Institution: University of Hertfordshire

Unit of Assessment: UOA3 Allied Health Professions, Dentistry, Nursing, and Pharmacy

1. Unit context and structure, research and impact strategy

Context and Structure

This submission from the University of Hertfordshire (UH) comprises 75.91FTE academic and independent research staff. For REF2014 the University made two submissions to UOA3, one encompassing research aligned to Nursing and the Allied Health Professions located in the School of Health and Social Work (HSK), and the other for Pharmacy and Pharmacology, housed in the School of Life and Medical Sciences (LMS). A collaborative strategic approach to research across the two Schools since 2014, formalised with the establishment of a joint Research Management Group in 2018, has resulted in this single submission to REF2021. The University-wide Health and Wellbeing research theme, introduced in 2016, acts as a mechanism for the promotion of collaborative research across UOAs and within the Unit.

Highlights from this cycle include:

- 100% increase in mean annual external research income
- £13.0M NIHR grant capture
- 120% increase in mean annual number of doctoral awards
- 82% overall satisfaction in the 2019 Postgraduate Research Student Experience Survey (PRES) with 92% for research skills, 90% for supervision and 88% for professional development
- £61.2M investment into new Science Building
- Winner, *Times Higher Education* STEM Research Project of the Year Award, 2018

Research is driven through three University designated Centres for Research and a Research Group as displayed in Figure 1. The Unit research environment benefits from a structure that transcends both School and health care professional boundaries. It enables an interdisciplinary perspective to be brought to questions of fundamental importance for biological and physical science, health care, social care and public health by working with health-related industries, the third sector and government bodies.

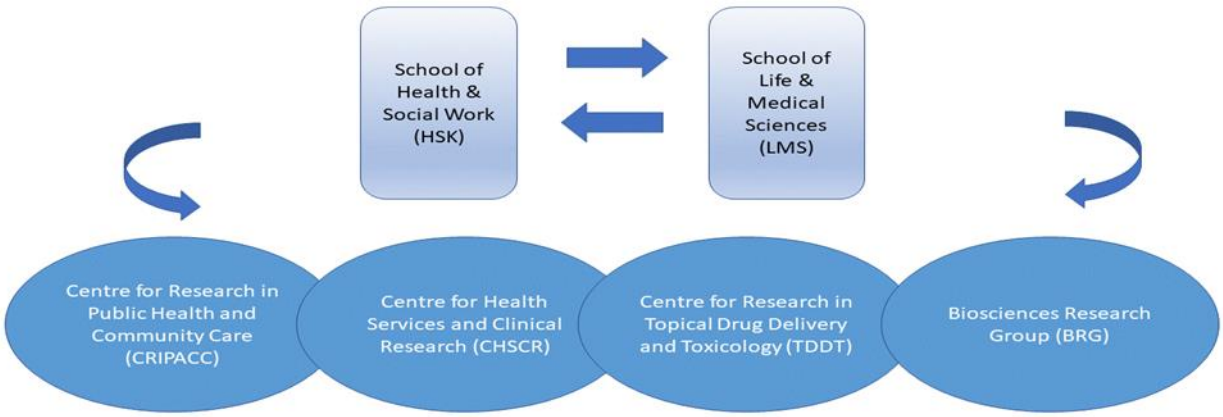

Figure 1: Research structure of the Unit

Specialisms include:

- Understanding the cellular and molecular mechanisms underlying illness presentation and management.
- Physical science and the design and use of novel model systems that accelerate medicine development and provide understanding of environmental exposure to toxic materials.
- Treatment, management and patient experience relating to long-term health conditions.
- Managing and promoting public and population health, care and wellbeing across the life course and the investigation of inequalities among different groups.
- The development and delivery of health services, working in partnership with the health sector and related industries such as care homes.
- Implementing inclusive research approaches with the involvement of patients, service users, carers and members of the public.

Strategy

The Unit Research Management Group comprises the Deans, Associate Deans for Research (ADR), Heads of Research Centres and Group, and REF coordinators from the two Schools. It contributes to the development of, and provides scrutiny for, the Unit research strategy, and ensures it is aligned with that of the University. Each School operates a Research Executive Group (REG) whose members include Deans, ADRs, Professors and Associate Professors, Heads of Department and Centres, REF2021 coordinators, early career research (ECR), postgraduate research (PGR) and Equality, Diversity and Inclusivity (EDI) representatives. The REGs plan and monitor the use of QR funding to support research activity and impact against agreed Delivery Plans.

The Unit-specific strategy during this REF cycle has been to consolidate and invest in areas of research growth in public health, community care, health services and clinical research, disease mechanisms, drug delivery and toxicology. Strategic objectives over this research cycle, building on REF2014, were to:

- Support academic and research staff development across the career pipeline, taking account of our Equality, Diversity and Inclusivity agendas.
- Increase external grant income
    - this has increased by 170% over this research cycle, to £23.5M, representing £309k per FTE submitted for REF2021.
    - The University has consistently been in the top 35% of the HEIF index for grants received throughout this research cycle; to which income from the Centre for Research in Topical Drug Delivery and Toxicology (TDDT) has significantly contributed.
- Develop the postgraduate research (PGR) degree portfolio and PGR student numbers.
    - Mean annual doctoral awards increased by 120% and PGR enrolments by 32% over the cycle.
- Invest in facilities to support and promote life sciences research.
    - £61.2M was invested in a new Science Building, which provides equipment, specialised laboratories and purpose-built offices for researchers and PGR students.
- Extend links with stakeholder organisations and industry and enhance the Unit's reputation for service user and public involvement in research.
- Broaden the reach and significance of the Unit's impact.

The focus of Centre and Group research programmes and key achievements resulting from the Unit strategy are described below.

Centre for Research in Public Health and Community Care (CRIPACC)

Led by Professor Wendy Wills, CRIPACC brings together expertise across social and behavioural sciences and clinical areas to address key issues for public health, community care

and the ongoing challenges for health and social care services. There are three intersecting research areas:

- Older People's Health and Complex Conditions (led by Goodman)
- Communities, Young People and Family Lives (led by Almack)
- Patient Experience and Public Involvement (led by Jones)

Development of research into Older People's Health and Complex Conditions was an integral part of CRIPPAC's strategy, in line with the Government's Ageing Society Grand Challenge. Strategic objectives were achieved by developing applications for large grants, leadership from senior academics and investing in new ECRs. Over £6.5M NIHR funding was secured for this field of research. Goodman contributed significant leadership and involvement with the NIHR CLAHRC (Collaborations for Leadership in Applied Health Research and Care) East of England (EoE). She was appointed Deputy Director of CLAHRC EoE (2014) and awarded NIHR Senior Investigator status in 2016; Bunn was promoted to Professor in 2018 and Assistant Director of CRIPACC in 2019. Their research underpins Impact Case Study 06 (ICS 06). Two ECRs were appointed to University-funded five-year fellowships and secured major grant awards from NIHR and the Alzheimer's Society totalling just under £1M.

Research activity in relation to public health and prevention research was expanded within the Communities, Young People and Family Lives programme, in response to the emphasis on prevention and population health in NHS Sustainability and Transformation Partnerships (STPs) and the NHS Long Term Plan. Objectives to invest in ECRs, build stronger collaborations and maximise impact were integral to this research area. Wills provided leadership for the development of the professional doctorates in line with the Unit strategy for developing its PGR portfolio. Two University five-year ECR fellowships were secured relating to food and public health. Collaborations with the Hertfordshire Business School (UOA17) and Sports, Health and Exercise Group (an emergent area within UOA3, see 'future strategy') led to grants from the ESRC, Food Standards Scotland and Barts Health. The work with Hertfordshire Business School has informed Impact Case Study 02 (ICS 02).

The Unit's service user and public involvement strategy was reviewed by CRIPACC'S Patient Experience and Public Involvement group in line with the strategic objective to take greater account of public involvement in research. The Public Involvement in Research group (PIRg) contributed to the development of 39 funded research studies (see Section 4).

Centre for Health Services and Clinical Research (CHSCR)
Led by Professor Ken Farrington, CHSCR conducts research on the mechanisms and management of long-term conditions and mental health, bringing together pharmacologists, clinicians and applied health researchers, along with the NIHR Research Design Service (RDS) and Clinical Trials Support Network (CTSN). CHSCR's objectives included identifying synergies for greater collaboration with colleagues across the Unit and clinical partners to facilitate greater grant capture and generate interdisciplinary research findings.

The number and value of externally funded clinical trials was significantly increased by drawing on the Unit's expertise in research design, the CTSN and collaborations with clinical partners. The CTSN benefits from input from local NHS Trusts and received increased investment from the University since 2014 to increase capacity. This resulted in 11 trials within this research cycle (grant value >£5.4M) including in long-term conditions such as obsessive-compulsive disorder (OCD) and renal disease, and in mental health conditions such as the large-scale NIHR-funded READY trial in depression (see 'interdisciplinary research').

Exploiting its expertise in conducting high impact research in renal disease (ICS 01), a key aspect of the Unit's strategy was to further develop links with stakeholders and external collaborators. This included work with the UK Renal Registry which has led to Hawkins, Wellsted and Farrington partnering in the validation and rollout of the national Patient Reported

Experience Measure (PREM) in renal disease. The CHSCR collaborated with NHS renal units on clinical trials and studies of service delivery funded by NIHR, British Renal Society and Kidney Research UK. This portfolio was broadened to include an interdisciplinary focus (with UoA4) on the experience of patients from ethnic minorities, which has been funded by NIHR Research for Patient Benefit (RfPB) funding stream and the British Renal Society (Sharma, Farrington).

In line with the strategic objective to strengthen links with industry, pharmacologists and chemists in CHSCR have drawn upon the Hertfordshire Science Partnership (see section 4 – collaboration and contribution to the research base) to partner with industry and increase external grant income. Outcomes include four funded projects (Iravani, Kirton, Lione, Rossiter), including one to progress work on a potentially 'druggable' target implicated in pancreatic cancer.

The Psychopharmacology, Drug Misuse and Novel Psychoactive Substances (NPS) team in CHSCR identified as research foci for this research cycle i) the monitoring of trends of emerging NPS, ii) identifying adverse consequences of drug misuse for both NPS and prescription drugs. They addressed these aims by increasing international collaborations and delivering two EU-funded projects, which have led to significant impact, for example resources aimed at the health professional community (ICS 05; see 'Impact Strategy').

Centre for Research in Topical Drug Delivery and Toxicology (TDDT)
Led by Dr Liam McAuley, TDDT brings together expertise in biological, physical, analytical and toxicological science to address two key challenges i) Developing and refining topical medicines to enhance drug delivery whilst reducing toxicity and ii) Understanding exposure to toxic materials and its mitigation with a focus on Chemical, Biological, Radiological and Nuclear (CBRN) incidents.

Key to addressing these challenges is the breadth of scientific expertise in TDDT, which has enabled translation of basic science into development of medicines and evidence-based guidelines used by US and UK governments for handling CBRN incidents. TDDT strategy over this research cycle focused on fostering significant grants; developing people, collaborative links and facilities; and strategically increasing the reach and significance of research impact, which is delivered through engagement with industry, national governments, international charities and spin out companies (Section 4).

The Drug Delivery group within TDDT led to the establishment of the Hertfordshire Science Partnership (HSP) (see Section 4), a £6M initiative to facilitate research between small and medium-sized enterprises (SMEs) and HEIs throughout the East of England. This group also had major successes under the Future Formulation of Complex Products Programme. The EPSRC INFORM 2020 Consortium (PI Murnane, £1.9M 2017-2021) was established with five UK HEIs and international industrial partners to address the transition to digital design and development of inhalation products.

Toxicology research led by Chilcott provided novel evidence-based approaches on how emergency services and civil contingency agencies should respond to CBRN exposure, leading to significant impact. The group were recognised with a Times Higher Education award in 2018 (see Section 4). Chilcott's approach has been implemented in both US and UK Government department protocols and been utilised in the Salisbury and Amesbury novichok incidents. Protocols have been made available to all US first responders via a mobile app (ICS 04; see also section 4). Key strategic priorities were the establishment of a £2.4M specialist toxicological facility (see section 3), and UKAS accreditation of Unit analytical facilities.

Biosciences Research Group
Led by Dr Maria Dimitriadi, the BRG carries out research across two key strands i) Microbiology & Infectious Diseases and ii) Molecular Medicine. The focus of this research is to understand the

fundamental molecular and cellular mechanisms underlying human disease with the goal of developing effective translational therapies. The group was established in 2017 and collaborates with researchers in TDDT and CHSCR. It is on the pathway to gaining University Centre status (see 'future strategy').

The BRG use a range of tools encompassing molecular, biochemical and computational approaches, such as gene editing, structural biology, molecular modelling, signal transduction, and animal models to understand human disease, including bacterial/viral infection, cancer, birth defects and motor neuron diseases such as Spinal Muscular Atrophy (SMA). The Group's research has contributed to increasing external grant funding and broadening the reach and significance of the Unit's research. For example, Dimitriadi was the first to show that endocytosis - a cellular process by which molecules enter a cell - is particularly important in SMA. These findings were later used by the Wirth lab at Harvard University, where it was identified that reduction of a key player in endocytosis was protecting humans from developing SMA.

Interdisciplinary Research

The Unit aims for interdisciplinarity in its research, driven by the objective to maximise impact from research outcomes, through the following strategies.

Within the Unit: Multi-disciplinarity is essential given the complex nature of many research questions the Unit seeks to address, and this generates interdisciplinary innovation for scientific, health and social care outcomes. Drawing on specific disciplinary expertise across the Unit has enabled the development of ambitious and innovative interdisciplinary RCTs that build on the success of smaller-scale studies. For example, the NIHR HTA-funded READY trial (£2.27M) brings together expertise in clinical trial methodology (Wellsted, Trivedi, Mengoni), exercise physiology (Bottoms), health inequalities (Sharma), Patient and Public Involvement and Engagement (PPIE; Jones) as well as behaviour change (Psychology; UOA4). Different disciplinary approaches have been integrated in the development of the study's logic model, the specification of the intervention and the evaluation framework.

With other UOAs: The University promotes and supports multi- and interdisciplinarity through its cross-School Health and Wellbeing Research Theme. Bunn is the University's Theme Champion for Health and Wellbeing research and her role involves facilitating collaborative research across the University as well as within the two Schools in this Unit. Bunn and other senior academics in the Unit organise networking meetings on specific topics to bring colleagues together from different Centres and Research Groups so that research expertise, external collaborators and resources/facilities can be discussed and shared. This strategy is supported by the Pro Vice-Chancellor (Research and Enterprise), who has provided small grants for cross-School collaboration among researchers (particularly ECRs) who do not typically work or publish together, as well as funding for international interdisciplinary collaborations, an example being with the University of Technology Sydney. These initiatives have led to grant applications and outputs drawing together pharmacists, applied health researchers, social scientists, statisticians and PPI experts.

Academics in the Unit are encouraged via regular networking meetings to collaborate with colleagues from other University research themes, notably Information and Security, and Food. For example, the NIHR-RfPB funded KASPAR study brought together expertise in applied health research (Sharma, Wellsted, Mengoni) and Psychology (UOA4) with Computer Science (UOA11); the KASPAR robot embodies psychological theories of autism and has been programmed to apply this in its interactions with children. Vasdev has collaborated on novel haptic feedback techniques for robotic surgery with colleagues in Computer Science, including co-authoring a systematic review. Fineberg co-supervises a University-funded ECR fellow based in Computer Science to conduct novel research regarding the use of autonomous robots to elaborate models of human mental disorders. This team published the first peer-reviewed robot model of obsessive-compulsive disorders.

Wills, Dickinson and Hamilton worked with Hertfordshire Business School (UOA17) on research relating to young people's dietary decisions in and around schools (funded by Food Standards Scotland) and older people's access to food and the prevention of malnutrition (funded by ESRC). Public health, nutrition, sociology and social marketing were brought together to inform the development of study research questions, the analytical framework and engagement with stakeholders in terms of translation of the research. This interdisciplinarity has informed the way impact has been generated (ICS 02).

Doctoral research inquiry often presents an opportunity to create interdisciplinarity and Unit academics work with colleagues in different UOAs to provide effective supervision. Jones for example, co-supervises an architecture PhD student in the School of Creative Arts to provide healthcare focused PPI and qualitative research expertise; the student is studying tactile wayfinding for people living with dementia in care homes.

Interdisciplinary collaborations with external specialists are outlined in Section 4.

Impact Strategy

The Unit's strategy for maximising and achieving impact centres around the targeting of key audiences and setting objectives to facilitate communication with them. Enablers include the Unit supporting active engagement with relevant networks, including policy-making groups, clinicians, industry partners and parliamentarians; dissemination approaches to ensure research directly feeds into health, care and service development and/or achieves a wide reach; and ensuring our research is informed by Patient and Public Involvement and Engagement (PPIE). These enablers align with the University's 2015-2020 strategic vision to be the UK's leading business facing university and to bring innovation to contemporary social, economic and scientific challenges. This strategic approach is applied across all research activity and has facilitated the development of the impact case studies (ICS) submitted in this research cycle as well as providing an infrastructure for the longer-term development of impact.

Active engagement with relevant networks. A key element of Unit strategy was supporting academics to regularly engage with government bodies, clinical/care partners and third sector/charitable agencies about research gaps and recommendations for new research questions/facilities, and to expedite effective dissemination once findings from research become available. Exemplars include Farrington's work on management of renal disease (ICS 01), which has contributed to guidelines on conservative management and individualised diseases, achieved by working closely with policymakers and stakeholders such as the Renal Association, European Renal Best Practice and NICE. The Health Behaviour in School-Aged Children Study (HBSC) for England (ICS 03) is the focus of regular meetings with PHE, DHSC and the Department for Education (DfE) and they request specific analyses and briefings based on the data. For example, HBSC data were used by the DfE when developing and revising the curriculum and making Personal, Social, Health and Economic education (PSHE) and Sex and Relationships Education (SRE) compulsory within secondary schools.

TDDT's focus was on establishing and strengthening industrial collaborations to facilitate transition of research to market, creating spin-out companies (Section 4) and generating opportunities for preferred supplier status with large Contract Research Organizations for performance testing in high impact fields such as drug delivery. TDDT has worked closely with the Pro Vice-Chancellor (Business and International Development) to exploit the creation of the Hertfordshire Local Enterprise Partnerships (LEP), given the high concentration of pharmaceutical, life sciences and agri-tech industries in the region. In 2018 this development resulted in the establishment of the Hertfordshire Science Partnership (HSP), described by the then Business Minister as a means to 'strengthen links between business and academia to accelerate cutting edge scientific R&D to market'. The HSP has already yielded significant industry partnerships and income generation (Section 3).

In Section 4 details are given of c.50 international, national and regional/local bodies and organisations that Unit staff work with as, for example, advisors or chairs of working groups. This activity is included in staff workload allocations and supported through the appraisal system. For example, NPS researchers are members of key committees such as the Advisory Council on the Misuse of Drugs (ACMD). NPS research (ICS 05) has significantly contributed to UK drug classification decisions and policy reports. In addition, the Unit works with Category C staff from the NHS, including individuals offered joint appointments (e.g. Pattison; Gorog). These relationships are instrumental in establishing interdisciplinary stakeholder groups in the health sector, to strategically position the Unit with a long-term view to impact generation.

Influencing parliamentary business. The Unit has promoted the involvement of staff with parliamentary committees by, for example, funding attendance at training days for engaging with parliament. Funding and support are given for academics to submit oral or written evidence at All Party Parliamentary Group (APPG)/Select Committee inquiries. Bunn (ICS 06) was invited by the Alzheimer's Society to give evidence to the APPG inquiry on care for people living with dementia and other chronic conditions and Wills and Dickinson (ICS 02) gave oral evidence at the APPG inquiry on older people, malnutrition and hunger. The subsequent reports from these inquiries extensively cite research generated by these Unit academics.

Within TDDT, academics worked with government bodies to develop an appropriate purpose-built facility for CBRN, which has generated findings that governments and PHE have implemented in their emergency response protocols (ICS 04). The protocols have been used by UK Government departments to demonstrate the UK's preparedness for a CBRN incident. Engagement with the US government led to the development of the Primary Response Incident Management System (PRISM) and resources to support first responders for CBRN.

Effective dissemination to impact health, care and service development achieved by writing blogs and updates for NIHR/funder websites or in their newsletters; Chief Investigators having social media strategies for effectively informing stakeholders about research findings; and by researchers organising fora to engage different audiences or presenting findings at appropriate events. These activities are supported by the University's Business Development and Public Policy teams. Wills and Dickinson (ICS 02) have developed ongoing relationships with the customer service directors of several national supermarkets, which has informed the development of their ESRC research on older people's food security. Ongoing engagement informed the strategic direction of two supermarket chains to support older adults to avoid malnutrition and food insecurity prior to COVID-19 as well as during the pandemic. Time is allocated to senior academics to ensure they lead events to showcase their research and engage with organisations tasked with making use of findings. For example, Care Home research led by Goodman informed how NHS England developed and evaluated Vanguard initiatives to improve working between the NHS and care homes (ICS 06), which led to commissioning briefs and service model development for GPs by two Clinical Commissioning Groups (CCGs).

Achieving a broad reach through dissemination activities including the use of media/other channels to broadcast Unit research; for example, the University is a member of The Conversation, an online source of news written by academics, supported by journalists and editors. Goodman (ICS 06), Wills (ICS 02), Chilcott (ICS 04), and Schifano, Corazza and Corkery (ICS 05) have all contributed to The Conversation. Staff also publish blogs, including writing about COVID-19 for the King's Fund and the international Long-Term Care Policy Network (Goodman, ICS 06). Films have been used in ICS 06 to generate interest in research on care homes and health services for people living with dementia and in ICS 02, to publicise research findings to public and practitioner audiences. Results from the EU-MADNESS and EPS/NPS 'Enhancing Police Skills concerning NPS' have been disseminated via 100+ EU-wide lectures to a range of health care professionals and have been used to develop education resources for health professionals and policymakers (ICS 05).

Patient and Public Involvement and Engagement (PPIE) forms a key part of the Unit's strategy. By involving users of research in its production and application the Unit aims to reduce research waste in the health and care sector by improving the quality and impact of research findings. The Unit's research has impacted on health policy and PPIE practice in the NHS nationally (e.g. RAPPORT study - Mathie; Goodman) and shaped good practice guidance by health organisations (statutory and charities) in Australia, Canada and the US. Simon Denegri, then NIHR National Director for Patients, Carers and the Public, wrote to all NIHR Senior Investigators in 2018 recommending they use the guidance for PPI feedback developed by Mathie and Jones.

Open Research Environment and Integrity

The Clinical Trials Support Network (CTSN) management group supports researchers applying for clinical trial funding and during study delivery. It reports to the University-wide Advisory Group for Research Governance of Clinical Studies, which ensures governance and management of clinical studies at the University, including fulfilling sponsorship responsibilities for NHS research. Colleagues from across the Unit sit on both these groups. The CTSN has developed Standard Operating Procedures to enable a robust and unified process for conducting clinical studies. These also incorporate the UK Policy Framework for Health and Social Care, Good Clinical Practice and the Concordat for Open Research Data, and ensure policies are enacted in practice: all clinical trials are registered on the appropriate databases, and open-access protocols, including statistical analysis plans, are published. Research involving human participants must receive ethics approval from the University Ethics Committee with delegated responsibility, or the Health Research Authority, depending on the research setting. A member of the Public Involvement in Research group (PIRg) sits on the UOA3-relevant University Ethics committee.

The Unit adheres to a position statement on the Reproducibility of Research, which emphasises research integrity and adherence to the University's Ethics and Research Integrity protocols. Specifically this commits to: (i) openness of research (by making research outputs available on the University Research Data Repository); (ii) making research results publicly available, to avoid any bias of data published; (iii) ensuring that research studies are adequately powered (iv) declaring conflicts of interest and (v) providing research methods training.

The University is a signatory to the Concordat on Openness on Animal Research, for which Lione is the University lead. The Unit's Parkinson's disease and diabetes licenced animal research is endorsed by the government Home Office, under the approval and direction of the LMS Research Executive Group and University Animal Welfare and Ethical Review Body (AWERB). The AWERB oversees all research involving animals ensuring it meets scientific, ethical and legal guidelines and follows the principles of the National Centre for the Replacement, Refinement & Reduction of Animals in Research (NC3Rs). Animal-free replacement research and research-informed teaching is conducted using computer simulations, computational biochemistry and biophysics with a track record of funding from NC3Rs and Animal Free Research.

Future Strategy

The Unit strategy for the next research cycle is focused on achieving further growth and development within its Research Centres and investment in nascent research groups, to complement its existing portfolio. Strategic objectives agreed by the Unit Research Management Group to achieve and sustain growth over the next research cycle include:

1. **Increase enterprise, non-academic and industry collaboration.**

The Unit's corporate collaborations will be enhanced through increased activity in the sectors of health protection, pharmaceuticals and advanced therapy medicinal product (ATMP) development. Unit researchers will engage through the Hertfordshire Science Partnership (HSP) with companies in the £1.6bn Stevenage Life Sciences Opportunity Zone, Europe's largest Cell and Gene Therapy industrial cluster, to develop the science of ATMP manufacture.

With the relocation of PHE to the East of England in 2021, a Memorandum of Understanding established between the University and PHE will enable the growth of collaboration in microbiology and environmental health. The Biosciences Research Group will collaborate with PHE (Colindale) regarding pulmonary infections, linking with TDDT, and Murnane will lead a new programme under Theme 4 of the National Core Study on COVID-19 Aerosol Transmission. The Unit will enrol ten new PhD students, through the national EPSRC Centre for Doctoral Training in Aerosol Science (Murnane - Deputy Director). Each supervisory team will include one member allocated from the 45+ industrial partners.

Chilcott and colleagues will capitalise on the £2.4M investment in a large-scale exposure chamber at a University facility for research into the characterisation and mitigation of risks from aerosol-generating medical procedures. Working with PHE, they will develop counter measures for CBRN incidents through development of improved protective equipment and the prediction of adverse health outcomes. The Unit will also develop its dynamic pupillometry expertise for rapid identification of exposures to toxic substances and assessment in neurodegenerative disorders.

2. Enhanced focus on applied health research, implementation and impact.

This enhanced focus on applied health research, implementation and impact will be achieved through the £9M NIHR Applied Research Collaboration (ARC) for the East of England (2019-2024). Unit academics are co-investigators and lead three of seven regional research and implementation themes:

- Prevention and Early Detection in Health and Social Care (Wills)
- Ageing and Multi-Morbidity (Goodman)
- Inclusivity and Involvement in Research-led Practice (Mathie co-lead)

Unit academics are also part of ARC national priority topic areas relating to prevention (Wills; Thompson; Rogers) and adult social care and social work (Almack; Goodman; Mathie; Bunn; Warmoth). Wills will also co-lead a £1.5M NIHR Public Health Interventions Responsive Studies Team (PHIRST) (2020-2023) with a UOA4 professor, to undertake public health evaluation research and translation for local authorities across the UK. Jones, Wellsted and Newby are co-investigators. Bunn and Lynch are partners in a new network for dementia technology and innovation (DISTINCT) and will host ECRs from other European nations in the next cycle. A recent regional mapping of social care research readiness undertaken by Almack and Wills for the NIHR Clinical Research Network (CRN) Eastern highlighted the Unit's strong position in terms of social care expertise. Social care research will form a key plank of research in the next cycle: for example, the £2.3M NIHR DACHA study (led by Goodman) will use existing data to improve life for residents of care homes, which has particular relevance in the light of COVID-19. Goodman's second term as NIHR Senior Investigator, from 2021, will also provide the infrastructure for growth in this area.

As lead of the emergent Paramedic Clinical Research Unit (PARA-Cru), Williams will collaborate with TDDT (Chilcott) on risks arising from exposure to aerosols generated through cardiopulmonary resuscitation of patients infected with COVID-19. This collaboration will help develop guidance to deliver optimal patient care while ensuring the safety of first responders and appropriate utilisation of Personal Protective Equipment (PPE).

The Unit will strengthen its focus on long-term conditions, applied health research and clinical trials by gaining Clinical Trials Unit (CTU) status for the Clinical Trials Support Network (CTSN) by 2025. University investment has been secured for this transformation to support further growth. Recent grants have been secured making use of this infrastructure and extending research beyond clinical settings: for example, Evaluating Family-based Interventions to Reduce Violence among Children and Young People (Youth Endowment Fund; Wellsted, Littlechild, Mengoni; £400k to UOAs 3 and 4; 2019-22).

The scope of Patient and Public Involvement in Research work will expand to incorporate Citizen Science at a regional, national and global level.

3. Consolidation and growth of research programmes and facilities.
The Unit aims to build capacity and collaboration by drawing together lab-based scientists. The Biosciences Research Group, for example, aims to become a University Research Centre, by increasing capacity through combining with elements of Pharmacology and Medicinal Chemistry research, currently situated in CHSCR. This will strengthen collaborative research on cancer and neurodegeneration with hospitals within our local acute NHS Trust.

The new state-of-the-art mass spectrometry facility will enable TDDT to expand its research into topical bioavailability bioanalysis in collaboration with Calvo-Castro (CHSCR), having recently recruited an additional ECR (Vuddanda) and PGR students. The BBSRC-Case studentship with GSK (McAuley) fosters collaboration between the drug delivery and toxicology groups through use of the advanced skin characterisation facilities and will be expanded to include in vivo assessment of the effects of dermatological products (Vuddanda).

The Sport, Health and Exercise Research Group is located in a new £7.8M Institute for Sport building, for which the Local Enterprise Partnership funded half of the build cost. The Institute houses cutting-edge sports science equipment, including significant investment in equipment worth £1M+ from GSK. This will enable new areas of collaborative and interdisciplinary research in the next research cycle with clinical academics specialising in musculoskeletal research, exploring trips and falls in neurological and orthopaedic patients, patients with musculoskeletal complaints and older people at increased risk of falling.

4. ECR retention and development and PGR investment.
Mentoring and supporting existing ECRs will contribute to planned expansion of research in the Unit's established Research Centres. Cook's award of an EPSRC New Investigator grant will expand his leadership within the drug delivery team in TDDT and A. Patel and Urbano will expand their research expertise in the pharmacological activity of inhaled aerosols, through HSP and the EPSRC Aerosol Science PhD programme. The Unit will invest in Senior Research Fellowships, which will sustain growth in, for example, Older People's Health and within Public Health. Opportunities to grow capacity in nascent groups relating to Musculoskeletal Research, Para-CRU and Clinical Nursing will be achieved through new ECR fellowships and QR-funded PhD studentships.

2. People

Staffing Strategy
Staffing in the Unit has increased by 135% FTE since REF2014.

The Unit places great importance on attracting and developing researchers and academics, rewarding excellence through its initiatives. It foregrounds equality, diversity and inclusivity in recruitment, training research leaders and sustaining a vibrant research culture by providing staff and PGR student development opportunities, including high-quality facilities and support.

Staff with significant responsibility for research have a minimum of 0.2 FTE pro-rata research time allocation. More senior academics with an established track record of significant income generation and publication have a time allocation of between 0.3 – 0.8 FTE for research activities. Career progression and personal development plans, together with performance targets, are monitored at annual appraisals (reviewed mid-year) and supported through internal training, staff development budgets, QR funding for conference attendance and University development initiatives.

The Unit has recruited ECRs to provide additional capacity in key research areas in line with its strategic aims. A quarter (23%) of staff (FTE) in the Unit are ECRs. 6 five-year ECR fellowships awarded competitively by the University were secured for the Unit (Handley and Lynch – older people's health; Rogers and Hamilton – food and public health; J Patel – pharmacology; Vuddanda – topical drug delivery and toxicology).

41% of Unit staff FTE are Professor or Reader/Associate Professor in Research which together with 33% lecturers and 23% ECRs is an effective balance of expertise and experience providing for both vitality and sustainability. New appointments and internal promotions to Professor and Reader/Associate Professor have also driven research and collaboration with clinical and industrial partners; and strengthened research leadership and global recognition in key research areas. Since 2014 nine individuals have been promoted to Reader/Associate Professor and seven promoted to Professor, reflecting investment in food and public health, health and complex conditions, public involvement and health, musculoskeletal research, exercise physiology, substance addiction, psychiatry, cardiology, pharmacology and drug delivery. Four new professors were also appointed (Almack – health, young people and family lives; Pattison – clinical nursing; Pike – sport, health and exercise; Salek – pharmaco-epidemiology).

The Unit increased opportunities for clinical academics across the career pipeline and strengthened collaboration with clinical partners, through two new clinical appointments (Young; Vasdev) and by awarding honorary titles to clinicians (Category C staff) who collaborate across areas such as pharmacology, clinical trials and community children's nursing. These individuals are fully integrated into the research environment of the Unit and access training, mentoring and facilities.

Staff Development

A comprehensive staff and student development strategy draws on institutional provision as well as local practices. All staff have access to the Researcher Development Programme (RDP) run by the Doctoral College described in the Institutional Environment Statement. ADRs and Centre Heads also arrange training in liaison with colleagues to address specific needs across the Unit, including strategic approaches to publications, clinical trials and grant capture.

ECRs are encouraged to engage with School-based and University-wide opportunities such as grant writing workshops, mentoring, and to take up University-wide roles such as becoming a researcher development representative or ECR rep on the University's Research Committee. ECRs are also supported by networks such as Conversations and Connections (CoCo) for women academics (led by Lione) - 75% of submitted ECRs are women. Professors and Associate Professors act as mentors to early and mid-career researchers to support career aspiration. This led to successful applications for promotion to Senior Research Fellow (Hawkins, Rogers, Lynch). ECRs also receive mentoring to develop external funding applications resulting in prestigious grants (Handley, Hawkins, Lynch).

Research Students

PGR students are integral to the strategic development of the Unit's research capacity and research environment. This is achieved through supporting and mentoring students from enquiry stage, through to enrolment, progression, submission and award, via peer and tutor networks, training programmes and the guidance of Unit academics. PGR students are enrolled in programmes including PhD with Industrial Experience, the Doctor of Medicine (MD), the professional doctorate in health research (DHRes) and the professional doctorate in public health (DrPH), which commenced in January 2020.

Table 1. Numbers of Doctoral students enrolled in Unit at 31 July 2020

PhD students	DHRes students	DrPH students	MD students	Total doctoral students currently enrolled	Increase in enrolments since REF 2014 (%)
117	20	9	4	150	32

Table 2. Increase in Doctoral Awards between REF2014 and REF2021 cycles

	2008/9 – 2012/13	2013/4 – 2019/20	% Increase in awards
Total number of Doctoral awards	35	108	209
Awards per FTE of staff	1.08	1.42	32

External funding for doctoral training has been awarded by the NIHR CLAHRC/ARC EoE, NIHR project grants, research councils, local NHS Trusts, the Hertfordshire Science Partnership (HSP) and charities such as Alzheimer's Society. In addition, QR funding is used to support high calibre candidates. HSP funding is matched with £500k industrial funding and £300k HEIF funding to support innovative, four-year PhDs with Industrial Experience, and currently supports fifteen students across the University, six in this Unit.

In 2018-19 the initiation of a new professional Doctorate in Public Health (DrPH) followed feedback from students on the Masters in Public Health and from Directors of Public Health regarding the need for a programme designed for public health practitioners unable to regularly access face to face meetings at the University. Over the next REF cycle, the pipeline will be further strengthened to increase numbers of students on the DrPH and a new Doctorate in Health and Social Care which will replace the existing DHRes to be more attractive to social care professionals. Studentships will be funded via HSP, EPSRC Centre for Doctoral Training in Aerosol Science and QR.

In the 2019 Postgraduate Research Student Experience Survey (PRES) students in the Unit indicated overall satisfaction rates of 82% with 92% for research skills, 90% for supervision, 88% for professional development and 87% for assessment and progression. The University as a whole was ranked 21st for overall satisfaction, 4th for research culture and 15th for research supervision out of 103 participating institutions, based on a 62% response rate.

All students are supported by the University's Doctoral College, which provides training through the comprehensive Researcher Development Programme (RDP) that incorporates the QAA Code of Practice for Research Degree Programmes and the Concordat to Support the Career Development of Researchers (see Institutional Environment Statement). Further support is provided through PhD tutors in each School and DHRes/DrPH/MD programme leads, who are supported at Unit level by an Associate Director from the Doctoral College. All students are integrated into the research culture of their respective School and Centre, contributing to research seminars and participating at annual School research conferences.

The Science Building, launched in 2016, provides PGR office and laboratory space, with specialised and state-of-the-art equipment and communal areas to facilitate networking among PGR students and academic staff. Senior academics hold monthly 'drop in' sessions to provide support on specific topics such as research ethics, use of NVIVO or statistics and preparing for a

viva. There is an equipment library for doctoral students who wish to borrow small items such as digital cameras or audio recorders. All students can access conference funding through Unit support and through the Doctoral College. Students participating in the University Alliance's Doctoral Training Alliance (DTA) Bioscience for Health programme are funded to attend annual summer schools and DTA courses.

Supervisory teams typically consist of two supervisors with relevant subject, profession and/or methodology expertise and who have undertaken the Doctoral College supervisory training. Less experienced supervisors are supported through a formal mentoring arrangement. Students are assessed at 8 months and 24 months (full-time)/48 months (part-time) after enrolment to examine their research plan and progress.

Equality and Diversity

The Unit is committed to fostering equality, diversity, and inclusivity (EDI). There is a strategic emphasis on addressing barriers to progression, supported by clear structures and lines of accountability. There are 59.3% women in the Unit which is a proportion almost reflected at senior levels with 57.1 % women Professors and Readers/Associate Professors. It contains 19.7% BAME staff who have a presence at all academic levels.

Schools have EDI Teams (EDIT), which review EDI data, formulate action plans, evaluate the impact of Unit-level initiatives and feed into School Research Executive Group meetings. EDIT membership includes diverse perspectives such as those of BAME PGR students and staff; staff with different contract types; and a mix of declared protected characteristics. The Unit also has an EDI Executive Lead (a new post implemented over this research cycle (Sharma)). There is an increasing emphasis on inter-sectionality and this is reflected in the Unit's support for priorities around charter marks such as Race Equality and Stonewall. HSK attained Athena Swan Silver in 2018 and LMS currently holds an Athena Swan Bronze but is making substantial progress towards a Silver application in November 2021 (led by Sharma).

All staff, irrespective of contract type or life circumstances (such as being on maternity leave) have access to dedicated funds for conferences and training, and the Unit supports a fund to cover childcare costs for staff attending conferences. Unit-level inclusive support for career development includes workshops, mentoring and networks such as the Menopause Network, established in the Unit in 2015 and adopted as a formal University staff network in 2019. Consideration of work-life balance has been emphasised through policies that discourage emails being sent outside core business hours. The Unit has two dedicated Wellbeing Champions who promote EDI events such as International Women's Day/ Men's Day. EDI posters are displayed throughout buildings to highlight Unit role models and safe spaces to discuss biases that may limit career success as well as promote support available for staff and PGR students. The Unit achieves a gender balance at its research conferences in terms of plenary speakers, session chairs and student presenters.

3. Income, infrastructure and facilities

The Unit's mean annual research income has increased by 100% over this REF cycle, while total research income has increased by 170%.

These substantial increases are the outcome of the Unit's strategies for grant capture. Senior academics were allocated time and resources to develop applications for major grants and build iteratively on earlier projects. Less experienced colleagues and ECRs were mentored and supported to secure their own awards, as evidenced throughout this submission. Implementation of this strategy was monitored through staff action plans and researcher development forums.

A key source of income in this cycle was a variety of ongoing and new awards from US government agencies, primarily supporting research in toxicology.

Table 3. Research Income over REF2014 and REF2021 cycles (£Million)

REF period	Unit Total Research Income	Mean Annual Income
2008-2013	8.7	1.7
2014-2020	23.5	3.4

Table 4. Main Sources of Income in REF2021 cycle (£Million)

UK UKRI, Royal Society British Academy	UK Central + Local Govt, Health Authorities	UK National Institute Health Research	UK Other	EU Govt	EU other	Non-EU	**Total**
1.1	3.7	4.7	2.6	1.8	0.3	9.3	**23.5**

New Awards
Grant capture across different funders, topics and staff within the unit is discussed below.

NIHR
The Unit has secured £13.0M in NIHR funding during this REF cycle, most of which will support research in the next cycle. These include the Applied Research Collaboration (ARC) (Goodman, Wills and Mathie; £9M in total; £1.3M to UH; 2019-2024); the East of England infrastructure awards for the Research Design Service (Wellsted; £605k to UH; 2018-23),and Collaborations for Leadership in Applied Health Research and Care (CLAHRC) (Goodman's Deputy Director role; (£104k 2014-2019) and Senior Investigator award (£75k 2016-2021)).

The CTSN has secured awards for feasibility and full-scale randomised controlled trials. These include 'READY - A randomised controlled trial of Energetic Activity for Depression in Young people' funded by NIHR HTA (£2.27M; 2019-2023), awarded to joint leads from CHSCR (Wellsted) and CRIPACC (Trivedi).

The workstream on older people's health and complex conditions has been awarded over £6.5M including for 'DACHA - Developing research resources and minimum dataset for Care Homes Adoption and use' funded by NIHR HS&DR (£2.3M) awarded to Goodman (2019-23).

The strategy to support ECRs to make grant applications resulted in Lynch being awarded an NIHR Knowledge Mobilisation fellowship grant to improve assistive technology commissioning, service provision and sustained implementation (£201k; 2018-21).

UKRI
New awards worth £3.9M were secured, including Murnane and Hutter being awarded an EPSRC INFORM Future Formulation of Complex Products programme grant (£1.9M; 2017-21) in partnership with companies including AstraZeneca and GSK, supporting the strategy to increase industry collaborations.

Following mentorship and QR investment in a PhD studentship to support preliminary data collection, Cook was awarded an EPSRC New Investigator award (2020-21; £149k) for his work on applications of polymeric systems as absorption barriers.

Wills and Dickinson's research on older people's perceptions and experiences of strengths and vulnerabilities across the UK food system was funded by the ESRC within a Food Standards Agency programme (£267k; 2014-17).

Industry
Liu was awarded £476k from Fluid Pharma (2016-17) to develop novel medicine formulations for older adults. Lione, in collaboration with Transpharmation Ltd, was awarded a Knowledge Exchange Partnership PhD studentship via HSP (£166k) to refine neuropathic pain endpoints, in line with the concordat on openness on animal research.

Clinical research has also received industry funding: Conmed, a global medical device company, awarded Vasdev £70k (2018-20) to develop haptic feedback techniques for robotic surgery.

Charities
Awards from charitable funders include research to expand the understanding of disease mechanisms: Dimitriadi received £112k from Wellcome Trust (2018-20) to identify pathways critical for Spinal Muscular Atrophy and Iravani received £135k from Parkinson's UK (2019-21) to explore underlying mechanisms by which nicotine may remediate symptoms of Parkinson's Disease.

Hawkins led the validation and reporting of the national Patient Reported Experience Measure in renal disease, including the development of an online version, funded by the UK Renal Registry since 2016 (£125k; also Wellsted and Farrington). Bunn and Goodman have been awarded several grants from the Alzheimer's Society in this cycle (total £471k; also involving Mayrhofer and Handley), for realist evaluations and interventions to support people living with dementia.

Government departments/agencies
Chilcott was awarded £5.9M by US government agencies for multiple projects to develop optimal methods and guidance for decontamination, including the £4.3M GO-AHEAD (Guidance On All-Hazards Enhanced Action Decontamination) project (2016-18), which led to a mobile app to ensure effective and proportionate responses from first responders.

A study on patient perception of dry powder inhaler airflow resistance was awarded by the Office of Generic Drugs of the United States Food and Drug Administration to a collaboration of academics, clinicians and industry scientists including Murnane (2017-21; £1.8M total; £545k to UH).

The Health Behaviour in School-Aged Children study (HBSC) is a cross-national study in collaboration with the WHO. The Unit received £342k from DHSC to fund HBSC England in this cycle.

European sources
Schifano, Corkery and Stair have received two awards to monitor, profile and address the rapid increase in Novel Psychoactive Substance use (European Commission; £419k to UH; ICS 05), also involving institutions in Germany, Hungary, Italy and Spain. Fineberg received COST Action funding (£530k; 2018-21; also Corazza, Jones, Wellsted) to establish a European network to advance the scientific understanding of problematic usage of the internet, bringing together researchers from 42 countries.

Organisational support and resources
The Unit receives approximately £800k of QR funding per year to support research development. This is allocated against a Research Delivery Plan, which is approved and monitored at School and University level. Additional University investment enabled researchers from across the Unit to forge new partnerships on collaborative projects.

Potential funding sources are identified and shared by the Research Design Service (RDS), Clinical Trial Support Network (CTSN), ADRs and Centre/Group Heads. Development of new internal and external collaborations are facilitated by the Centres and the University Research Theme Champions. Writing grant applications is supported by the RDS, CTSN, research mentors and the University Research Grants Team. QR investment is awarded by the Research Executive Groups where appropriate e.g. to support preliminary data collection. The Conversations and Connections network (CoCo) for female academics and researchers hosts annual workshops in the Unit, to discuss funding streams, highlight pathways to impact and receive feedback on draft applications from colleagues.

Staff in the Unit access University funding sources to support impact strategy e.g. Impact Support and Proof of Concept grants. This has led to outcomes including the development of an educational board game 'Food in Later Life' (Dickinson; Wills) used to train individuals and organisations who support older people to prevent malnutrition. Unit-level QR funding is also used to support impact strategy by, for example, supporting the set-up of the UK's first licenced drug-checking service (ICS 05), and funding a PhD studentship that contributed to the formation of a spin out company, ImmuOne (£289k from Innovate UK; Hutter).

Operational infrastructure and facilities

A new Science Building was opened in 2016. This major £61.2M investment provided equipment and office space for researchers and PGR students across the Unit. Facilities are dedicated to enhancing operational research capacity including state of the art resources for inhalation simulation pharmaceutical testing; cell culture research; bioanalytical mass spectrometry; and solid oral dosage production. Small and medium-sized enterprises (SMEs) are also able to hire the cutting-edge facilities and commission research and development projects through the HSP 'Research Hotel' and 'Science Concierge Service' as part of the Unit strategy to facilitate further industry collaborations.

University investment of £2.4M in a secure, off campus, chemical weapons convention compliant facility for toxicological research has provided a globally unique facility for research and development of new protective equipment, detectors and decontamination systems for emergency responders and military personnel responding to CBRN incidents. The facility is suitable for full-scale human and building decontamination trials and is capable of the full range of testing (in vivo and in vitro) and incorporates advanced analytical and characterisation instrumentation required for this research.

Unit staff have access to University capital expenditure (Capex) funding. Successful applications have facilitated the purchase of a Real Time Particle Analyser for the off-campus toxicology research facility (Chilcott £96k), an imaging system to support high-quality publications and generation of pilot data for external funding applications (Dimitriadi; £60k), and increasing capacity and refurbishing post-operative care equipment in alignment with the Unit's culture of animal care (Lione, £58k). Capex supported refurbishing and equipping the Musculoskeletal Research Unit (MSK-RU) Laboratory (Lewis, £42k), which includes sonographic evaluation, thermographic imaging, sensory testing and virtual reality facilities. The MSK-RU facilitates strong links between laboratory and clinical research regarding assessment and management of musculoskeletal conditions and fosters cross-Unit and interdisciplinary research across the University.

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

Research Collaborations and User Partnerships

Unit strategy included targeted objectives to facilitate effective collaborations with a range of external academic and non-HEI stakeholders to complement internal expertise. The effectiveness of this approach is evidenced through increased research income, joint

appointments and outputs, impact, and national and global dissemination to share research knowledge with a range of audiences and publics.

National and international partnerships

The Unit (Goodman; Mathie) was a significant partner in the NIHR CLAHRC EoE, which also involved academics at the Universities of Cambridge and East Anglia and strengthened links with health and care partners and a range of non-academic organisations. This partnership provided research income, research capacity funding to enable external health and care professionals to be mentored by Unit academics (Dickinson; Smeeton) and routes for dissemination of research. It also facilitated involvement in the NIHR ARC EoE from 2019 (Goodman; Mathie; Wills; Thompson; Warmoth).

The Unit led the Health Education England (HEE)/ NIHR Integrated Clinical Academic (ICA) Mentorship Collaboration from 2014-18 (£356k). This involved six HEIs, one NHS Trust, the NIHR CLAHRC EoE and the Council for Allied Health Professions as co-applicants. Approximately 25 HEIs, 10 NHS Trusts and the CLAHRC were involved in mentoring 126 clinical academics during the programme, which was well evaluated by mentors and mentees.

Airway drug delivery involves extensive collaboration with UK HEIs, as well as industry partners. For example, the University is an academic partner on NC3RS Crack It – Inhalation Translation Challenge led by King's College London, along with the National Physical Laboratory, GSK and Envigo (£1M in total; Murnane, Hutter; 2015-18). This is a major collaboration to better predict pulmonary toxicology through in vitro immune modelling technologies.

To ensure the Unit informs and reflects developments in PPIE it has developed strong collaborations with national partners including INVOLVE, the James Lind Alliance and Public Health England, as well as the Clinical Trials Alliance of Australia and the Citizen Science team at the University of Sydney.

Internationally, the track records and activity of Unit academics resulted in new opportunities to develop joint research projects and facilitate networks for the benefit of PGR and ECR development.

The NPS team (Schifano, Corkery, Stair) led the EU-MADNESS project in 2014-16, which involved 12 international partners. Along with Corazza, they are also instrumental in organising the worldwide NPS conference series, supported by the United Nations, which typically attracts 400 participants from 30 countries. The NPS group hosted 40+ visiting international fellows and clinicians, resulting in 55 papers and new PGR enrolments. The Biosciences Research Group have fostered collaborations to support PGRs, for example with Universidad Autónoma de Nuevo León in Mexico, to train and host PGR students in C. difficile techniques (Baines), and undertake dual-PhD awards.

Murnane collaborates with international academic and industry partners, including the FDA-funded "Patient Perception of Dry Powder Inhaler Airflow Resistance" in collaboration with Imperial College London, University of Groningen (Netherlands), two UK University NHS Trusts, and Clement Clarke International Ltd. Collaborators on grants under the EPSRC INFORM 2020 programme include AstraZeneca, (Sweden), Zeiss Microscopy (Germany), Coral Drugs (India) and in the UK GSK, Malvern Panalytical, NanoPharm Ltd, Intertek Melbourn Scientific and four HEIs.

Cook collaborates with the University of Dusseldorf (Germany) and the University of Maringa (Brazil), to develop technologies for the development of age-appropriate formulations and buccal cancer therapies, respectively. He also collaborates with the Institut Laue-Langevin (ILL) France for neutron scattering experiments for formulation characterisation.

The toxicology group collaborate with international bodies including the US Department of Health and Human Services, Federal Emergency Management Agency (FEMA), Organisation

for the Prohibition of Chemical Weapons (OPCW), Spiez Laboratory (Switzerland) and TNO (Netherlands). The team also works with the US Army Combat Capabilities Development Command (CCDC), the UK's Defence Science and Technology Laboratory (Dstl), Armed Forces Biomedical Research Institute (France) and Zurich University of Applied Sciences. Through work with Médecins Sans Frontières, Chilcott has produced a new clothing system to protect charity workers in areas of conflict where chemical warfare agents are a real and present danger.

CRIPPAC staff (Bunn, Goodman, Mathie, Lynch, Handley) are active in the pan-European network for early and timely interventions for people with dementia (InterDem) and Bunn is a partner on the Interdisciplinary Network for Dementia Utilising Current Technology (INDUCT). INDUCT is a Marie Sklodowska-Curie Innovative Training Network which provides comprehensive training for ECRs. CRIPACC hosted two ECRs as part of this programme.

Industrial partnerships for the translation of research

Using partnerships to achieve commercial translation of research is a key aspect of Unit strategy. In the area of personalised therapies, healthy ageing, targeted therapeutics and collaboration with the regional life sciences industry, Murnane secured £3.9M from the Departments for Business, Energy and Industrial Strategy (BEIS) and Community and Local Government (DCLG)/European Regional Development Fund (ERDF) to establish the Hertfordshire Science Partnership (HSP), with an additional £400k HEIF funding. The HSP enables SMEs to access facilities and expertise by: i) working with PhD students who spend 12 months embedded in the organisation through a Knowledge Exchange Partnership, ii) a Therapy Accelerator Competition to help bring products to market, iii) the 'Research Hotel and Concierge Service', that enables access to the University's £61.2M Science Building facilities.

Grants with industry partners have delivered direct translation of research outcomes into new products and services. As part of the NC3Rs CRACK IT challenge, Murnane and Hutter worked with partners to achieve industrial adoption of their toxicity screening models and secured funding from Innovate UK launching a spin-out company, ImmuONE. They also secured EPSRC funding to develop inhalation technologies with Team Consulting/Alviol Ltd, maturing the technology prior to its sale to DS Technology GmbH, the technology development subsidiary of global pharmaceutical engineers Harro Hofliger Verpackungsmaschine GmbH.

Two spinout companies (ImmuOne – Hutter; Fluid Pharma – Liu) have been established in this REF cycle, attracting investment and creating employment. Fluid Pharma was a finalist in both the Pitch@Palace event in 2019 and the Royal Society of Chemistry's Emerging Technologies Competition in the Health category in 2020. Fluid Pharma uses the proprietary technology, MicroCoat^{TM} developed from Liu's research, and this is being utilised to develop a paediatric formulation for a novel compound for the treatment of respiratory viral conditions in children, in partnership with Glatt GmbH.

Pharmacologists within CHSCR have also strengthened industry links. Iravani is working with AstraZeneca to test his patented compound further with a view to commercialisation and has an HSP Knowledge Exchange PhD student with Neurolixis Inc. Lione collaborates with Transpharmation Ltd to provide translational research data for regulatory filings for approval of clinical trials and facilitating translation of research to market. Lione and Transpharmation Ltd have also collaborated on research to identify a novel way to treat diabetic neuropathic pain without hyperthermia.

Working with industry partners is a focus for physiotherapy research led by Watson and Kumeran; their research for Actegy Health Ltd regarding the optimisation of electrical muscle stimulation parameters for lower limb blood flow led to the significant modification of the existing Actegy Revitive foot stimulator, which is now being evaluated by the Unit in a Randomised Control Trial.

Collaborations with health and social care partners to deliver research

To achieve its strategic objectives, the Unit has strengthened partnerships with local NHS Trusts and regional health and social care organisations, increased the number of honorary and substantive clinical appointments and established interdisciplinary strategic groups to bring together health and social care research and practice across the East of England.

The Unit established the Hertfordshire and West Essex Health, Wellbeing and Social Care Research Strategy Group in 2014 to promote synergy and collaboration for research and its application across health and care organisations in the STP/Integrated Care System footprint. The group includes 60+ members including Unit researchers and regional partner organisations such as Clinical Commissioning Groups (CCGs), NHS Trusts, the Eastern Academic Health Sciences Network, and lay members.

University-NHS Trust partnerships have facilitated research collaborations with stakeholders and increased grant income. The University's formal partnership with Hertfordshire Partnership University NHS Foundation Trust (HPFT), which provides mental health services, was renewed in 2016. A research workstream with East and North Hertfordshire NHS Trust (ENHT), which provides acute secondary care, has also been established. Many of the Unit's Category A clinical staff hold senior positions at these Trusts, for example, Fineberg and Gorog are Clinical Leads for Research at HPFT and ENHT respectively and Vasdev is the lead consultant for ENHT's COVID-19 Response for Cancer. Vasdev led a bladder cancer study at ENHT to validate a biomarker in patients, which has recently been awarded CE marking, and also acts as an advisor to KDx Diagnostics, the manufacturer. Examples of collaborative research with Trust researchers include novel models of vascular calcification in nephrology and diabetes (Farrington, Thakur), which have been further developed by the appointment of a University ECR fellowship (J. Patel), and OCD feasibility clinical trials (Fineberg, Wellsted). The partnership also works together to supervise PhD students, form cross-organisation committees and organise joint events.

The Unit supports and seeks secondments and joint appointments with healthcare organisations. Pattison was appointed as a Florence Nightingale Foundation (FNF) Professor of Clinical Nursing, one of only seven such posts approved within the UK; her post is a joint clinical academic appointment between the University and ENHT. Pattison has been instrumental in developing research internships and training events to build capacity and establishing research as a core pillar in nursing strategy. The Unit has established relationships with all 13 UK Ambulance Trusts via the National Ambulance Research Steering Group and the 999 Research Forum. Williams is a member of both groups, has a fractional seconded role as Head of Research at the South East Coast Ambulance Services NHS Foundation Trust, and leads research for the College of Paramedics.

There are 55 Category C staff across the Unit, mostly employed by local NHS Trusts across acute secondary care, mental health and community care. They collaborate on research projects and outputs such as the NIHR-HTA READY trial; the European Problematic Use of the Internet (EU-PUI) COST Action Research Network; and the NIHR CLAHRC funded project into enhancing resilience in families of children with complex health needs and disabilities.

The Unit established a public health strategy group with the local authority in 2015, 'Hertfordshire Public Health Connect'. A quarterly public health Master Class series was established under a Memorandum of Understanding with the local authority; sessions typically attract 70-100+ people from a range of non-academic sectors and showcase Unit research including LGBT health and wellbeing (Almack); obesity (Wills), addiction (Corazza); and mental health recovery (Ramon). The Director of Public Health pump-primed the development of a Public Health Connect website, to showcase Unit research, training, blogs and collaborations with the local authority. This partnership informed the development of the professional Doctorate in Public Health. The University is a partner organisation of the East of England Population Health Research Hub (PHResH), which was established by PHE and the EoE Directors of Public Health; Wills is on the steering group. Unit academics contribute to PHResH blogs and updates

including end of life care (Almack; Pattison), dietary inequalities (Wills, Thompson, Rogers, Hamilton, Mathie, Dickinson) and hospital discharge for people living with mental health conditions (Jones).

Involvement and engagement with research users and the public

The Unit excels at involving patients, service users, carers and the public in its research. Integral to this way of working is the Public Involvement in Research group (PIRg), chaired by Jones. The PIRg helps to engage key beneficiaries, contributes to research outcomes and generates impact. The PIRg links with PPIE groups across the East of England and with condition-specific organisations. Over this REF cycle the PIRg have been involved in the development of 39 funded research studies, resulting in 61 research outputs, with 70% of these outputs discussing the role of PPI in the research process. A collaboration with Jones, Liu and the PIRg was supported through Unit funding and involved the PIRg evaluating the user acceptability of novel technology, leading to a patent application for a medicine dispenser for patients with multiple medicines and dysphagia who cannot swallow tablets. Two Young People's Advisory Groups have been established to strengthen PPIE activity: one to enable young people to collaborate on research in Hertfordshire (Almack, Jones) and a study-specific group for the NIHR-HTA READY study (Jones, Sharma, Mengoni). To ensure that research is co-produced with people from diverse groups, the Unit engages with organisations including Autistica, the National Black, Asian and Minority Ethnic Transplant Alliance, Shaping our Lives and local CCG Diversity boards.

Along with sharing findings with the direct recipients of its research, the Unit seeks to inform and engage the wider public. Staff are supported by the University Press Office to enhance impact opportunities through local, national and international press, radio and social media coverage. The Conversation has published articles by 14 researchers on diverse areas including psychoactive substances (Lione), exercise in extreme temperatures (Muniz; Bottoms), and pregnancy in prisons (Abbott). Staff also contribute talks to the University's Café Scientifique (Abbott, Bottoms, Dickinson, Dimitriadi, Wills). 'Twenty-Five: Lives Seen through Food', was a national public exhibition visited by 3000 people arising from ESRC-funded research (Wills; Dickinson). The exhibition received significant media interest with an estimated reach of 22 million during one month in 2017.

Contributions to Economy and Society

Impact and practical applications of Unit research

The Unit's strategy and objectives for impact outlined in Section 1 inform the pathways to impact and associated engagement activities undertaken by staff. For senior and clinical academics, impact is enhanced through their leading reputations whereas less experienced researchers are supported to develop a track record in impact generation through funding and time allocation to attend training and networking events.

Unit academics have contributed to **national and international healthcare guidelines**, particularly from studies led by our clinical researchers. Research by Pattison informs the intensive care medicine curriculum for medical specialist training; she is an author of the Faculty of Intensive Care Medicine's report on care at the end of life, which has been widely cited and used in practice. Young's collaboration with the Early Rheumatoid Arthritis Study (ERAS) and Network (ERAN) has had a wide-reaching effect on clinical policy and practice, impacting on NICE guidelines. Farrington and Vilar contribute to the Renal Association haemodialysis national guidelines. Fineberg contributed to the classification of OCD and related compulsive disorders as a new diagnostic group as an expert consultant for the WHO and has co-authored guidelines for the British Association for Psychopharmacology and for specialist assessment and care units for OCD.

Working with **industrial partners** and creating spin-out companies (ImmuOne and Fluid Pharma) was a key part of the Unit's impact strategy. Murnane's work informed the development of the Flo Tone device to improve inhaler technique and drug delivery by the medical device

manufacturer Clement Clarke. Murnane's work with TEMAG Pharma enabled them to develop a quality management system and led to the creation of two new quality control positions within the company. Drug delivery research (McAuley) has also continued to develop impact regarding appendageal drug delivery in collaboration with MedPharm, a contract research organisation (CRO), which has helped them to develop their service delivery provision.

In addition to the **parliamentary networks** in which senior academics leading on established programmes of work participate (Section 1), the Unit supports less established academic and research staff to influence parliamentarians by funding travel to parliamentary meetings. Abbott, for example, contributed to the parliamentary Joint Human Rights Committee report into the right to family life for children whose mothers are in prison and her research has informed the development of the operational policy from the Ministry of Justice for every female prison to have resident mother and baby specialists available.

Contributions to Sustainability of Discipline

Many staff have received recognition for their contributions to biomedical, health and care research disciplines and have carried out significant scholarly work for learned societies, conferences and government panels, nationally and internationally.

Table 5. Overall number of staff contributions to activities that help sustain the disciplines of the Unit.

Journal editorship and membership of editorial boards	98
Participation on research grant/funding committees or reviewing proposals for research grant/funding committees	116
External Fellowships relating to research	21
Prizes relating to research	48
Membership of Research Council or similar national and international advisory committees	90
Invited keynotes	258
Other invited lectures and talks	626
Invited conference Chair roles	210
Journals for which staff peer review	521

TDDT was awarded STEM Research Project of the Year by the Times Higher Education (THE) in 2018 and have been described as "one of the world's leading toxicology research labs" by Nature News. Along with local leadership during the COVID-19 pandemic, academics in the Unit provided timely expert advice relating to COVID-19 to a range of government departments, funding committees and learned societies, reflecting their expertise across disciplines.

Below are a selection of international, national and regional/local organisations and bodies that Unit academics and researchers work with to sustain their discipline and to benefit science, health and care policy and practice.

International government advisory roles:

- US Department of Homeland Security and EU Scientific Committee on Health, Environmental and Emerging Risks (SCHEER) for Rapid Risk Assessment of Chemical Threat (Chilcott)
- Deputy High Commission of India Expert Working Group consultation on care home regulation and standardisation for care homes (Goodman)
- Drug strategy advice for National Institute of Health Sciences, Japan (Corazza)
- Young offending policy advice for Bulgarian government (Littlechild)

National and local government advisory roles:

- Advisor to Chief Scientific and Medical Officers, and regional Public Health directors (Chilcott)
- Member of UK Government's Advisory Council on the Misuse of Drugs full committee (Schifano) and subgroups (Corkery) and Chair of the Image and Performance Enhancing Drugs working group (Schifano)
- Medical Advisor to NHS Scotland, member of NHS England Specialised Mental Health Clinical Reference Group and member of the Neurology, Pain & Psychiatry Expert Advisory Group for the Medicines and Healthcare products Regulatory Agency (MHRA) (Fineberg)
- Advisor to the Chief Social Worker for England and to NICE regarding domestic violence (Littlechild)
- Chair, Youth offender Referral Panels, Hertfordshire County Council (Littlechild)
- Member of Dietary Guidance Steering Group, Food Standards Scotland (Wills)
- Member of Chemistry Pharmaceutical Standards Expert Advisory Group, MHRA's Commission for Human Medicines (Murnane)
- Advisor to Hertfordshire Local Enterprise Partnership's Enterprise and Innovation Board (Murnane)

European and global advisory and committee roles:

- Co-chair, expert working group of the European best practice guideline for advanced kidney care in the elderly (Farrington)
- UN Office on Drugs and Crime consultancy roles on opioid use (Schifano; Corazza)
- World Anti-Doping Agency (WADA) and European Crime and European Monitoring Centre for Drugs and Drug Addiction (EMCDDA) on issues around drug misuse (Corazza)
- Commissioned advice regarding substances in food to European Food Safety Authority (EFSA) (Chilcott)
- President, International Society for the Study of Emerging Drugs (ISSED), supported by the UN, EC, WADA and the US Department of Justice (Corazza)
- Secretary, International College of Obsessive-Compulsive Spectrum Disorders and Chair of OCD research network for the European College of Neuropsychopharmacology (Fineberg)
- Working Group on Thrombosis for the European Society of Cardiology (Gorog)
- Member of scientific working groups for the European Haematology Association; Chair, Patient Engagement Special Interest Group of the International Society of Quality of Life Research (Salek)
- Member of the 'We-Thrive' international working group for care home data, hosted by the Gerontological Society of America (Goodman)
- Coordinator, Pharmacology and Basic Neuroscience subgroup, International Parkinson and Movement Disorder Society Non-Motor Parkinson's Disease Study Group (Iravani).
- President, UK and Ireland Aerosol Society (Murnane)
- Co-lead, Age-appropriate Formulations Workstream, European Paediatric Formulation Initiatives (EuPFI) (Liu)
- Expert advisory member, Victorian Active Ageing Partnership, Australia (Jenkin)

UK health and social care committee roles:

- Co-chair, Intervention Workstream for Transforming Participation in CKD initiative, NHS England and UK Renal Registry (Farrington)
- Chair, UK Critical Care Research Group; Vice Chair for UK Critical Care Nursing Alliance and the National Outreach Forum; nursing/PPIE representative for the NIHR National Specialty Group for Critical Care (Pattison)
- Member of Psychopharmacology Committee, Royal College of Psychiatrists (Fineberg)
- NIHR RfPB EoE regional advisory panel (Bunn, Wills, Trivedi, Gorog, Jones)
- PHE East of England Population Health Research Hub steering group (Wills)
- Co-chair, Age-related Medicines (ARM) Group, Academy of Pharmaceutical Sciences (APS) (Liu)
- British Society of Rheumatology Quality Standards Group and British Society of Rheumatology/NICE Working Group (Young)
- Head of Research, Royal College of Paramedics (Williams)
- Treasurer and Trustee, British Renal Society (Farrington)

COVID-19 advisory roles:

- Royal Society of Canada Task Force on COVID-19 (Goodman)
- The Foreign and Commonwealth Office and Cabinet Office response to the COVID-19 pandemic (Goodman)
- UK Parliamentary Office of Science and Technology (Murnane)
- NHS England Clinical Cancer Cell for COVID-19 response (Vasdev)
- PHE COVID-19 and effects of substance misuse (Schifano; Corkery)
- Care Inspectorate for Wales/Welsh Government Social Services COVID-19 advisor (Goodman)
- NHSE/DHSC Surge Staffing levels in critical care (Pattison)
- Royal Society Rapid Approaches to Modelling the Pandemic (RAMP) initiative Theme 7; National Core Study (Theme 4) on COVID-19 Transmission (Murnane)
- College of Experts for the UKRI-DHSC and NIHR COVID Recovery and Learning Research Initiatives (Goodman; Jones, respectively)
- British Association of Sport and Exercise Sciences COVID-19 Steering Committee (Bottoms)