivery** *(Blunn*, *Cox*, *Lalatsa*, *Roldo*, *Tsibouklis*, *van der Merwe*) focusses on the design, synthesis and medical applications of biomaterials, biosensors, drugs and drug delivery systems.
- **Ageing and Lifelong Health** (*An*, *Brown*, *Butt*, *Fillmore*, *Haque*, *Kandala*, *Louca*, *Hafizi*, *Lewis*, *Maherally*, *Newsom*, *Parker*, *Rutter*, *Shute*, *Sivardeen*, *Swinny*, *Young* plus "Category C" staff, *Bhandari*, *Chauhan* and *Longcroft-Wheaton*) have broad biomedical and clinical interests and utilise an array of model organisms (zebrafish, rodent, human) to investigate the health and disease of various organ systems (gastrointestinal, nervous, ocular, respiratory, urinary), and to develop targeted therapeutic or management programmes for associated medical conditions.

These groups support extensive collaboration within IBBS, with NHS trusts, patient groups, industry, and with national and international research institutes. This extensive network reflects our multidisciplinary approach to research in the biosciences and provides an environment that supports the translation of our fundamental science for societal benefit.

1.2 Achievement of strategic aims for research and impact

In REF2014, 90% of IBBS' research was recognised as 'world-leading' or 'internationally excellent', and 100% of our impact judged as 'outstanding' or 'very considerable'. Unit research has benefitted significantly from the University's decision to devolve REF2014 QR funding to Faculties (REF5a, p.63), and we have used this, together with external funding and additional investment from the University, to strategically enhance this profile. As a result, the size of our submission has increased from 23.8 FTE to 40.1 FTE, we have generated over £12M research income, supported 104 postgraduate research students (PGRS) to completion, and delivered positive societal impacts, as evidenced in our Impact Case Studies and more broadly (4.3). Throughout the assessment period, we have formally evaluated and updated our strategic aims, notably through University Reviews of IBBS in 2016 and 2019, and our achievements of these are summarised below:

1.2.1 Investing in underpinning bioinformatics capability

Identified as a strategic priority in 2014, we have recruited bioinformatics expertise (*Le* (2015-16), *Robson*, 2017) and invested in infrastructure (3.3) that has facilitated large-scale, high-throughput genome sequencing analyses and supported the development of our gene-editing technologies and transcriptomics approaches. Current projects include investigation of differential gene expression during development, gene regulation in proliferating myoblasts in Duchenne Muscular Dystrophy (DMD) and the genetic bases of addiction. Bioinformatics expertise has also contributed to interdisciplinary research on: biofilm composition as a predictive biomarker for infection in medical implants, the effects of environmental contaminants on aquatic organisms, the origins of human and animal remains from the Mary Rose and the identification of novel enzymes from plastic-degrading bacteria.

Since March 2020, *Robson* has led the Sequence Tracking Of Phylogeny in COVID-19 (STOP COVID-19) project and the South Coast sequencing hub for the COVID-19 Genomics UK Consortium (COG-UK). Working in close collaboration with partner NHS Trusts, he manages a team undertaking extensive clinical sequencing of SARS-CoV-2 positive viral samples, enabling the Unit to make a major contribution to the national response to the COVID-19 pandemic.

1.2.2 Extending our research focus and developing new research areas with societal relevance

We have used strategic recruitment and investment to extend the scope of our research strengths, aligned with our extant expertise and international health priorities.

Our Molecular Biophysics group has an established profile of international excellence in fundamental structural biology and biophysical studies of macromolecules, including those relevant in disease. Scientific achievements include structure determination of lignin- and plastic-degrading enzymes, matrix metalloproteinases involved in the remodelling of collagenous matrices and inflammatory processes associated with arthritis, the structural and molecular regulatory mechanisms of ribonucleases relevant to bacterial resistance and screening technology to develop novel antibacterial compounds (*Nature*, *Nature Communications*, *Nucleic Acid Research* and *Proc. Natl. Acad. Sci.*). This research, underpinned by collaborations with

biotechnology companies and a growing portfolio of patented technologies, has attracted sustained funding for RNA aptamer-based methods for analyte detection and research to develop new antibiotics.

We have extended the focus of our Genetic basis of disease research to include mitochondrial genetic mutations in cancers (*Lloyd*) and invested in postdoctoral support for gene-editing technologies. Recent research with clinical geneticists and computational genome scientists has identified a gene variant underlying neurodevelopmental disorders and developed CRSPR/Cas9 technology in *Xenopus* to test the significance of particular genetic variants as causative agents for rare genetic diseases (*Guille* and *Sharpe*). Recent funding (£992k, MRC) to scale-up the pipeline of *Xenopus* gene function analysis evidences the societal importance of this research.

The Biomaterials and drug delivery group has developed novel nano-carriers for brain delivery of biopharmaceuticals and hydrogels for bone regeneration. In 2017, we made a senior appointment, *Blunn*, a biomedical engineer with 25 years' experience at the forefront of joint replacement technology, who extends their work into orthopaedic implants for surgical interventions. As a result, strong collaborations with bioengineers (UoA12) have been established, underpinned by access to shared facilities (3.3) and joint investment (£50k) in specialist equipment to support research on patient-tailored bone fracture repair interventions and 3D bioprinting for targeted drug delivery and scaffolds for tissue regeneration (*Lalatsa*, *Roldo*). As the Director of the University 'Health and Wellbeing' Theme, *Blunn* also supports interdisciplinary research across the Unit, through mentorship and leadership of regional consortia.

To address emerging priorities in Ageing and Lifelong Health**,** we have expanded our basic and translational research into the pathophysiology, diagnostics and therapeutics of major medical conditions, including respiratory and gastrointestinal disorders, developmental diseases, cancers and urinary medicine. New areas of research with particular clinical relevance include the development of novel mucolytics, new therapeutic applications for heparin, the use of urinary fibrinopeptide A to detect the onset of an asthma exacerbation, and the identification of molecular urine markers to improve the diagnosis of bladder disorders in the elderly. Group members in degenerative diseases have unique expertise in the role of glial cells in dementia, the impact of muscular dystrophy (MD) on brain impairment, and the impact of Alzheimer's and Parkinson's (PD) on the gastrointestinal tract, enabling new research programmes on the broader effects of neurodegenerative diseases. To capitalise on this, and an extended range of animal models, we are strategically broadening the focus of our neuroscience research from brain tumours to include neurodevelopmental and brain disorders.

1.2.3 Extending partnerships with key regional NHS stakeholders to support clinical research and translation

We have consolidated research collaborations with NHS-employed (Category C) researchers in the Departments of Gastroenterology and Respiratory Medicine at the Queen Alexandra Hospital, Portsmouth, which have generated significant societal benefits, as evidenced in Impact Case Studies, *UoP03Oesophagus* and *UoP03MISSION*. Broader academic-clinical collaboration with Portsmouth Hospitals NHS Trust (PHT) has been supported by Unit investment in a Partnership facilitator (2016) and in statistical expertise to establish a joint Portsmouth

Technology Trials Unit (PTTU, 2018). Since 2016, >10 MD-PhD clinical research students are registered in the areas of gastroenterology, airway diseases, cardiovascular and metabolic medicine and jointly supervised by Unit staff at any one time. From 2014 to 2018, the Unit hosted joint research conferences and networking events with PHT; these continue through the University 'Health and Wellbeing' Theme. A University-level strategic partnership agreement (2019; REF5a, p.16) formalised this collaboration, with PHT subsequently achieving University Hospital status (now PHUT). Appointments of joint UoP-PHUT academic-clinical Chairs are in progress.

Broader regional NHS collaborations have been supported by funding for research assistants and project costs. Collaborations with clinicians at University Hospital Southampton NHS Foundation Trust (UHS) underpin translational research in the: diagnosis of urinary conditions (*Young* – with Southampton Urinary System Network); use of inhaled heparin to treat cystic fibrosis (CF) (*Shute*); identification of genes involved in neurodevelopmental disorders (e.g. autism spectrum disorder), and the use of *Xenopus* in genomic clinical testing (*Guille, Sharpe*); and optimisation of medicines use (*Rutter* – Drug Safety Research Unit). We are members of the Wessex NIHR Applied Research Collaboration (ARC), the Wessex Academic Health Services Network (WAHSN) and *Blunn* leads the SIGHT (Supporting Innovation and Growth in Healthcare Technologies) project, a UoP-PHUT collaboration with the CRN Wessex supporting the adoption of innovative medical technologies. Enabled through our NHS collaborations, the Unit has made significant and scientifically diverse contributions to the national response to the COVID-19 pandemic. These include diagnostics and virus monitoring (*Callaghan*), repurposing heparin to treat COVID-19-induced lung inflammation (*Shute*), stress-induced alcohol misuse during long-term isolation (*Parker*) and establishing a rapid-response laboratory at PHUT for SARS-CoV-2 genomic sequencing as part of the STOP COVID-19 project (*Robson*).

1.2.4 Supporting and increasing interdisciplinary research (IDR)

A strong element of the Unit's IDR has emerged from the Molecular Biophysics group, focussed around enzymatic breakdown of complex natural and synthetic polymers through interfacial catalysis. *McGeehan*, working with marine zoologists (submitted to UoA7), the US National Renewable Energy Laboratory (NREL) and Diamond Light Source (DLS) and supported by the BBSRC, applied structure-guided protein engineering approaches to lignin-degrading enzymes, whose products are valuable building blocks for the chemical industry, and to enzymes, PETase and MHETase, which can digest one of the most commonly polluting plastics, PET (*Nat. Comms., Proc. Natl. Acad. Sci.*). Recognising the research excellence in this Unit and the potential impact of enzyme innovation to address global health and environmental challenges, the University committed £6M to establish the Centre for Enzyme Innovation (CEI, Director *McGeehan*). In 2019, this was further enhanced by a £5.8M Expanding Excellence in England (E3) award and the PETase project was awarded the Times Higher STEM Research Project of the Year. The CEI acts as an IDR "hub" that draws together research excellence in this Unit (in molecular biophysics, computational chemistry, biochemistry and bioinformatics), connecting it with broader research areas, applications and networks to drive growth in enzyme innovation, spanning a pipeline from discovery to application.

With E3 and University investment, we have embedded IDR within the Unit by creating new laboratories, investing in instrumentation with multi-disciplinary applications (3.3) and recruiting Senior Research Fellows (SRF) with specific expertise in surface analysis (*Bemmer*), *in silico* modelling (*Koenig*), protein design (*Lichtenstein*) and X-ray crystallography (*Zahn*) to work on problem-based challenges. IDR research teams are also supported by Senior Research Associates, Specialist Technicians and PGRS working across disciplinary interfaces.

A focus of the CEI is to develop bio-based solutions for plastic pollution and its far-reaching effects, aligned with our 'Health and Wellbeing' and 'Sustainability and the Environment' Themes. This interdisciplinary ethos and infrastructure has supported *Callaghan*'s new IDR, with colleagues in UoAs B7, B12 and at PHUT, to develop a wastewater biosensor for detailed COVID-19 population surveillance (BBSRC, £466k), as well as new areas of biomedical research within the Unit exploring the health effects of exposure to microplastic particles.

1.2.5 Supporting the delivery of societal impact

Our strategic approach to impact has been to extend our collaborations with key research users (4.2) and to invest in capabilities that underpin, and extend, the societal relevance of our research. We have also employed several mechanisms to embed impact in our research environment and across the research lifecycle, including: (i) consideration of impact in our induction, mentoring and appraisal programmes, and our internal grant peer-review systems; (ii) dedicated Impact Leads in Schools to provide one-to-one guidance, support for non-academic collaboration and raise awareness of the "knowledge exchange" agenda; (iii) specific workload allocations for impact activities; (iv) flexible working arrangements that allow staff to undertake consultancy and maintain practitioner links; (v) impact away-days and "Dragon's Den" style sessions with stakeholders; and (vi) rapid response, "impact acceleration" funding schemes to facilitate implementation. Staff also attend workshops on networking, Intellectual Property (IP) and commercialisation, and on strategies to engage wider audiences, as part of the Research and Innovation Services (RIS) Development Programme (RISDP; REF5a, p.33).

These initiatives have enabled the translation of our research into societal impacts that underpin our Impact Case Studies and wider impact across the Unit (4.2, 4.3). Collaborations with clinicians have underpinned the development and adoption of new techniques and models, which have improved diagnosis of Barrett's oesophagus (*UoP03Oesophagus*), improved the assessment and care of individuals with chronic respiratory symptoms (*UoP03MISSION*) and transformed the speed of diagnosis of rare genetic disorders (*UoP03Xenopus*). Clinical trials are underway to assess novel medical implants, formulations and materials for drug delivery, and new treatments for neglected tropical diseases and conditions such as COPD, CF, DMD and, most recently, COVID-19. New biomarkers, enzymes and enzyme systems, and the development of innovative, patented technologies are improving detection and diagnosis of disease and the screening and development of new therapeutics. Significantly, provision of our research expertise and facilities have improved the excellence, efficiency and integrity of biomedical and health research across the world (*UoP03Xenopus, UoP03Ethics*), and are contributing to the national response to the COVID-19 pandemic.

We will continue this portfolio approach to facilitating impact across the Unit, with an additional emphasis on the translation of patented technologies (3.1) and on new areas of research, particularly IDR, with significant potential societal impact.

1.3 Open research, ethics and integrity

We are committed to an open research agenda: 97% of our outputs have been published under open-access (OA) licences since 1.4.16, 100% of our in-scope REF2 outputs meet Research England's OA requirements and all IBBS members are ORCID registered. Datasets are deposited on University and open-source repositories, such as the European Bioinformatics Institute, Protein Data Bank and Xenbase. All clinical trials are registered on open databases. Since 2018, 72% of the Unit's outputs have been assessed as compliant with the University's Research Data Management policy (REF5a, p.24). IBBS supports primary research on this agenda. *Kolstoe*'s research on research transparency and data sharing was highlighted in the House of Commons Science and Technology Select Committee (STSC) report 'Research Integrity: clinical trials transparency' (2018) and underpinned the Health Research Authority's Make it Public' Strategy (*UoP03Ethics*). *Parker* is the UoP lead for the UK Reproducibility Network and leads the UoP Open Science Network, which has established a ReproducibiliTea journal club and, in 2019, hosted Professor Stephen Lindsay, a key driver of the replicability and open science agenda, to deliver a series of lectures and workshops.

The University Strategy commits us to the highest standards of academic, professional and research integrity (REF5a, p.22-24). This is supported at School level through quality assurance processes that ensure sound research design, participant safety and adherence to ethical codes, openness and transparency. Members of the Unit (*Fillmore*, *Rutter*) sit on the Faculty Ethics Committee that oversees a mandatory ethical review process for all research. As University Ethics Advisor, *Kolstoe* has implemented new systems, including monitoring the registration and reporting of studies involving humans in medical and health care areas. *Guille* chairs the University Animal Welfare and Ethical Review Board and leads the European *Xenopus* Research Centre (EXRC) in driving the incorporation of '3Rs' in animal research into national and international policy and practice (*UoP03Xenopus*). An annual 'Culture of Care' meeting ensures that all individuals undertaking animal research are appraised of recent developments within this area.

1.4 Research strategy to 2026

Our Unit has engaged with the University's new Vision 2030 and Strategy 2025 (REF5a2.0) through consultation in our Research Groups. Beginning with articulation of Groups' research ambitions, we have identified four objectives to build our global reach and reputation and deliver societal impact. These are underpinned by our commitment to staff development, support for PGRS and equality, diversity and inclusivity.

- **Continue developing our established and emergent areas of research excellence** that address global health and life science priorities. This includes building on our expertise in structure-guided protein engineering, synthetic biology, gene editing technology, bacterial resistance, molecular medicine, neuroscience and disease diagnostic biomarkers and extending our excellence in structural cell and molecular biology to translational medicine. We

will enhance the vitality and relevance of our research by using the links of our clinical and practice-based staff to increase patient and public involvement in our research.

- **Further exploit our unique IDR infrastructure and expertise to deliver societal benefits.** We will focus support in areas where IDR approaches, in combination with our expertise in structural and synthetic biology, bioinformatics and biomaterials, can provide unique research solutions. We will develop the CEI as a catalyst for transformative IDR research and impact, and will use this model to support the establishment of other UoP centres of IDR excellence.
- **Nurture our collaborations to develop translational research improving the health and care of individuals, groups and populations.** We will support staff to develop links with beneficiaries through research mentoring and networking, financial support for high-quality engagement opportunities, including secondments and exchanges, and investing in patient and public involvement. We will accelerate the pace of research on the biodesign of enzyme expression systems, biosensors for virus detection, biomarker diagnostics, nanomedicine and technologies to address antimicrobial resistance and improve the diagnosis of rare genetic diseases, aiming for all research groups to develop 'case studies' of impact.
- **Embed a broader, more inclusive approach to supporting all career levels in research excellence.** We will expand our research training capacity and programmes to develop the IBBS talent pool, support professions-based staff into research and postdoctoral researchers towards research independence. We will prioritise support for female leadership programmes, moving towards an improved gender-balance at all grades. We will build on our collaborations with regional NHS Trusts and networks to develop academic-clinical career pathways.

2 People

Category A staff in this submission comprise 22% Professors, 27% Readers/Principal Lecturers, 45% Senior Lecturers/Senior Research Fellows, 5% Lecturers/Research Fellows and 17% are ECRs, indicating a balanced leadership portfolio and a strong pipeline for staff development and progression.

2.1 Staffing strategy

Our strategy is to strengthen areas of existing and potential international research excellence through strategic recruitment and the development and promotion of extant staff. Strategic recruitment of SRFs with specific expertise has supported the expansion of our bioinformatics capabilities (*Robson*) and interdisciplinary enzyme innovation (*Bemmer*, *Koenig*, *Lichtenstein* and *Zahn*). SRFs are appointed on a 4- or 5-year tenure track basis, endorsing our commitment to staff development. Recruitment of *Parker* extended our nervous system research into the study of neuropsychiatric, neurodevelopmental and neurodegenerative disorders, whilst *Draheim* adds bacterial synthetic biology expertise to our antimicrobial resistance research. *Blunn*'s recruitment supports the achievement of our objectives for clinical translation and leadership of IDR. New expertise in medical statistics (*Kandala*) and healthcare modelling (*Haque*) enhances our mixed-methods capabilities for developing interventions to manage long-term health

conditions, whilst the recruitment of new staff with clinical practice expertise (*Louca*, *Newsom*, *Rutter*, *Sivardeen*) supports future pathways to impact.

2.2 Staff development

The University has held an HR Excellence in Research Award since 2013 and is a signatory to the Researcher Development Concordat (REF5a, p.41). Our staff development strategy aims to grow the capability and profile of our researchers through resourcing their time and providing a portfolio of support at all career stages. Since REF2014, we have introduced a new workload model (REF5a, p.2); research-active staff (those regularly publishing research articles) are allocated a minimum of 0.2 FTE for research, with additional time for grant writing, externally-funded research and impact activities. New staff are integrated into our research environment through research group membership, enhanced research workload allocation (0.2 FTE, Year 1) and eligibility for research 'start-up funds'. All early- and mid-career staff have a research-mentor and workload hours are allocated to both mentor and mentee. Annual Performance and Development Reviews (PDR) ensure linkage of individual and Unit-wide research objectives and the identification of development needs. All staff have equal access to School or Faculty funding for staff development (study leave, sabbaticals, conference attendance) and to a variety of IBBS funding opportunities (up to £25k per award) that have supported individuals' research and impact through recruitment of research assistants, project costs and short-term placements. IBBS initiatives to improve publication and grant application quality include 'pitch-to peer', manuscript and grant writing workshops, and internal peer review. IBBS also delivers a unified programme of research seminars that provides staff and PGRS with opportunities for external collaboration and networking. Workshops on funding, publishing, open research and dissemination are offered via the RISDP.

Early-career researchers (ECRs) continue to receive enhanced research workload in Year 2 (0.1 FTE), are preferentially considered for internally-funded PhD studentships as first supervisor with additional supervisors to provide mentorship, and have access to ring-fenced ECR funding to support pilot data collection and collaboration. Through these processes, all ECRs in our REF2014 submission (*An*, *Kolstoe*, *Lalatsa*, *Lewis* and *Young*) are now established researchers, evidenced by senior author publications in discipline-leading journals, external income generation, PhD completions and contributions to Unit and University leadership. Funding support for ECRs can be substantial; for example, support for tenure-track SRFs includes investment in associated specialist facilities, bursaried PhD studentships, project costs, external collaborations and bid development. These mechanisms enabled *Robson* to secure over £250k external funding and lead the regional contribution to the national COVID-19 virus surveillance effort; his position was made permanent on 01.09.2020.

The Unit's postdoctoral research staff (22.1 FTE, 49%F) are members of Research Groups, mentored by permanent IBBS members, and supported to apply for external and IBBS funding and to present their research at national and international conferences. Research staff are represented through a Research Staff Forum, have an annual PDR and are provided with additional career development training and coaching via RISDP (REF5a, p.42). They are also supported to engage with external development opportunities, e.g. specialist training from DLS and EMBL, and programmes to enhance communication (NCCPE and Royal Society) and

commercialisation (Innovate UK ICURe) skills. During this assessment period, research staff, [text removed for publication] (3F) have been appointed to permanent academic positions at the UoP and *Maherally* has secured external funding as an independent Research Fellow. Other postdoctoral researchers have progressed on to roles in academia (e.g. De Montfort), research (e.g. PetMedix; Temasek Life Sciences Laboratory, Singapore) and business (e.g. South Coast Centre of Excellence in Satellite Applications).

We have also targeted support to mid-career researchers to enhance their research profiles and develop their research leadership capabilities, particularly on collaborative projects across discipline and professional boundaries. For example, *Draheim* received a PhD studentship and project costs to develop a high-throughput platform to screen novel antimicrobial compounds that underpinned a patent application and secured Innovate UK funding. *Swinny* has received Unit funding (£60k) and multiple PhD studentships to support the development of research programmes on stress-induced inflammation of the colon, novel and therapeutic targets for the gastrointestinal symptoms of PD (both with *Brown* and *Bhandari*), and antioxidant therapeutics for Alzheimer's (University of West Australia). These have underpinned publications in respected journals (e.g. *Gastroenterology*, *Neuropsychopharmacology*) and awards (£365k) from Alzheimer's Society and Parkinson's UK. Additional support for established researchers includes external mentoring, underwriting or extending postdoctoral appointments while grant renewals are pending, reduced teaching loads and support for mobility between external collaborators and end-users. Staff also attend leadership development programmes, such as "Leader and Manager as Coach". Evidence of the effectiveness of this support includes: *Callaghan* as Deputy Chair of BBSRC Research Committee D; *McGeehan* providing academic and strategic leadership as Director of the CEI; and *Swinny* leading on the strategic expansion of the Unit's neuroscience research.

The principal mechanism for enabling research and impact activities is workload allocation. Staff are recognised and rewarded for research and impact leadership through promotion; the University's Policy on Promotion and Appointment to Reader and Professor includes a broad range of research and impact activities and recognises co-authorship of publications and income generation as PI or CoI. In this assessment period, *Callaghan* and *McGeehan* (1F:1M) have been promoted to Professor and *Fillmore*, *Hafizi*, *Lalatsa*, *Pickford*, *Swinny* and *Young* (2F:4M) to Reader. Reflecting support and development over this census period, *Cox*, *Pickford* and *Swinny* were promoted to Professor and *Draheim* to Reader in September 2020.

Moving forward, a priority will be to support staff with a clinical background to undertake doctoral study and develop their research careers. We will also develop clinical-academic roles; the first appointment, a joint Chair with PHUT in Acute and Emergency Medicine, will be made in 2021. Through development of these roles and membership of the Wessex ARC, we will provide opportunities for academic and clinical staff to develop their research skills and carry out high-quality, impactful research.

2.3 Support for, training and supervision of PGR students

The strength and breadth of IBBS research attracts external PGRS sponsorship from UKRI (e.g. NERC, DLS), medical charities (Alzheimer's Society, Headcase Cancer Trust, MS Society, Ollie Young Foundation, RoseTrees Trust), government agencies (e.g. DSTL, NREL) and industry.

Significant internal resources (£1.0M) have been strategically invested in PhD studentships in priority areas, such as biocompatible bone treatments, genetic regulatory networks, cognitive impairment in MD, discovery of novel antibiotics and antibacterials, and diagnostic tests for mesothelioma. Together, this has resulted in 104 successful completions in this assessment period and 176 PGRS are currently registered on a variety of degree pathways, including PhD, MD, Professional Doctorates and DPharm, indicating the vitality and sustainability of our PGRS community.

PGRS selection is based upon presentations and interviews of shortlisted candidates with the supervisor(s) and Research Group Lead, supported by a trained interviewer. PGRS supervisory teams typically consist of three staff, including external supervisors where they bring additional expertise. PGRS attend mandatory induction at University, Faculty and School levels, covering health and safety, record keeping, laboratory induction, technical training and progress monitoring processes. Specific training needs for each student and project are identified in the first meeting with the supervisor and updated through regular reviews. Supervisors are expected to have regular informal contact with their students and to hold monthly meetings for their research group. Progress in Year 1 is formally monitored by a Major Review Report and presentation to a panel that includes two assessors independent of the supervisory team. Annual reviews with presentations to the same panel are held thereafter. Each School has a Research Degrees Coordinator who is responsible for the monitoring and development of PGRS and is a member of the Schools' Research and Innovation and Faculty Research Degrees Committees.

In line with Vitae recommendations, PGRS attend at least 10 days of researcher development training each year. The University Graduate School Development Programme provides professional and generic skills training (REF5a, p.38) whilst IBBS provides discipline-specific training, including biomedical imaging, genomic and transcriptomic sequence analysis, human tissue usage, statistics, analytical methods and Ethics in Scientific Research. IBBS hosts a PGRS journal club and all PGRS present in Research Groups, at IBBS and School research days and at the annual University Festival of Doctoral Research.

Our PGRS engage in a range of additional development activities to improve their employability. All PGRS receive a bursary to fund attendance at least one conference over the course of their studies and conference presentations by PGRS have won awards, e.g. British Society of Nanomedicine (2016), Global Experts Meeting on Frontiers in Alzheimer's Disease & Dementia (2019). External networking is facilitated by supervisors' extensive collaborations, by the IBBS seminar series, and through access to regional research networks. PGRS accompany supervisors on visits to collaborators and, since 2015, we have invested in an IBBS PGRS placement scheme that, together with the BBSRC PIPS, has supported independent visits to national (e.g. UCL; Target Discovery Institute, Oxford; Cardiff University; Cambridge University) and international (e.g. University of Caen; University of Copenhagen; Danish Technical University; Stem Cell and Brain Research Institute, Lyon; University of Warsaw; Montana State University; NREL, Colorado) research institutes and biotechnology companies (Amyris, California). Since 2016, IBBS has also provided £100k support for high-cost projects that facilitate training in advanced methodologies and techniques. Our PGRS are supported to publish their work; more than 50% of the Unit's returned outputs have PGRS as co-authors.

PGRS are also included on patents and contribute to public engagement and impact activities. All PGRS involved in teaching are enrolled on the University Graduate Students Professional Development programme that is aligned to accreditation by the UK HEA.

Our training and development portfolio is well received (>80% overall satisfaction score across the constituent Schools, PRES, 2019). With strong research, professional and networking skills, our PGRS are well prepared for careers in academia (Senior/Lectureships at Brighton; MMU; UiTM, Malaysia; Assistant Professorships at Baghdad University College of Science; Al Ain University, UAE); research (Humboldt Postdoctoral Fellowship, Goethe-Institute, Germany; Staff Scientist, NREL; Marie Curie Fellow, University of Padua; Research Fellow, National Heart and Lung Institute), clinical settings (University of Massachusetts Medical School; Xuhui Central Hospital, Chinese Academy of Sciences; Senior Biomedical Scientist, UHS; Consultant gastroenterologist, PHUT) and industry (Business development roles with IBM, NIPD Genetics, Ximbio).

Our Unit also contributes to national research training as a core partner in the BBSRC South Coast Biosciences (SoCoBio) DTP; *Pickford* is Training Lead, Unit staff are currently supervising three students and UoP delivers a residential Science Communication Summer School for all SoCoBio PGRS.

2.4 Equality, diversity and inclusion

The University is a signatory to the Race Equality Charter, a Stonewall Diversity Champion, Disability Confident and Working Families and Mindful employer, and holds an Institutional Athena Swan Bronze Award. All staff undertake mandatory training including Bullying & Harassment, Unconscious Bias, and Equality, Diversity & Inclusion (EDI). The Unit's constituent Schools hold Departmental Athena Swan Bronze Awards, have EDI Committees that report to School Management Groups and an EDI Lead (0.1 FTE) who oversees the promotion of equality and diversity, from the point of staff recruitment onwards. Vacancies are advertised through multiple avenues, including the Women in Science and Engineering Campaign, and advertisements state that applications for employment on a part-time, job share or other flexible working basis will be considered, even where a position is full-time. We have successful experience of this approach; for example, *Callaghan*'s research team has had three members (3F) working on a part-time basis in recent years. IBBS and School meetings and seminars are held at family-friendly times and the IBBS seminar series features a gender-balanced (47%F) blend of speakers. All staff with caring responsibilities have access to flexible teaching arrangements. The University has guidance for staff and managers on maternity, paternity, shared parental and adoption leave and funding is available to support research re-engagement after periods of extended absence. This has supported two staff members returning from adoption and maternity leave, and *Callaghan* and *Draheim* have hosted Daphne Jackson Fellows.

Table 1 summaries the profiles of staff in our wider Unit (eligible staff), submitted staff and the Biosciences sector nationally. 10% of our submitted staff work part-time and 12% are on fixed-term contracts.

Table 1: Unit Profile and demographics

Indicator	Proportion of Cat A staff			Doctoral degrees awarded
	Sector	Eligible staff	Submitted staff	
Gender (Female)	46%[1]	45%	29%	61%
Ethnicity (BAME[2])	9%[1]	17%	14%	23%
Declared disability	3%[1]	10%	3%	6%
Age (36-55)	49%[1]	64%	63%	n/a

1-Academic and research staff Biosciences Advance HE, 2020; 2-Reported as Black, Asian and Minority Ethnic.

Our submission includes 46% of the Category A eligible population (FTE); this reflects the high proportion of staff who have been recruited from clinical backgrounds where they were not researching. We are committed to developing these staff into research and are supporting them with mentoring, collaboration with more experienced researchers, and to undertake doctoral studies.

The gender profile of submitted staff, and particularly by career stage, reflects EDI issues within the Unit, and in STEM subjects more broadly. Women are well-represented in postgraduate research (61%) and at immediate postdoctoral research career stages (49%), although these posts are usually on short/fixed-term contracts, conditional on grant funding. There is, however, underrepresentation at senior grades (23%F Reader/Senior Research Fellow; 25%F Professorial). We will address this as a priority going forward. Female staff are encouraged to undertake the Advance HE 'Aurora' programme: four Unit staff have attended this programme and act as role models and mentors for others. We will support more of our female staff to participate in 'Aurora', apply for sabbaticals and to access bespoke coaching and mentoring offered by the University, and externally, to facilitate progress to senior positions.

REF Submission: Unit leadership positions were openly advertised and candidates selected after interview by a gender-balanced panel and the Unit Leadership Team attended an 'Equality and Diversity in the REF' workshop (Advance HE, October 2019). All returned staff were involved in the review of proposed outputs, which were reviewed and selected according to the UoP Code of Practice. There has been no expectation on any staff to contribute a specific number of outputs and the primary criterion used to select outputs was their quality. An EIA has confirmed that REF2 outputs reflect the profile of submitted staff for gender (30%F), ethnicity (15% BAME), disability (3%), contract type (14% fixed-term, 6% part-time) and career stage (20% ECR).

3 Income, infrastructure and facilities

3.1 Research funding and strategies for generating research income

Our income strategy has focused on aligning our research with health and life sciences priorities, developing the expertise and profile of our researchers, extending our national and international collaborations and supporting engagement with a broad range of research users.

This strategy has successfully supported a wider group of staff to submit to a broader range of funders. Excluding four staff appointed within the last 12 months, 85% of our Unit have contributed to income generation through over 300 projects, indicating the vitality and sustainability of our funding base. Our total research income has grown by 60% (from £8.9M to £14.2M). We have attracted significant support from a range of funders, including UK Research Councils (e.g. BBSRC, EPSRC, MRC, NERC: £4M) and the Wellcome Trust (£1.9M) and increased funding (up by £4.3M to 47% of our income portfolio) from specialist biomedical charities (e.g. Age UK, Alzheimer's Research UK (ARUK), Brain Tumour Research, Headcase Cancer Trust, MS Society, Muscular Dystrophy Association, Parkinson's UK, Rosetrees Trust). Reflecting our strategic focus on collaboration with health and hospital bodies, our portfolio includes increased support from the NIHR and hospital trusts (+£1.3M).

Prestigious external income has generated high quality outputs and impact across all IBBS groups. As well as significant block grants to the CEI (£5.8M Research England) and EXRC (£1.9M BBSRC, Wellcome Trust), major individual awards include:

- **Molecular Biophysics:** BBSRC funding to *Callaghan* (£855k) enabling the molecular and structural characterisation of ribonucleases regulating bacterial RNA (*Nucleic Acids Research*) and underpinning the invention and patenting of new high-throughput platform technology, and to *McGeehan* (£400k) for UK-US collaboration on the discovery and engineering of enzymes for the degradation of lignin and plastic, which featured in the BBSRC highlights, and Innovate UK funding to *Draheim* (£564k) as part of a UK-China collaboration to tackle antimicrobial resistance;

- **Genetic Basis of Disease:** European Commission and Muscular Dystrophy Association awards to *Górecki* (£750k) to develop therapeutic drug targets to treat DMD (*Acta Neuropathologica Communications*, *PloS Medicine*);

- **Biomaterials and Drug delivery:** awards to *Blunn* (EPSRC, EC, NIHR; £720k) for research on biomaterials for implants in orthopaedic and oncology medicine; support to *Lalatsa* (Headcase Cancer Trust, Royal Society; £100k) for the development of pharmaceutical nanotechnology for site-specific drug delivery (*Journal of Controlled Release*); and to *Tsibouklis* (£240k) to host a Marie-Curie International Incoming Fellow working on a novel delivery platforms for hydrophobic drugs;

- **Ageing and Lifelong Health:** BBSRC, MRC, MS Society awards to *Butt* (£1.2M) supporting pharmacogenomic research into glia and neural regeneration (*PLoS Biology*, *Stem Cells). Swinny* has been supported by Alzheimer's Society, ARUK and Parkinson's UK (£365k) to

identify the impact of amyloid beta oligomers on neuronal activity in Alzheimer's and drug targets to reverse such effects (*Neuropathology and Applied Neurobiology, Journal of Neuroscience*), and awards to *Young* (Rosetrees Trust, EPSRC/NIHR, Innovate UK ICURe, Wessex AHSN) for the development of a diagnostic biomarker 'fingerprint' for Overactive Bladder (OAB), and for broader projects in biomarker discovery (EPSRC, DTA3/COFUND PhD Fellowship, DSTL).

To support long-term sustainability, we have increased our focus on developing novel technologies and supporting these towards commercialisation. This is reflected in increased funding from UK government (Innovate UK, DSTL) and biotechnology organisations (e.g. GlaxoSmithKline, Johnson Matthey, Oxford Drug Design). A key component of our future strategy is exploitation and commercialisation of our research excellence. To date, IBBS researchers are inventors on 11 patents that have been granted or filed for discoveries relating to the immobilisation of RNA onto a surface, 'all-in-one' cell verification and contamination assays, novel zeolite frameworks, two-component system technologies, peptide nanomaterials for targeted drug delivery, enzyme structures, and urine-based biomarkers for diagnosis of OAB. We will target specific funding streams (e.g. BBSRC Follow-on Funding) to secure support for the creation and exploitation of IP, typically in partnership with industry, and major revenue streams are anticipated through licensing and spinout of assets.

We will continue to ensure our research aligns with the priorities of a wide range of funders and that we are well positioned to contribute to the agendas of specialist biomedical charities. We will further extend our collaborations with clinicians, industry and other end users, through engagement with national and international networks. Strategic investments in our capabilities, such as in enzyme innovation, gene-editing and bioinformatics, provide a transformative increase in our capacity to respond to new, emerging research challenges and to secure research and commercial funding.

3.2 Organisational infrastructure supporting research and impact

Research and impact is supported across the Unit at IBBS and School levels. The IBBS steering committee is composed of the IBBS Director (*Young*), Associate Dean Research (*Thorne*) and the Associate Heads Research and Innovation (AHR&I) from the constituent Schools, ensuring linkage between Unit and School objectives. IBBS strategic directives are implemented by School R&I Committees (SRICs), chaired by the AHR&Is. The SRIC identifies research priorities, agrees the strategic distribution of internal investment e.g. in studentships and small grants, considers equality and diversity issues, manages research integrity and monitors delivery against KPIs and the Research Concordat. SRIC membership is inclusive in terms of gender and career stage and includes the IBBS Research Group Leads, the Research Degrees Coordinator and ECR, research and technical staff representatives. The SRIC reports to the School Management Group and Faculty RIC. The REF Unit Coordinator (*Swinny*) is a member of the Faculty and the University REF Steering Committees. All Research Groups operate a peer-support system at the early stages of research design to improve project rigour and quality and, where appropriate, bid-quality. Competitive external bid applications are reviewed through the University's peer-review college and, for projects involving clinical populations, our staff utilise the NIHR Research Design Service (RDS) to develop their protocols. Aligned with the

broader strategic development of health-related research across the host Faculty (Science and Health), we have also enhanced our research environment through further integration with NHS Trusts, the NIHR RDS, Wessex ARC and AHSN (4.2.1).

In addition to Unit-specific support, staff in Faculty and the central RIS team (REF5a, p.56-57) provide support for bid development (including finances and co-ordinating internal reviews), developing pathways to, and evidencing, impact, research ethics applications and post-award administration of externally funded research projects. Linked to our focus on collaborative working and research translation, our Unit is supported by colleagues in RIS with expertise in IP, patenting and complex international government contracts. This has been particularly important in supporting strategic long-term partnerships, such as that with NREL.

3.3 Specialist infrastructure and facilities

IBBS has world-class research facilities and instrumentation, acquired through external grants and significant internal capital investment. Facilities are managed by 18.5 FTE technical staff (67%F), with specialisms in biomedical imaging, tissue culture, chemical analyses, animal care and husbandry and biophysics, overseen by School Technical Managers. Technical staff are supported to achieve Science Council Professional Registration, contribute to publications and achieve additional qualifications (MRes, Degree Apprenticeships). All staff and PGRS have equal infrastructure access, irrespective of seniority, Research Group affiliation or availability of external income.

During this assessment period, the Unit has invested >£5M in infrastructure and equipment to enhance capabilities in strategically important areas, including enzyme innovation, bioresources, advanced microscopy and bioinformatics.

- We have grown our enzyme innovation specialisms through significant strategic University and external investment. Our Biophysics Instrumentation Laboratory houses state-of-the-art instrumentation for investigating structural and functional aspects of macromolecular interactions. This has been augmented by a crystallisation robot, high performance Calorimetry (MicroCal PEAQ-ITC and PEAQ-DSC), high-precision microarrayer and facilities for bacterial fermentation and protein purification. Two Specialist Research Technicians with expertise in bioinformatics and microbiology have been recruited on 5-year tenure-track posts. A £1.1M estate refurbishment has created new laboratories (Category 2) to facilitate interdisciplinary working and embed the CEI in the scientific research community. The Solent LEP has recently invested £1M in our enzyme innovation work to create an industrially-relevant, bio-recycling development facility that will support research translation and regional economic growth.

- [Text removed for publication]

- Our advanced imaging instrumentation enables the interrogation of a range of biological samples. These include the molecular and biophysical characterisation of fixed preparations using automated scanning and quantification of immuno-histological staining (Leica Ariol microscope), conventional (LSM 710) and super-resolution (Zeiss 880 AiryScan) confocal microscopy, or atomic force microscopy (Nanoscope 4 multimode). Live cell sorting (EVOS

FL Auto and Zeiss Axiovert 200M) and calcium imaging (LSM5Pascal confocal calcium imaging) allows for investigations in living systems. IBBS researchers also benefit from shared access to facilities outside the Unit that enable correlative microscopy approaches. The Electron Microscopy and Microanalytical Unit (hosted by UoA7) includes new SEMs (Zeiss EVO MA10 and Tescan FEG source, £240k) with probes for elemental analysis and distribution. Advanced imaging facilities in the Zeiss Global Centre (ZGC), located in the Faculty of Technology, hosts X-ray micro CT and X-ray 3D microscopes (Versa 510 and Versa 520), capable of sub-micron (~100 nm) resolution, phase-contrast and dual-energy acquisition. [Text removed for publication]. The ZGC also provides specialist in-situ loading devices (Deben rigs: 500N, 3kN and 5kN; Femtotools: modular micro/nano-probing down to 5nN) and software for digital volume correlation that support IDR into natural materials, biological structures, biomaterials and bio-inspired engineering materials (*Górecki, Blunn*, *Roldo*, *Lalasta*).

- We have invested £250k to establish a bioinformatics-specific, high-performance computing cluster that has supported the development of a range of next-generation sequencing data types. This includes a new laboratory providing high-throughput Nanopore sequencing (GridION X5 and MinION) facilities, supplemented by access to the University's SCIAMA (4000 core cluster) supercomputer. With further investment in research assistants (£135k) and equipment (£100k), we are establishing a sequencing facility, led by *Robson*.

IBBS facilities and instrumentation are accessible to wider academia and industry via the University Research Portal and equipment sharing databases, such as Equipment.data and Konfer. We will continue to invest in infrastructure, ensuring that future enhancement is driven by our strategic priorities and maximises the opportunities for shared resource use.

Our researchers also access world-class research facilities that complement those in IBBS and build a global perspective for our staff and PGRS. IBBS structural biologists are members of block allocation groups and have received highly competitive, peer-reviewed synchrotron beam time at ESRF and DLS (equivalent to £489k in this REF period) for crystallography of biological molecules, as well as small angle x-ray scattering (SAXS) and synchrotron radiation circular dichroism (SRCD) studies. Our high-profile research on the structures of lignin and plastic-degrading enzymes was conducted at the DLS and features in their 2018 highlights. Neutron beam time at the ISIS Neutron and Muon Source (STFC-awarded) has enabled *Cox* to characterise the complex zeolite structures of materials for a range of applications, including drug formulation and automotive catalytic convertors.

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

4.1 Research collaborations, networks and partnerships

Our strategic focus on supporting collaborations to enhance the quality of our research and income generation is evidenced by 77% of our publications in this assessment period being with international or national co-authors (SciVal) and staff in our Unit collaborating with researchers in >50 countries in Asia, Europe and the Americas. Research collaborations with the USA feature strongly in IBBS' research portfolio and include prestigious institutes such as Harvard Medical

School, Johns Hopkins University, Rutgers University and Woods Hole Laboratories. European collaborations are also extensive and include Max Planck, INSERM, CNRS and EMBL. Our formal research partnership with the US National Renewable Energy Laboratories includes *McGeehan*, *Pickford* and *Robson* as affiliate members of the Centre for Bioenergy Innovation and has supported staff and student exchanges for research and training, jointly-funded PhD studentships and high-quality joint publications (*Proc. Natl. Acad. Sci.*). Similarly, partnerships with the Nencki Institute, Poland, and Nihon University, Japan, have facilitated exchanges (*Butt*, *Górecki*, *Guille*, *Hafizi*, *Lalatsa*, *Lewis*, *Swinny*), publications, funded research projects and PGR studentships.

All submitted staff have led or contributed to collaborative projects, networks or partnerships; notable examples include:

- structural biologists in the CEI, led by *McGeehan*, with NREL and DLS, on structure-led engineering of lignin- and plastic-digesting enzymes. The long-term partnership with NREL, places our researchers in a highly competitive position for access to funding, training and international networks, while providing the critical mass for leveraging industry engagement with large multinationals. Through this, *McGeehan* is on the leadership team, and the UoP is the only non-US member, of the US Dept of Energy BOTTLE consortium, the largest US R&D consortium in plastics recycling, which includes MIT, Montana State University and Oak Ridge National Laboratory;

- *Guille* and *Sharpe* with clinicians at the UHS and the Wessex NHS Genomic Medicine Centre, as part of the Genomics England 100,000 Genomes Project, which has identified genes involved in neurodevelopmental disorders and clarified variants of unknown significance as causative in rare genetic disorders;

- *Robson* leading UoP's contribution as one of 15 academic partners providing sequencing and analysis capacity to the COG-UK consortium, aiding with regional COVID-19 outbreaks and infection control, and providing coverage of surveillance of viral spread across the country;

- *Górecki*'s leadership of the European Peptide Research Network of Excellence (2012-2015) and UoP participation in IONCHAN-IMMUNRESPON (2014-19), a network of scientists in 15 European countries working on immune cell physiology and new therapeutic approaches;

- *Lalatsa* with scientists from Brazil, Ireland, Spain, Paraguay and the USA developing novel endocrine therapies for the treatment of breast, brain and brain metastatic tumours, and medicinal nanotechnologies for neglected tropical diseases (e.g. leishmaniasis, Chagas disease);

- *Cox*'s molecular simulation approaches for designing and synthesising zeolites for controlled-release drug design (with Aristotle University of Thessaloniki and University of Delaware) and environmental and biorenewables catalysis (with UCL, St Andrews and the UK's leading commercial catalyst company, Johnson Matthey);

- *Butt*'s research on neuron and glia regeneration with scientists from Brazil, France, Germany, Italy, the Netherlands, Spain and Switzerland; and

- *Swinny* working with scientists from Germany, Japan, Mexico, Norway, Poland, Spain, Switzerland and the USA on the molecular, cellular and physiological correlates of the central and peripheral nervous system stress circuits.

IBBS members hold visiting researcher positions at institutions around the world and the Unit encourages international researcher visits (e.g. by providing laboratory and research facilities), many of which are funded by competitive exchange grants e.g. Royal Society, Marie Curie International Fellowship, China-UK R&I Partnership Fund, National Natural Science Foundation of China. The IBBS seminar series has run fortnightly throughout the assessment period and attracts scientists, clinicians and industry specialists from around the world. In the last 5 years, 88 of 108 seminars have been delivered by external speakers, providing opportunities for discussion, training sessions and collaborative activities with academic and research staff and PGRS. We are also members of regional research consortia e.g. Southern 4 Proteomics, South Coast RNA, South West Structural Biology (SWSBC), ARUK Southcoast Network, which provide access to state-of-the-art instrumentation, exchange of expertise, and advanced training and support for ECRs and postdoctoral researchers.

4.2 Relationships with key research users, beneficiaries or audiences

Our research has wide-ranging societal relevance and clear pathways to impact, that are enabled by our collaborations and engagement with research users and key stakeholders. These include:

4.2.1 NHS stakeholders and health and social care providers

For many years, the partnership with Portsmouth Hospitals University Trust (PHUT) has provided our researchers with access to patient tissues and containment facilities for extraction of proteins or nucleic acids, for subsequent analyses within UoP laboratories. This collaboration enabled a rapid response to the COVID-19 pandemic in March 2020 when, with £40k funding from the Unit, we temporarily moved our sequencing equipment and staff to PHUT to deliver the STOP COVID-19 virus surveillance project. The contribution of PHUT Category C staff (n=3) to the Unit is evidenced by joint publications, funding and impact (*UoP03MISSION, UoP03Oesophagus*), supervision of clinical PGRS and delivery of advanced clinical and biomedical sciences training and is recognised through Honorary academic positions (Professor – *Chauhan* (2008), *Bhandari* (2011); Reader – *Longcroft-Wheaton* (2020)). The Portsmouth Technology Trials Unit runs clinical trials, particularly in new healthcare technologies, and has supported research projects on smoking cessation in NHS settings and Innovate UK funding applications with SMEs.

Regionally, collaborations with clinicians at UHS have enabled access to expertise, patient groups and data. These underpin, for example, clinical trials of inhaled heparin as a treatment for patients with CF, and with COVID-19 as part of the Accelerating COVID-19 Research & Development (ACCORD-2) multicentre trial (*Shute*), and *Xenopus* research identifying causative links between genetic mutations and rare human genetic diseases (*Guille*, *Sharpe*). Since 2013,

UoP has co-led the NIHR RDS South Central (with the Universities of Oxford and Southampton), hosting 3 research advisers who support research design, PPI and all aspects of grant applications. A Research Nurse, funded by Solent NHS Trust, is employed in the UoP Dental Academy (UPDA, led by *Louca*) to support the evaluation of interventions and outreach to improve oral public health. As a member of the Wessex AHSN and ARC, the Unit benefits from opportunities for developing academic-clinical career pathways, access to funding, and links to relevant communities to ensure that impact is achieved quickly and at scale.

4.2.2 Patient and public involvement (PPI)

Increased PPI underpins our growing portfolio of projects with clinical application. Staff undertake PPI through specialist charities (e.g. brain tumour (*Fillmore*, *Lloyd*, *Schubert*) and dementia (*Swinny*); the Duchenne Parent Project (*Górecki*); MS Society (*Hafizi*); CF Trust (*Shute*); Bladder and Bowel Foundation, Bladder Health UK (*Young*)), the PTTU, Wessex ARC and AHSN, as well as the University's Social Work Inclusion and Ageing Networks. In 2015, IBBS supported (£135k) the first birth cohort in Portsmouth; data collected has underpinned projects and publications on, for example, the association between genetics and environmental exposure on diet, allergy, sleep and temperament. PPI activity has been supported by external funding, for example, from the NIHR RDS (to *Rutter* with patients in GP clinics and the 'Healthy Living' and 'Dementia Friendly' Pharmacy programmes) and from Innovate UK's ICURe programme (by *Young*'s team as part of broader stakeholder engagement to inform the design of a diagnostic kit for OAB).

4.2.3 Government Agencies

A number of our researchers work with the UK Defence Science and Technology Laboratory. Projects include developing P2X7 inhibitors to protect against post-injury heterotopic ossification (*Górecki*), identifying novel genetic strategies to improve pre-deployment training (*Myers*), high throughput toxicology screens (*Parker*), novel antibacterial approaches to combatting bioterrorism (*Callaghan*) and biomarker analysis in non-freezing cold injury (*Young*).

4.2.4 Biotechnology, drug design and healthcare companies

Our research develops tools, technologies and resources that can be widely applied to deliver impact. Staff receive expert support (3.2) and have secured external funding to support early stage commercialisation and translational work. As a result, *Callaghan*'s unique, patented functional-RNA array is being used in collaborative projects with [text removed for publication], UK, to develop high-throughput analysis within the RNA epigenetics domain, and [text removed for publication], USA, to explore the capability of the RNA array within the oligonucleotide therapeutics field and as a high throughput assay for testing gapmer/RNase H drugs. *Draheim* is working with Oxford Drug Design and Wuhan WVSEN Biotechnology Co Ltd, China, to develop novel arrays for high-throughput detection of compounds to combat antimicrobial resistance in humans and animals, *Shute* is working with [text removed for publication] to test novel non-anticoagulant heparin derivatives as anti-viral, mucolytic and anti-inflammatory agents, and *Blunn* with [text removed for publication] to clinically assess medical implants made by selective laser 3D printing. *An* and *Fillmore* used the ICURe programme to engage with Public Health England and commercial companies [text removed for publication] on development of their 'All-

in-One' cell line authentication testing kit and *Young* is at an advanced stage in the development of diagnostic kits for OAB with commercial collaborators. *Young* is also a consultant for TENA (incontinence products manufacturer), providing information underpinned by his research for patients and carers. The ERDF-funded SIGHT project, launched in August 2019 and led by *Blunn*, supports the adoption of medical innovations in the healthcare sector; it has already provided business development support to over 100 SMEs, leveraged £375k private investment and was instrumental in facilitating NTL Biologica to establish SARS-CoV-2 genomic testing of UoP staff and students. Engagement with industrial partners to deliver the significant potential of our enzyme innovation work in the circular economy is supported by our membership of national (e.g. UK Circular Plastics Network, High Value Manufacturing Catapult and the BBSRC Networks in Industrial Biotechnology and Bioenergy) and international (e.g. BOTTLE) networks.

4.3 Benefits to the economy and society

Our research expertise and collaborations deliver a wide range of societal benefits that are responsive to national and international priorities. In addition to impacts mentioned previously and those captured in our Impact Case Studies, these include:

- New diagnostic technologies, such as *Callaghan*'s RNA array technology that is being used in studies developing a detection method for SARS-Cov-2 and by a number of industrial collaborators for screening of RNA therapeutics, the use of the zebrafish model to detect environmental pollutants and hazards (*Parker*) and *Young*'s biomarker analyses that are being used to detect and characterise the physiological effects of stressors in military situations;

- New clinical interventions, including an osteointegrated HA porous collar for medical implants that prevents loosening and eliminates the need for joint replacement in young patients (*Blunn*, with [text removed for publication], the use of a topical haemostat to control bleeding in endoscopic submucosal dissection (*Brown*), topical delivery of nano-engineered anaesthetic formulations for eyelid surgery (*Lalatsa*), a novel P2X7 blocker treatment for DMD, currently in clinical trials in India (*Górecki* and Duchenne Parent Project), and inhaled heparin for the treatment of COPD (*Shute*);

- New products with improved properties. For example, *Roldo* works with [text removed for publication] to develop oral healthcare products with improved biofilm control, and the application of *Cox*'s computational modelling of structure-function relationships in zeolites has underpinned the design and synthesis of new catalysts to control automobile emissions and new fertiliser products for high-value amenity markets;

- Changes in clinical practice and national prescribing guidelines on the compatibility and stability of IV infused medicines used in paediatric intensive care (*Van der Merwe*);

- Workforce development supported by new training materials created by *Young* for Health Education England on the management of urinary continence that will be mandatory CPD for all relevant NHS staff.

Our research portfolio addresses international priorities in ageing, dementia and long-term conditions, as well as supporting diagnosis, monitoring and therapeutics and responding to emerging challenges, such as antimicrobial resistance and virus surveillance. Our interdisciplinary research offers significant potential in new public health areas, such as the effects of microplastics on human health.

4.4 Wider influence, contributions to and recognition by our disciplines

Contributions to the wider scientific community are recognised in workload allocations as an important vehicle for extending intellectual leadership. Staff have served as editorial board members for 13 journals, including *Cells*, *Scientific Reports* and *Perspectives in Pharmacology*, and have guest-edited 6 journal special issues. Unit staff have provided expert review for five UKRI Councils, the European Commission and national funding bodies in 16 countries, and have chaired or been members of major grants committees, including: *Blunn* - Scientific Foundation, Ireland, allocating €26M in medical technologies in 2018 and 2020; *Butt* - Finnish Academy of Sciences, Agence Nationale de Recherche, National Science Foundation (USA); *Callaghan* - Deputy Chair of BBSRC Committee D and member of sLoLa and iCASE panels that have collectively distributed £170M biosciences funding in this assessment period; *Guille* - BBSRC BBR, CNRS/INRA, MRC Advisory Group on Animals in Science, NIH USA; *McGeehan* - DLS User Committee, MaxIV Synchrotoron Crystallography Panel Sweden; *Pickford* - DLS S angle X-ray Scattering Committee; *Swinny* - Alzheimer's Society, Parkinson's UK; *Tsibouklis* - Vice-Chair, Chemistry panel, Marie Skłodowska-Curie Fellowships.

Staff have also convened conferences and symposia e.g. *Swinny* (Pan-American Congress of Physiological Sciences, Brazil, 2014); *Guille* (UK *Xenopus* meeting, 2015; 16th International *Xenopus* Meeting, 2016); *McGeehan* (SWSBC Conference, 2016); *Górecki* (Bilateral UoP-Nencki Polish Academy of Sciences Conference, 2016, 2017); *Sharpe*, *Scarlett* (South Coast RNA Meeting, 2017); *Fillmore* (7th annual UK & Ireland Early Career Blood Brain Barrier Symposium, 2017).

We provide expert opinion through advisory and influencing roles, such as: *Blunn* (President, British Orthopaedic Research Society (2016-2019), Orthopaedic Research UK); *Guille* (NXR, USA; RSPCA; DEFRA); *Kolstoe* (Chair of MOD, PHE and Hampshire A NHS REC; HRA - Confidentiality Advisory Group, National Research Ethics Advisory Panel, Emergency COVID-19 REC); *Rutter* (Royal Pharmaceutical Society Pharmacy Voice; DSRU, Southampton; Wessex AHSN and ARC medicines optimisation groups); *Scarlett* (Genes' Committee, Biochemistry Society); *Shute* (CF Trust; DSTL Porton Down; PHE ACCORD-2 COVID-19 triage group); *Swinny* (Coordinator, ARUK South Coast Network); *Van der Merwe* (Southampton Hospital Pharmacy Research Centre R&D Committee); *Young* (International Consultation on Incontinence, Wessex AHSN Healthy Ageing Programme and Focus on Incontinence). *Callaghan* was the UK-Research Staff Association South East Representative and a Panel member for the HR Excellence in Research Award (2015-16) and a member of the Vitae Research Staff Advisory Group (2014-2016).

Unit staff have also demonstrated intellectual leadership through high-level contributions to science-led policy development. Examples include: *Callaghan* contributes to recommendations on support for research staff development, part-time/flexible working and gender disparity in

funding within her BBSRC leadership roles; *Draheim* provided evidence to the STSC on the UK Five Year Antimicrobial Resistance Strategy (2013-2018); *Guille* led the international community response (2019) to EC proposals to designate *Xenopus* as an Invasive Alien Species; *Kolstoe* advising the HRA on research transparency; *Lalatsa* was invited to discuss policy changes to promote the adoption of new technologies for neglected diseases (British Council Science, Brazil, 2015); and *Lloyd* contributed to the UK Parliament Hansard debate (2016) on brain tumour research funding. Our enzyme innovation research features in the BBSRC/UKRI report on "UK Industrial Biotechnology impacting everyday lives" (2019) and in the 2018 Analysis & Policy Observatory for Synthetic Biology in Australia. In 2017, *McGeehan* participated in exchange visits to Westminster, as part of the Royal Society Parliament Pairing Scheme (with Flick Drummond MP) and has contributed to policy debates on addressing "the plastic challenge" on the national (Westminster Energy, Environment & Transport Forum (2018), House of Lords (2019)) and international (Arctic Circle Assembly, Reykavik (2018), Almedalen Political Retreat, Roundtable at Lambeth Palace (2019)) stage. *McGeehan* was also part of a UK delegation to Sweden with the UK Ambassador and Head of Science and Innovation Nordics in 2018.

4.5 Engagement with diverse communities and publics

We are passionate about public engagement and employ a variety of mechanisms to do this. Staff and PGRS participate in: public talks; hosting events and laboratory tours (CF Trust, MS Society, STEM Days, U3A): Science Fairs (Big Bang @ Solent, Harwell Science Fair); public events (Cafe Scientifique, Pint of Science, Portsmouth Victorious Festival); meetings with local organisations (Pompey Pensioners, Probus Organisation, Solent Energy & Environment Group, Women's Institute); and delivering STEM sessions in schools across Hampshire. The UPDA team work with local authorities on oral public health outreach in some of the most deprived wards in the country, for example, with Southampton City Council on the Healthy Early Years Award – Mouth programme, with Portsmouth City Council and families on an oral health promotion video, and with Solent NHS Trust, schools and nurseries on "tooth-friendly" snacking. Throughout the assessment period, researchers have supported fundraising and awareness events for paediatric brain tumour charities. Interdisciplinary projects have provided additional opportunities to engage the public with our research. For example, genotyping of a crewmember and a dog from the Mary Rose (*Robson*, *Scarlett*) contributed to the Channel 4 documentary, 'Skeletons of the Mary Rose' (2019), and to a major exhibition ('The Many Faces of Tudor England') and the creation of 'Hatch', the canine Museum mascot.

Finally, we engage with global audiences by writing articles in specialist publications, giving radio and television interviews and publishing in high-quality journals that attract significant media attention. For instance, *Young*'s research combining patient stratification and urinary biomarkers to improve diagnostic accuracy for OAB (*Nature Scientific Reports*) was reported across the UK (*Express*, *i*, *Mail*, *Mirror*, *Nursing Times*), in Europe and the USA (*Reuters*). Similarly, *McGeehan* is routinely invited to speak in the media (e.g. UK, USA, China) and at national and international "Science and Society" events on "plastic-eating enzymes". In 2018, *McGeehan*'s PETase research reached the Altmetric Top 100 from 2.8 million publications. A follow-up paper was ranked 39th in Altmetric's 2020 list of research that most caught the public's imagination. Over the last two years, our research on turning waste into sustainable products

and engineering an enzyme that degrades PET plastic has featured in 967 news articles and broadcast clips, with a potential reach of over 4 billion.