Institution: University of Manchester

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

1. Unit context and structure, research and impact strategy

1.1. Overview

The University of Manchester (UoM) UOA3 comprises 125.52 FTE staff, covering Allied Health Professions, Dentistry, Nursing, and Pharmacy, with core strengths in: (1) underpinning basic and translational science and methodology; (2) applied health and social care research; and (3) policy and population-health research. The unit encapsulates basic, translational, clinical and applied health and social care scientists. As individual disciplines and via collaborative working we have produced responsive and impactful research across the translational pathway. The submission evidences how our 'One Manchester' approach (Section 1.1.1) is at the centre of our environment and has resulted in positive impact on the population in general, as well as for specific groups of service users, health and social care professionals, the academic community, and industry. Deliverables and metrics that evidence our overall excellence in this REF period are summarised in Figure 1.

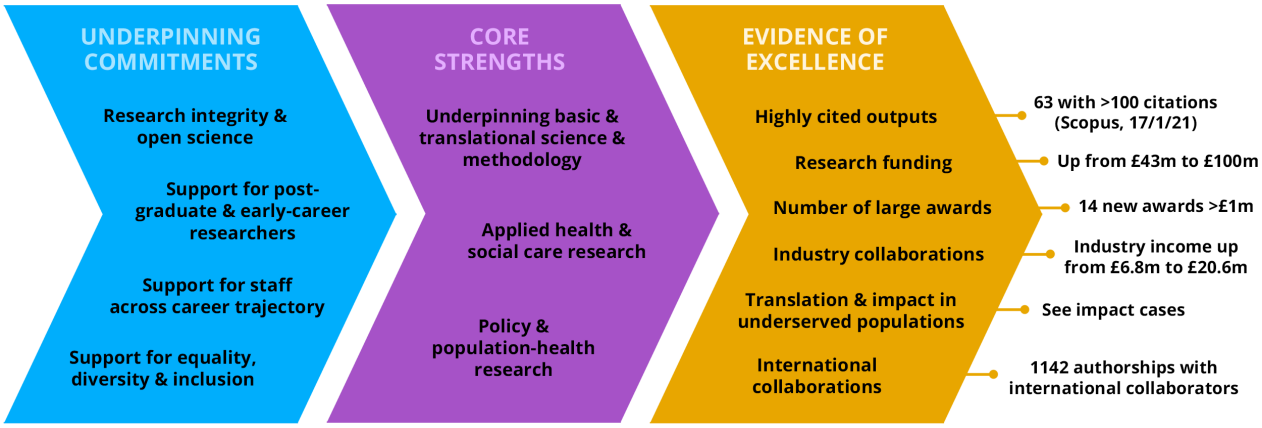

Figure 1. Manchester UOA3 vision: commitments, strengths, and key indicators

1.1.1. UOA3 within the 'One Manchester' approach

In 2016, the devolution of the health and social care budget (£6bn pa) to Greater Manchester (GM) catalysed the creation of a unified, integrated, health science and innovation system: Health Innovation Manchester (HInM). HInM unites the GM health and social care systems (Manchester Academic Health Science Centre, MAHSC; re-designated by NIHR for a further five years in 2020) and the Academic Health Science Network (AHSN), local academic partners, local industry and patients/public, in a 'One Manchester' approach. UOA3 researchers are at the heart of this approach (Figure 2), listening to the needs of the local NHS, social care system and the local population, and mounting appropriate research responses. HInM then enables rapid deployment, where appropriate, of cost-effective innovation at scale and pace across GM, and nationally for innovation adopted by the AHSN.

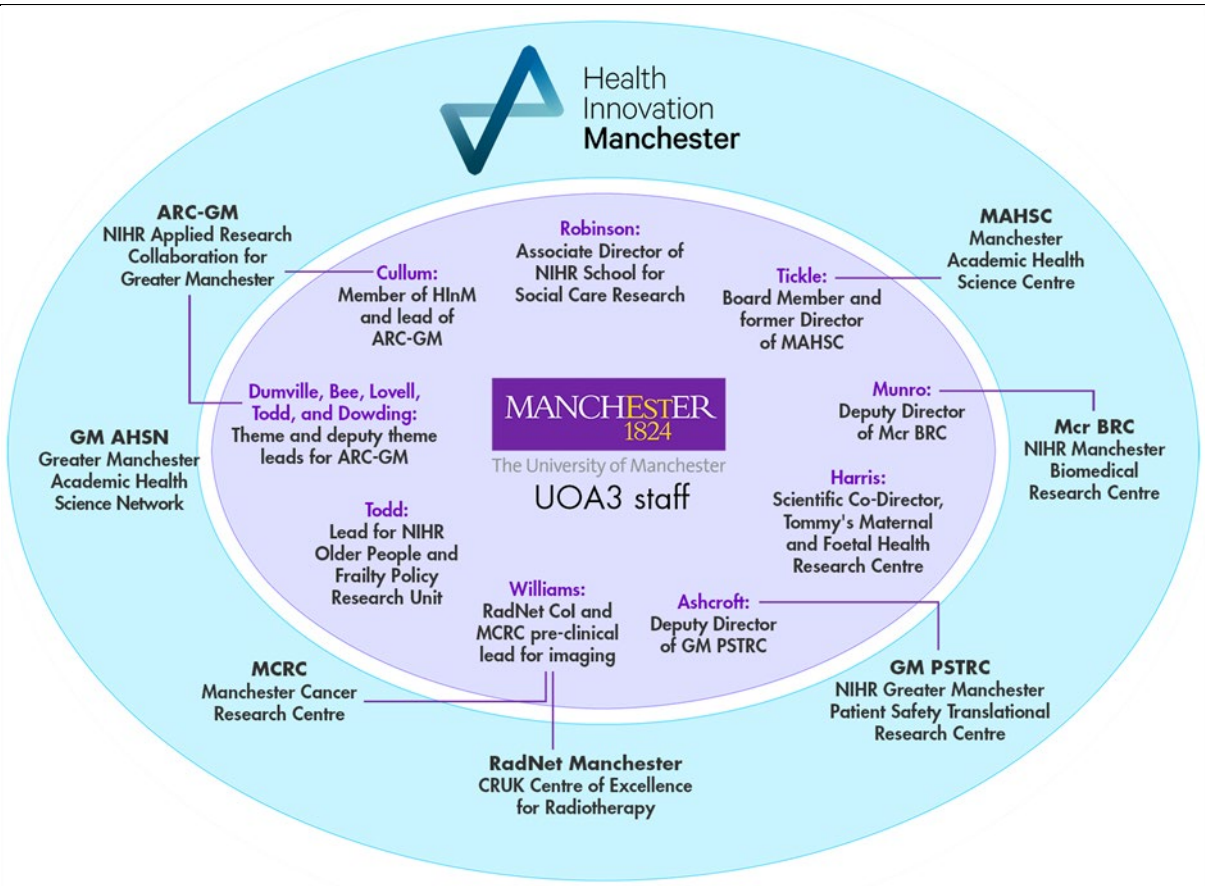

Figure 2. UOA3 staff in the One Manchester environment

Key activities are delivered via MAHSC (previous Director/board member **Tickle**, now **Cullum**). Evidence of UOA3's contribution to large multi-discipline research centres include:

- NIHR Collaboration for Leadership in Applied Research and Care for Greater Manchester (CLAHRC-GM; 2013–19), an interdisciplinary research collaboration co-led by **Luker** and Boaden in Humanities (£20m: £10m NIHR; £10m matched funding) and the subsequent NIHR Applied Research Collaboration (ARC-GM), led by **Cullum** (2019–2024; £11.3m).
- NIHR Older People and Frailty Policy Research Unit (PRU) led by **Todd** (£5m)**.**
- NIHR Greater Manchester Patient Safety Centre, **Ashcroft** is Deputy Director (£5.9m total; £1.1m to UOA3).
- NIHR Biomedical Research Centre (BRC), **Munro** is Deputy Director and lead for Hearing Health Theme (£4.5m).
- NIHR School for Social Care Research, **Robinson** is Associate Director (£1.9m).
- CRUK RadNet Radiation Research Unit within Manchester Cancer Research Centre (£16m; **Williams** Co-I [12% credit share], **Kostarelos, Yorke** are theme leads).
- Tommy's Maternal and Fetal Health Research Centre (rolling annual budget: £450k; **Harris** (Scientific Co-Director).

UOA3's research emerging from such centres is detailed in Sections 1.1.2, 1.6, 3 and 4.

1.1.2. Research achievements

UOA3's key achievements during the REF period are highlighted below, grouped according to our core strengths and our response to COVID-19. Submitted outputs are identified by journal/year/number indicating the institutional unique identifier. Outputs referred to, but not

submitted, are accompanied by their DOI number. Impact cases are referred to as IC. Staff submitted in UOA3 are in bold throughout.

Underpinning basic and translational science and methodology

- Level and activity of drug transporters in the human blood brain barrier quantified in different patient groups allowing prediction of drug disposition in the brain, permitting precision dosing in special populations including those with dementia. **Barber** *Mol Pharmaceutics 2019,*119302837.
- **Butterworth** invented, and was responsible for, the pre-clinical development of Tagrisso (Am Chem Soc prize, see Section 4.2.1, now licensed world-wide to treat Non-Small Cell Lung Cancer. *J Med Chem 2014,*51494903.
- First prognosis review reporting the lack of basic science evidence on biomarkers for wound healing; stimulating back translational research to consider the rationale for a number of available treatments. **Dumville** *Cochrane Database Syst Rev 2018,*82468359.
- Identified novel candidate causative genes involved in orofacial clefts. **Dixon J** *Hum Genet 2016,*84815152.
- Demonstrated that antioxidant supplementation and its inhibition of oxidative stress-induced DNA damage is a realistic strategy for the clinical prevention of Treacher Collins Syndrome. **Dixon J** *Nature Comms 2016,*50390554.
- Demonstrated that ERK5 is a critical mediator of inflammation-driven cancer. This suggests that targeting tumour-associated inflammation via anti-ERK5 therapy will have broad implications for treating human tumours. **Finegan** *Cancer Res 2015,*51480914.
- Design and synthesis of inhibitors of the inflammasome which protect against Alzheimer's disease in animal models. **Freeman** *Nature Comms 2016,*51499699.
- Discovered the *in vivo* protein corona surrounding nano-scale delivery systems with potential for use as a biomarker of disease. **Hadjidemetriou** *Nano Today 2020,*173956176.
- Maternal Immune Activation established as an important factor in early brain development and cognitive behaviour in rodent models, with implications for early cognitive deficits in humans. **Harte** *Brain Behav Immun 2019,*83131414.
- Oxygen-enhanced MRI detects therapeutically relevant physiological changes in hypoxia in tumours in patients treated with radiotherapy, which means patients can be stratified to particular drug/radiation treatments. **Latif** *Clin Cancer Res 2019,*116755399.
- Demonstrated that cyclooxygenase-derived prostaglandin E_2 (PGE_2) drives cirrhosis-associated immunosuppression and showed that strategies to reduce circulating PGE_2 levels attenuate immune suppression thereby reducing infection risk. **Nicolaou** *Nat Med 2014,*39070392.
- One of the first demonstrations that immunotherapy (PLD1 blockade) potentially improves radiotherapy outcomes. **Stratford** *Cancer Res 2014,*39330997.
- Tumour-homing peptides demonstrated to be potent tools for targeted delivery of payloads to the placenta. **Tirelli** *Sci Adv 2016,*50861261.

Applied health and social care research

- Investigation of developmental trajectories in children with specific language impairment revealed childhood-onset persistent or adolescent-onset problems. **Conti-Ramsden** *J Child Psychology Psychiatry 2014,*39056990.
- First network meta-analysis of the effects of support surfaces for pressure ulcer prevention highlighted the value of active air surfaces over guideline-recommended surfaces. **Cullum** *PLoS One 2018,*82468362.
- Predictive risk model developed to identify patients at high risk of infection in community care settings that can impact on nursing care and resources. **Dowding** *J Healthcare Quality 2020,*132173058.
- Compression hosiery is cost-effective for venous leg ulceration; informed national practice. **Dumville** *Health Technol Assess 2014,*39060387.

- Demonstrated that a carer support intervention to facilitate carer-led assessment and support during end-of-life care led to better outcomes. **Grande** *BMJ Supportive and Palliative Care 2014,*50851091.
- Demonstrated non-inferiority of interpersonal therapy for Post-Traumatic Stress Disorder (PTSD) compared with gold-standard treatment. PTSD treatment may not require cognitive-behavioural exposure to trauma reminders. **Lovell** *Am J Psychiatry 2015,*39067804.
- UK Biobank resource determined prevalence of hearing loss and showed that 10% of older adults have substantial hearing impairment, with highest prevalence in individuals from low socioeconomic and ethnic minority groups. **Munro** *Ear Hear 2014,*39069703.
- In the largest worldwide study of Obsessive-Compulsive Disorder (OCD), low-intensity interventions did not lead to clinically significant benefits and may reduce uptake of therapist-led Cognitive Behaviour Therapy (CBT). **Price O** *PLoS Medicine 2017,*60196061.
- Demonstrated that increased use of physical, occupational and speech therapies for stroke survivors was associated with shorter length of stays, less resource and lower risk of mortality. **Tyson** *Health Serv Deliv Res 2020,*158746452.
- No evidence of a difference in oral health between a 'typical' six-month routine check-up or a risk-based recall interval. **Worthington** *Health Technol Assess 2020,*85376916.

Policy and population-health research

- Demonstrated variations in prescribing safety in primary care. Existing prescribing risks are identified particularly for older patients and those taking multiple medications. **Ashcroft** *BMJ 2015,*46998671.
- Demonstration that speech difficulties at school entry are a significant risk factor for later reading difficulties. **Burgoyne** *Early Child Res Q 2019,*158099043.
- Demonstrated that individuals with a history of self-harm and violent criminality have a high risk of accidental death and dying from external causes. **Carr** *Lancet Public Health 2019*,133728732.
- A pharmacist-led safety medication interventionin primary care resulted in reduced rates of potentially hazardous prescribing and inadequate blood-test monitoring in general practices. **Keers** *Plos Medicine 2020,*178218588.
- Policy changes by the FDA and EMA regarding new drug registration and labelling has been driven by physiologically based pharmacokinetic modelling (IC5). **Rostami-Hodjegan** *Expert Rev Clin Pharmacol 2018*,DOI:10.1080/17512433.2018.1501271.
- Demonstrated that caries prevention package delivered to 2-3 year old children in a primary care setting may slow down caries progression. **Tickle** *J Dent Res 2017*,61956587.
- Four European population-based cohort studies were pooled to develop and validate a clinical prediction model for onset of functional decline in older people. **Todd** *BMC Geriatr 2019,*158751620.

Response to COVID-19

- Demonstrated that COVID-19 resulted in many physical and mental health conditions going undiagnosed, and the potential impact on NHS and care services. **Carr** *Lancet Public Health 2020,*177114697.
- In response to dental services closure/reduction during COVID-19, Cochrane Oral Health, NHS Education (Scotland), and the Universities of Aberdeen and Dundee, conducted a rapid review of evidence related to aerosol generating procedures in dental health care, informing Public Health England's COVID-19 infection prevention and control dental appendix. **Clarkson**, **Glenny** *SDCEP 2020* (sdcep.org.uk).
- Two papers presented evidence-based guidance to optometrists and contact lens practitioners regarding safe contact lens wear during the pandemic. Authors given the American Public Health Association Outstanding Scientific Papers Award. **Morgan** *Clin Exp Optom 2020,*DOI:10.1111/cxo.13088; *Cont Lens Anterior Eye 2020,*DOI:10.1016/-j.clae.2020.03.012.

- 13% of hospitalised COVID-19 patients experienced persistent changes in hearing and tinnitus. **Munro** *Int J Audiology 2020,*DOI:10.1080/14992027.2020.1798519.
- The use of Anakinra to reduce hyperinflammation in COVID-19 has potential clinical utility. Recommendations are made regarding patient selection, dosing and outcome measures. **Ogungbenro** *Lancet Rheumatology 2020,*DOI:10.1016/S2665-9913(20)30160-0.
- Identified the impact of COVID-19 on the diagnoses, HbA1c monitoring and mortality in people with type 2 diabetes: a UK-wide cohort study involving 13 m people in primary care. **Carr** *Diabetes Care 2020*,DOI:10.1016/S2468-2667(20)30201-2.
- Demonstrated that dose adjustments will be needed for patients exhibiting hepatic/renal impairment. **Rostami-Hodjegan** *Br J Clin Pharmocol 2020*,DOI:10.1111/bcp.14668.
- **Thompson** identified how Covid-19 impacted on dental antibiotic prescribing in England, Br *Dent J* 2020 DOI: 10.1038/s41415-020-2336-6.
- **Todd** sat on Scientific Advisory Group for Emergencies (SAGE) Social Care Working Group during 2020. He wrote briefing papers including Personal Protective Equipment (PPE) for unpaid carers (09/2020).

1.2. Research Areas

Below we detail the research areas represented by this submission, evidencing activity with outputs and key grants.

Allied Health Professions (research staff 25.2 FTE)

We address topics including: sensory disorders, healthy ageing, and communication and development.

Audiology at UoM is the UK's largest audiology research group, with 13 research-focused staff at lecturer level and above. We conduct a broad range of research from the physiology of hearing and its impairment (**Plack** *Neuropsychologia 2014,*39071756), noise induced hearing loss (**Kluk** *Hearing Res 2017,*61948372), and hearing and cognition (**Dawes** *PLoS ONE 2014,*39344043), to auditory devices (**Saunders** *Ear Hearing 2016,*164510534), advanced diagnostics (**Schlittenlacher** *Trends Hear 2018,*DOI:10.1177/2331216518788215), and pediatric audiology (**Dillon** *Pediatrics 2017,*132976941). The research group constitutes the Manchester Centre for Audiology and Deafness (ManCAD) led by **Munro**, who also leads the Hearing Health Theme (£4.5m) in the NIHR Manchester BRC (£28.5m), bringing together researchers from audiology, speech and language therapy, genomics, health psychology, and engineering. Audiology staff contribute to the Horizon 2020 SENSE-Cog programme (€6.5m), investigating links between sensory impairment and cognitive decline.

Early Language Development develop models of typically developing children's early language and communicative development and study children's linguistic environment and its role in supporting language acquisition (**Polišenská** *J Speech Lang Hear R 2016,*64558530). We include the Parents and Children Together project (led by **Burgoyne**); a long-term early language teaching programme involving 47 nursery schools, and approximately 450 families, in Manchester and Lancashire.

Language Impairment investigate the causes and associated difficulties of language impairment and have the UK's largest longitudinal study of language disorders from childhood to early adulthood (The Manchester Language Study, started in 1995 and led by **Conti-Ramsden**, following 242 children from age seven years until their mid-20s; **Conti-Ramsden** *PLoS One 2016,*50810425). We also conduct intervention research on pragmatic language impairment (**Adams** *Res Dev Disabil 2015,*39051728).

Optometry and Vision Sciences improve our understanding of the structure and function of the human visual system and translate new knowledge into useful clinical tests, devices and

commercial products (**Aslam** *Am J Ophthamol* 2018,64635835). The Eurolens Group (led by **Morgan** with service and contract industrial research support >£8m) specializes in improving contact lens performance and studying the physiology of the tear film and the ocular surface (**Maldano-Codina** *Cornea 2020,*133768288).

Dentistry (research staff 16.8 FTE)

We undertake research encompassing the translational pathway, with demonstrable impact on the delivery and quality of dental services and clinical care.

Basic Dental Science: Our craniofacial genetic research uses the latest genomics technologies (**Bobola:** PI on MRC and BBSRC projects totalling £3m over the REF period). We generate and integrate data on chromatin states, occupancy of transcriptional regulators (ChIP-seq) and transcriptional profiles (RNA-seq), to decipher transcriptional networks that guide apparently similar blocks of tissue into forming anatomical structures such as the face, ear and heart (**Bobola** *Development 2016,*51323477). Research in our laboratories uses systems-level approaches to delineate gene regulatory networks underlying development of the lip and palate, and dissects how their modification relates to the pathogenesis of cleft lip and palate (**Dixon J** *PLoS Genet 2017,*62293836). Our biomaterials research has developed novel biomaterial formulations based on nanotechnology, exploration of molecular interactions between collagen and adhesive organic monomers and adhesive interactions with hard dental tissues and bone (**Silikas** *Dent Mater 2019* DOI: 10.1016/j.dental.2019.08.102. We host the editorial base for Dental Materials (**Watts**, **Silikas**).

Health Services: Our research includes public health and primary care, caries and diagnostic research, oral radiology and imaging, oral and maxillofacial surgery, orthodontics, and management/care of cleft lip and palate. Our research has improved oral health by contributing to the oral health evidence base to inform health policy, healthcare planning and clinical care of patients (**Thompson** *Antibiotics 2020,*176457873; **Worthington** *Health Technol Assess 2020,*85376916; **Tickle** *J Dent Res 2015,*39061069***)***. Our health services research has received over £8.5m NIHR funding for projects active over the REF period. The research theme incorporates the editorial base of Cochrane Oral Health (led by **Clarkson**, **Glenny**; previously **Worthington**; £1.1m infrastructure funding 2014-2020), which has also established the Global Evidence Ecosystem for Oral Health (GEEOH). Our researchers produce trustworthy evidence that is globally adaptable to end-users' needs. Our research also utilises data held by NHS Business Services Authority, part of NHS Digital, either wholly, or to support primary research (LOTUS: **Pretty** £330k; Reflect: **Tickle** £2.1m).

Nursing (research staff 36.1 FTE)

We enjoy an international reputation for multi-disciplinary applied health and social care research.

Nursing includes healthy ageing and palliative care research. **Todd** leads the NIHR Older People and Frailty Policy Research Unit (£5m): **Hawley-Hague** *Prog Cardiovasc Dis 2019,*84957733; **Stanmore** *BMC Med 2019,8552787.* **Keady** leads the Neighbourhoods and Dementia NIHR/ESRC Study (£4.2m). **Grande's** research supports improved end-of-life care (**Grande** *Patient Educ Couns 2014,*39061166). **Cullum** and **Dumville** undertake epidemiological and translational research on wounds and their complications including large RCTs (NIHR HTA: £1.9m), a programme in the Manchester BRC and **Cullum** leads Cochrane Wounds (**Dumville** *NIHR Journals Lib (HTA) 2014,*39060387*,* **Cullum** *NEJM 2018*,83397628*;* **Briggs** *NIHR Journals Lib 2015***,**64615722). **Bee** and **Lovell** lead internationally recognised mental health research. **Bee** and **Lovell** have each led large NIHR Programme Grants for Applied Research and **Price O** leads an NIHR-HTA project (£520k): **Bee** *Plos One, 2018,*43537400; **Lovell** *BMJ 2015,*39067806; **Price O** *Br J Psychiatry 2015,*39053415; **Renwick** *Schizophr Res 2015,*43537400. **Kirk** improves young people's mental health (NIHR HS&DR £643k). We also lead large, regionally focused programmes: **Luker** co-led the CLAHRC-GM (2013-2018; £20m:

£10m NIHR; £10m NHS funding) and **Cullum** leads the NIHR ARC-GM (2019-2024; £11.3m and additional NHS co-funding).

Midwifery and Women's Health undertake research to improve the health of women and babies during pregnancy and childbirth: they are a WHO collaborating centre. **Lavender** leads an NIHR Global Health Group in stillbirth in sub-Saharan Africa (£2m). **Lavender** *Lancet 2016,*51497652; **Cooke** *Acta Derm-Venereol 2015,*39055790; **Bedwell** *BMC Pregnancy Childbirth 2017,*51334957.

Social Research with Deaf People are d/Deaf and hearing researchers working with the d/Deaf community and stakeholders. **Young** leads the national prospective longitudinal study of d/Deaf young people in the UK (National Deaf Children's Society £600k). **Rogers** *NIHR Journals Lib 2017,*63971316.

Social Care and Society encompasses the NIHR School for Social Care Research. Their work includes research in the criminal and social justice system: **Robinson** *Health Social Care Com 2018,*135172250; **Clarkson** *Aging Mental Health 2016,*51483626.

Pharmacy (research staff 47.4 FTE)

Pharmacy-based research encompasses most aspects of the drug development translational pipeline from drug synthesis through to drug usage. Groupings are thematic, with staff moving from one to another depending on the project. Research income (accounting for credit share) was £34m in the period.

Patients: Diagnosis and Therapy focus on our understanding of disease biology to identify molecular targets suitable for therapeutic intervention (**Finegan** *Oncogene 2020*,174614833; **Williams** *Mol Cancer Ther 2014,*39330995), develop clinically relevant models of disease to assess drug efficacy (**Neill** *Int J Neuropsychopharmacology 2014,*39062308; **McBain** *J Invest Dermatol 2017*,63048674), and find biological markers that can predict the development of a disease, its diagnosis and its response to therapy (**Nicolaou** *J Pathology 2019,*84607212; **Finegan** *Cancer Res 2016,*39332147). Research awards total ~£9m, examples include**: McBain** (£365k Unilever), **Nicolaou** (£409k, Unilever).

Medicines: Design and Delivery develop new, clinically viable therapies, integrating structural, analytical, computational and synthetic chemistry with expertise in target biology (**Butterworth** *J Med Chem 2020,*170122962; **Freeman** *Chem Sci 2020,*178138437) and understand how and why therapies work, by using omics, imaging techniques and computer modelling (**Williams** *Theranostics 2017,*61959481; **Nicolaou** *Arthritis Res Ther 2019,*102777680; **Bryce** *Biomacromolecules 2015,*39054796). This group hosts the Nanotechnology in Medicine network (led by **Kostarelos**), a cross-faculty interdisciplinary network facilitating the exploitation of novel nanomaterials and nanotechnologies, including graphene and other 2D materials, to provide solutions for unmet clinical challenges (**Vranic** Nat. Nanotechnol *2017*,85045010). The group includes two Centres: The North West Centre for Advanced Drug Delivery (NoWCADD, led by **Lawrence**), which translates drug delivery science into treatments for serious and life-threatening conditions (**Tirella** *Mol Pharmaceutics 2017,*64347796), and the Centre for Applied Pharmacokinetic Research (CAPKR, led by **Rostami-Hodjegan**) studies how genetics, lifestyle and disease can affect the therapeutic and adverse effects of drugs (**Scotcher** *CPT: Pharmacometrics Syst Pharmacol 2020,*177331868). Research awards total ~£17m, examples include **Aarons** (£1.5m AstraZeneca Ltd), **Rostami-Hodjegan** (£127k Simcyp Ltd).

Drug Usage and Pharmacy Practice improve medicine use and safety, informing pharmacy policy and workforce behaviour. **Ashcroft** leads the Centre for Pharmacoepidemiology and Drug Safety medication safety theme of the NIHR GM Patient Safety Translational Research Centre where they develop, evaluate and implement new models and systems of healthcare practice ensuring safe and effective medicines-use (**Steinke** *BMJ Open 2020,*178187170; **Phipps** *Arch Dis Childhood 2019,*84667649). The Centre for Pharmacy Workforce Studies (**Schafheutle**)

researches pharmacy workforce, labour market and professional developments and culture (**Jacobs** *Health Serv Deliv Res 2017*,60219997). Research awards total ~£8m, examples include: **Ashcroft** (£394k Mundipharma Research Ltd); **Jacobs** (£200k ICF Consulting Services Limited).

1.3. Structure

1.3.1. UOA3 within University and Faculty structures

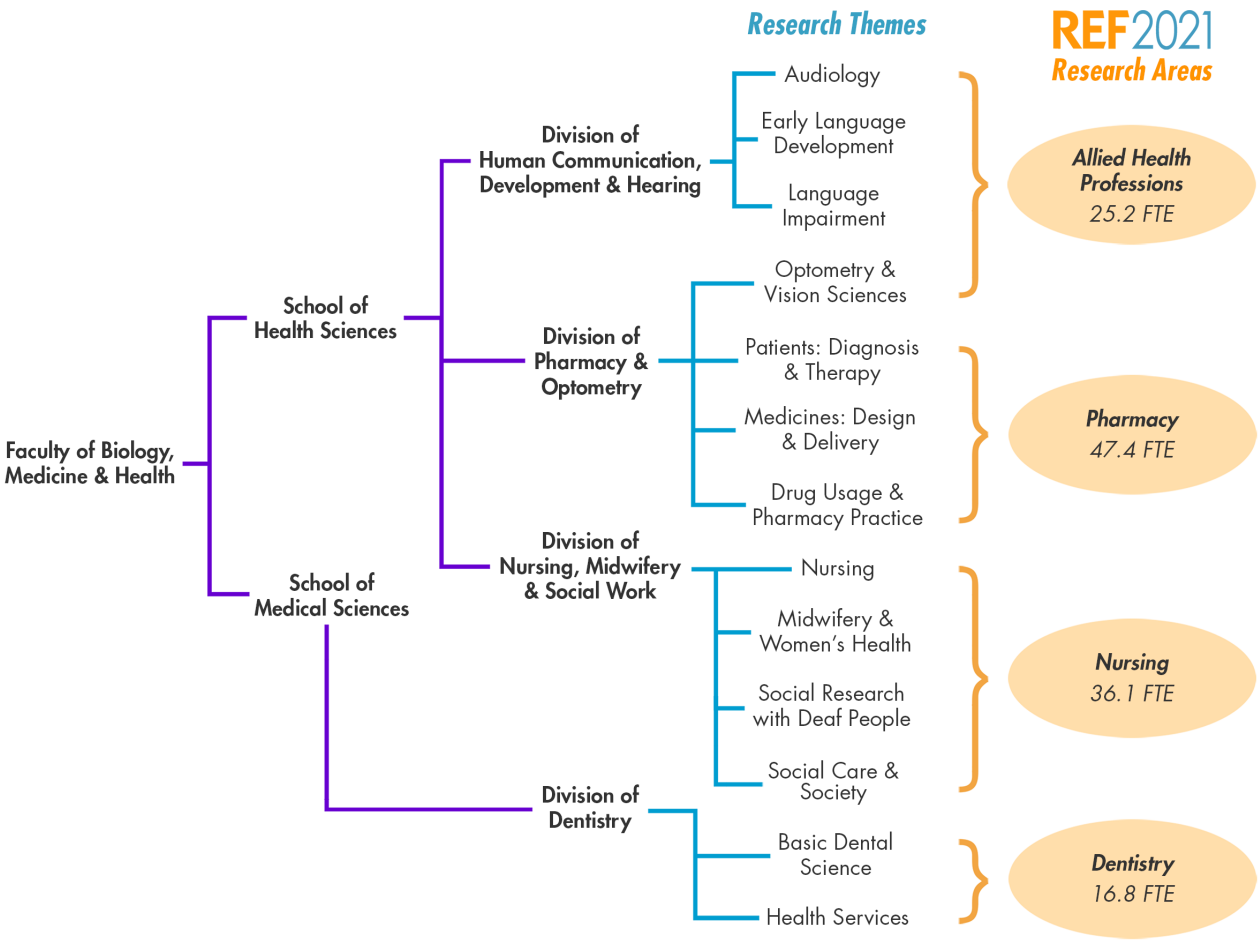

Figure 3. UOA3 staff locations within the Faculty of Biology, Medicine and Health

UOA3 sits within the Faculty of Biology, Medicine and Health (Figure 3), one of three University Faculties (FBMH, Science and Engineering, Humanities). FBMH was created in 2016 by integrating the Faculty of Life Sciences and Faculty of Medical and Human Sciences to facilitate translational research and greater interdisciplinary working, especially between basic and clinical sciences. UoM has invested ~£128m in new interdisciplinary research institutes (REF5a, Section 2iii). At a university level, further interdisciplinary working is showcased by the forward-facing Research Beacons (Advanced Materials, Cancer, Energy, Industrial Biotechnology, and Global Inequalities). The Beacons showcase UoM's pioneering discoveries, interdisciplinary collaboration, and cross-sector partnerships that are tackling some of the biggest questions facing the planet. Within these Beacons UOA3 staff play major roles, e.g. **Kostarelos**, **Tirelli** in Materials; **Williams** in Cancer; **Lavender** in Global Health.

1.3.2. Cross-faculty collaboration

UOA3's interdisciplinary working is further exemplified by intra- and cross-faculty collaborations. For example, investment in the Manchester Institute for Biotechnology, the National Graphene Institute, the Graphene Engineering Innovation Centre, the Christabel Pankhurst Institute for Health Technology (a £25m investment to capitalise on excellence in digital health and advanced materials), and the Sir Henry Royce Institute, spans Faculties to create an unrivalled opportunity to develop and apply new advanced materials to healthcare. The Nanomedicine Lab (led by **Kostarelos**) contributes to the Graphene Flagship, with a €1b budget funded by the European Commission. UoM is one of the largest academic partners and **Kostarelos** sits on the Flagship Project Management Board and leads on Biomedical Technologies, focussing on developing neural implants and bioelectronics-based therapeutic elements for specific clinical outcomes in neurology, ophthalmology and surgical oncology. **Kostarelos** is the Director of the 2D Materials for Next Generation Healthcare Technologies, a five-year cross-faculty programme funded by EPSRC (£5.3m). Outputs co-authored with Faculty of Science and Engineering include: **Pluen** *Mol Pharmaceutics 2020,*158115766; **Lawrence** *Langmuir 2019*,158672842. Examples of collaborations in the Faculty of Humanities (FH) include The Manchester Institute for Collaborative Research on Ageing (MICRA) which undertakes cross-disciplinary research addressing the major challenges posed by ageing populations. **Marshall** chairs MICRA's management board and **Todd** co-leads MICRA project Prevent IT, which gained EU funding to develop and evaluate behaviour change interventions with older adults. Outputs co-authored with FH include: **Hawley-Hague** *Pro Cardiovasc Dis 2019,* 84957733; **Hicks** *Sociol Rev 2020,* DOI: 10.1177/0038026120931424; **Keady** *Int J Geriatr Psychiatry 2018*, DOI: 10.1002/gps.4903

Support for cross-faculty translational research

Funding for this comes from rolling annual awards from the Wellcome Trust (ISSF consolidator awards), MRC (Confidence in Concept, CIC) and the UoM Strategic Research Infrastructure Fund (£6m pa).

- The ISSF Awards (£50k) aim to consolidate existing activity in emerging areas of strength, providing funding for multi-disciplinary projects. UOA3 staff awarded ISSF include **Bee**, **Bichenkova**, **Bryce**, **Lewis**, **Neill.**
- The University Interdisciplinary Research Pump-prime Competition awards funding to promote successful interdisciplinary research (8-10 annually of £10k-£50k). For example, in UOA3 this led Complex Wounds Manchester to develop point of care tests to predict wound healing, involving collaboration between Nursing (**Cullum**, **Dumville**); Pharmacy (**McBain**); Advanced Materials (Cartmell UOA12); Materials Engineering (Lu, Waigh UOA9); and Biological Physics (Reid, Wong UOA1). Other UOA3 staff to benefit from University of Manchester Research Institute awards include **Brooks**, **Burden**, **Bussy**, **Kostarelos**, **Nagington**, **Nicolaou**, **Stanmore**, **Tirelli**, **Tully.**
- The MRC CIC scheme awards fund proof-of-concept/feasibility studies. UOA3 researchers have benefitted from this funding and have generated preliminary data resulting in subsequent awards, e.g. **Finegan** (Friends of Rosie £67k, CRUK £82k**).**
- Further institutional investment in UOA3 comes from the University Endowments Project Research Fund (£1.7m), used to build targeted capacity in nanomedicine by recruiting ECRs and providing support over a five-year period. The aim is to diversify the nanomedicine research portfolio into specific scientific and therapeutic areas (cell biology, **Vranic**; oncology, **Hadjidemetriou**; neuroscience, **Wykes**; inflammation, **Bussy**).

1.4. Delivering research success since REF2014

1.4.1. REF2014 Objective 1: Increase and diversify our research funding

Overall research income increased from £42.7m in REF2014 to £99.7m in REF2021 (Figure 4; expanded in Section 3.1). Our funding has diversified particularly in global health, receiving £6.5m from the Global Challenges Research Fund (GCRF). We have increased funding from UK government and industry, e.g. we were awarded an STFC grant (>£1m) for access to analytical neutron beams in the UK and Europe (UKRI 'income-in-kind').

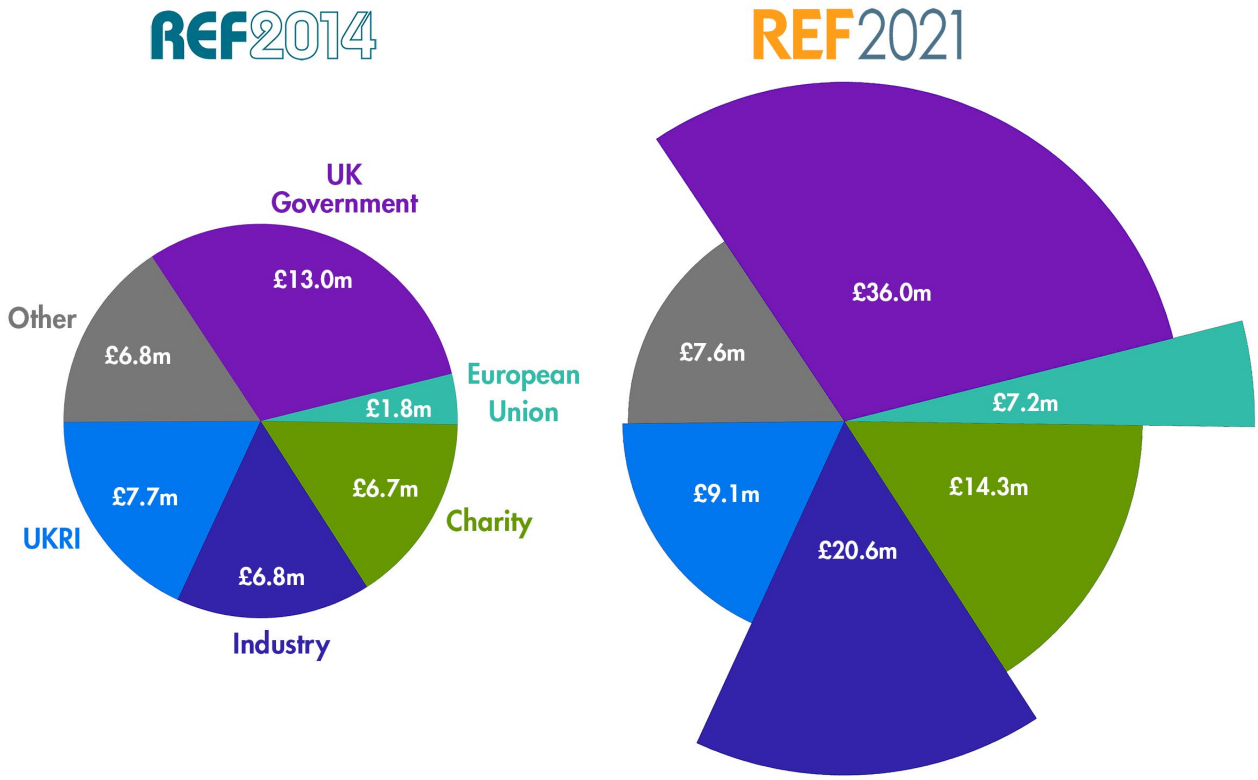

Figure 4. Research income in REF2021 compared with REF2014 across six categories (excluding income-in-kind)

1.4.2. REF2014 Objective 2: Recruit and develop talented researchers

We continue to promote, identify and recruit talented researchers. In the period we have promoted 54 staff (compared to 38 in REF2014), including 16 to Professor and 26 to Senior Lecturer/Reader. We have recruited six staff to Professor, eight to Senior Lecturer/Reader, 10 to Lecturer/Fellow and supported our researchers to gain prestigious fellowships (Section 2.1).

1.4.3. REF2014 Objective 3: Increase collaboration and prioritisation

Collaboration with local NHS and patients

UOA3's collaborations with local NHS are exemplified by successful funding of large research centres resulting from partnerships within the 'One Manchester' approach (Section 1.1.1). Our success depended on our collaborative and responsive ethos in several research prioritisation exercises, some supported by the James Lind Alliance, including End of Life Care (**Grande**),

Dentistry (**Glenny**), Wounds (**Cullum**), Mental and Physical Health (**Lovell**), Early Intervention Services (**Renwick**) and more efficient clinical use of biological therapies (**Ogungbenro**).

Global health in low and middle-income countries

UoM's infrastructure has enabled growth in our international collaborations. UOA3 researchers increased funding and impact in global health in low and middle-income countries. Examples include:

- **Lavender** leads a WHO Collaborating Centre, established programmes of research in sub-Saharan Africa, and was awarded an NIHR Global Health Research Group in Stillbirth (£2m).
- **Young** leads an AHRC/MRC GCRF Global Public Health Partnership Grant/ Global Impact Accelerator Grant (£222k) on enhancing resilient Deaf youth in South Africa.
- **Robinson** secured a GCRF grant 'The South Asia Self-Harm Initiative' (£4m) strengthening research capability in UK, India, and Pakistan.
- The Gates Foundation supports **Aarons** and **Ogungbenro** to build research capacity in pharmacometrics research in sub-Saharan Africa.
- A Newton-funded workshop (**Lovell**) enhanced research capacity for early-career researchers from the UK and Indonesia; resulted in awards: **Lovell**/Brooks (MRC £126k), **Bee** (MRC/DFID/NIHR £350k), **Renwick** (DFID/MRC/NIHR/Wellcome £148k).
- **Edge** Protecting Youth from Interpersonal Violence via Implementation of the Strengthening Families Programme in Panama (MRC £363k).

Examples of outputs in collaboration with low and middle-income countries include: **Lavender** *PLoS Medicine 2018,8*4781681; **Young** *Medical Humanities 2019,*132444619; **Bee** *Res Involv Engagem 2019*,DOI:10.1186/s40900-019-0161-3.

National and International collaborations

We collaborate widely, nationally and internationally (Section 4).

1.4.4. REF2014 Objective 4: Enhance academic and societal impact

UOA3 have demonstrated significant academic and societal impact (Section 1.6 and Section 4). We have maintained our publication output, with eligible staff publishing 3119 papers 2014-2020 compared to 2098 in REF2014 (Scopus 14/01/21). In terms of quality, 20.5% of our papers (639/3119) appear in the top 10% citation percentile (field weighted). **Rostami-Hodjegan** (2016) and **Kostarelos** (2018) were named in the top 10 highly cited researchers in the cross-field category (clarivate.com).

1.5. Objectives for the next five years

Our objectives are aligned and reflect our ambitions across all four Research Areas.

1.5.1. REF2021 Objective 1: Expand societal impact by maximising translation of our basic science into health and social care

Advancing translation and implementation of research in UOA3 (Section 1.2) will drive positive societal impact. The impact of our research is enhanced via utilisation and expansion of the networks in our 'One Manchester' approach. We will exploit these opportunities and leverage the maximal impact from our research.

We will:

- Develop, evaluate and implement five innovations addressing priorities for GM that have national and international impact.
- Double the number of researchers with translational/implementation expertise.
- Increase translational funding from NIHR, UKRI, charities and industry by 25%.

1.5.2. REF2021 Objective 2: Enhance research co-production and collaboration locally, nationally, and internationally

We will expand our research with a breadth of stakeholders focussing on boosting links with business engagement and offering targeted support to increase industry-academic funding across UOA3 Areas. We will increase co-production activity to underpin and shape our research locally in GM, nationally, and in global health.

We will:

- Increase interdisciplinary grants with practitioners, service users, industrial partners, and other stakeholders by 25%.
- Double the number of PhDs collaborating with industry.
- Increase the proportion of grant funding focusing on health and social care issues in lower and middle-income countries by 25%.

1.5.3. REF2021 Objective 3: Develop and evaluate new digital health technologies to improve health, person-centred care, and the economic sustainability of health and care services

One of our emerging interdisciplinary strengths, with opportunities for future research growth, lies in new digital health technologies. Digital innovation for improvements in economic productivity and innovation, health, social, cyber security and ethical standards in data usage, is driven through our Digital Futures multidisciplinary community (REF5a, Section 2iv*)*. UoM is one of 13 university partners of the Turing Institute, the UK's national Institute for Data Science and AI, and is home to the Centre for Health Informatics and the new Christabel Pankhurst Institute for Health Technology from where we conduct world-leading research and translation into health informatics and digital health technologies. There are Digital Health themes in both the NIHR ARC-GM and Hearing Health in the Manchester BRC. We will use our presence in HInM to exploit digital health technologies; to evaluate ways in which these new technologies can improve health, deliver person-centred care, and improve the efficiency of the health and care system.

We will:

- Increase the proportion of interdisciplinary research grants with a significant digital health technology component by 25%.
- Increase the proportion of grants conducted in collaboration with industry partners in the field of digital and new technology by 20%.
- Increase the impact of our use of digital technologies on health and social care.

1.5.4. REF2021 Objective 4: Recruit and develop talented researchers

We will continue to identify and recruit talented researchers who align to our priorities creating capacity, a critical mass and sustainability for interdisciplinary working. We will achieve this by

our internal investments including presidential fellows and our UOA3 specific development and support mechanisms (Section 2.1).

We will:

- Increase numbers of externally and internally funded academic and clinical academic training schemes, doctoral and post-doctoral fellowships by 25%.
- Increase the number of ECRs holding external grant funding by 15%.

1.6. Impact strategy

1.6.1. Approach to enabling and facilitating impact

Our institutional statement (REF5a, Section 2iv) outlines our focus on impact, where we were first in Europe in the 2018 THE University Impact Rankings. Networks and departments across UoM offer impact-related support and advice, e.g. the Knowledge Exchange Team, the Business Engagement Support Team, UoM Innovation Factory and Public Engagement at Manchester. Impact is aided by Policy@Manchester (which connects researchers with policy makers). UOA3 researchers, with Policy@Manchester and the Library, deliver 1-day workshops (75-100 participants) on 'Enhancing Research Reach and Impact,' with external sessions delivered by Kudos, The Conversation, and the Westminster Parliamentary Engagement Team.

UOA3 co-production starts by collaborating to get the research question right, and continues through to mobilise new knowledge generated, followed by dissemination and implementation. Our co-production partners include patients and the public, health and care commissioners, practitioners, policymakers, and industry. UOA3 are submitting nine impact case studies and evidence impact in three key areas:

- Health and social care: **Cullum/Dumville** (IC1), **Young** (IC2), **Aslam** (IC3)
- Patients and the community: **Grande** (IC4)
- Industry, government, and policy makers: **Rostami-Hodjegan** (IC5), **Todd** (IC6), **Pretty** (IC7), **Glenny** (IC8), **Worthington** (IC9).

1.6.2. Engagement and co-production with health and social care

UOA3 engages with health and social care organisations that support co-production of research. These links are strengthened by three professorial appointments with NHS Trusts: **Briggs**, Manchester University NHS Foundation Trust (MFT) co-funds her Florence Nightingale Foundation Chair in Clinical Nursing post; **Keady**, Greater Manchester Mental Health NHS Foundation Trust (GMMH); and **Yorke**, Christie NHS Foundation Trust until 2020 when she was appointed Chief Nurse retaining 20% FTE with UoM. **Yorke** founded the Christie Patient-Centered Research and developed the Christie Clinical Academic Pathway supporting combined clinical and research pathways for nurses and allied health professionals. **Duncombe** (Category C), Chief Pharmacist at the Christie, has facilitated our research on efficient and optimum dosing of individual antibody treatments (**Ogungbenro** *Clin Pharmacol Ther 2017,*64346561). This work demonstrated NHS cost savings due to more efficient use of expensive antibodies. **Lenney** (Category C), Chief Nurse for MFT, developed structures to support co-production of research, research capacity, establishing the MFT Nursing, Midwifery and Allied Health Professional research group and the Manchester Wound Care Group (**Lenney**, **Cullum**, **Dumville**). MFT awarded **Briggs** £619k to support research capacity for nurses, midwives and allied health professionals (2017-2022), funding 12 pre-doctoral, three doctoral and six postdoctoral fellowships. **Briggs** cements this collaboration by leading on capacity development for the NIHR ARC-GM. **Burden** has a 50% appointment with Salford Royal NHS Foundation Trust.

Examples of engagement and co-production include:

- **Cullum**, **Dumville** with the NHS improved care and outcomes for people with venous leg ulcers, increasing the efficiency of NHS care (IC1).
- **Young** engaged deaf people to enable the introduction of British Sign Language-centred health and social care (IC2).
- **Aslam** formed a spinout and collaborated with industry to improve compliance of asthma medication use in children (IC3).

1.6.3. Engagement and co-production with patients and the community

Researchers in UOA3 support the central role of patient/public involvement and engagement in shaping and guiding research. Well-planned, resourced and meaningful involvement necessitates that service users and carers achieve sufficient confidence, knowledge and skills. Examples include:

- **Grande** developed, tested and implemented an intervention for family carers to provide end-of-life care (IC4).
- **Young** developed training for British Sign Language users, highlighted by NIHR as exemplary practice.
- **Keady** established the 'Open Doors Research Group' (the largest group of people with dementia and their carer's as co-researchers in England) producing three films for Dementia Action Week, 2018.
- **Bee** developed and delivered research methods courses for users/carers of mental health services and developed into a co-produced book (2018, ISBN:9781526136527e).
- **Lovell** co-developed and co-delivered, with service users and carers, care planning to 1000 mental health professionals and was awarded the 2015 NIHR Mental Health Research Network for outstanding carer involvement and the NIHR 2017 'Let's Get Digital' award for a co-produced video.
- **Couth** with Colt Foundation funding (£152k) collaborated with musicians at the Royal Northern College of Music to determine effects of loud music exposure on hearing ability, and to find ways to promote the use of hearing protection.

1.6.4. Engagement and co-production with industry

Strong business engagement is promoted and supported by FBMH, with business engagement leads at faculty, school, and divisional levels. Represented in this submission are UOA3 researchers with strong industrial partnerships. We have benefitted significantly from Innovate UK funding with 10 grants totalling £3.3m and other substantive independent industry funding (Section 3.1). Examples include:

- **Rostami-Hodjegan**, **Galetin** (Deputy Director) lead CAPKR, which is a consortium of industrial pharma (currently eight companies paying up to £100k pa for membership) to carry out pre-competitive research, and have pioneered the concept of 'Precision Dosing' (IC5).
- NoWCADD is a partnership between Pharmacy and AstraZeneca (£1.5m), set up to create collaborative R&D programmes with research groups at UoM and across the global scientific community to translate emerging drug delivery science into value medicines (**Lawrence** MicroSun, Microfluidics Scale-Up of Nanoformulations; 2018-2020; £225k).
- **Stanmore** with MIRA Rehab developed and trialled Exergames (physiotherapy video games). Funding from NHS Trusts, MIRA Rehab, Burdett and UoM (£704k) has led to implementation in >150 clinics with >40,000 patients.
- **Burden** partners with pharma companies (£2m) producing Teduglutide, now marketed by Takeda as Revestive, to help people with intestinal failure to more effectively absorb fluid and nutrients.

- Dentistry has a 50-year collaboration with Colgate-Palmolive (**Pretty**) providing infrastructure funding (£200k pa) for primary research and funding PhDs.
- **McBain** has a rolling 15-year funding history from Colgate to underpin research into biofilms (£561k).
- **Morgan** leads the Eurolens Research Group with industrial support (>£8m) improving contact lens performance.
- **Neill** leads b-neuro. Industrial support (£762k) develops and utilizes murine models of cognitive deficits to evaluate novel therapeutic strategies.
- The Hearing Health theme of the BRC hosts the UK's only Hearing Device Research Centre, led by **Stone** and **Saunders,** working with industry to drive interventions for hearing loss and translate new technologies into the NHS, including hearing aid fitting procedures (NAL-NLII and CAM2) and the 'TEN' test for diagnosing cochlear dead regions (£170k industry funding).

1.6.5. Engagement and co-production with government and policy makers

UOA3 work with policy makers ensuring our research has a clear line-of-sight to policy.

- **Todd** works with policy makers and guideline developers showing how their research has transformed falls prevention services (IC6).
- Dentistry works with international guideline developers, Clinical Dental Officers, PHE and other stakeholders to close the loop between new research evidence and improved care. Over the past four years, Manchester has hosted three Oral Health Research & Policy Think Tanks in collaboration with the Chief Dental Officer for England. The Think Tank in 2019 highlighted key research findings and the translation of findings into a policy framework.
- **Pretty** evidences how, with NHS commissioners, researchers developed and implemented an online referral management system (IC7).
- **Glenny** shows how, working with national and international guideline developers, our research underpins recommendations and has optimised patient care for preventing dental caries (IC8).
- **Worthington** synthesises evidence that has influenced care provision and resulted in significant improvements in the oral care and management of disease in medically compromised patients (IC9).
- **Rostami-Hodjegan**, **Galetin** (IC5) have changed drug development policy in the Food and Drug Administration and European Medicines Agency.
- **Stratford** (*Nat Rev Clin Oncol 2016,*DOI:10.1038/nrclinonc.2016.79) and **Williams** (*Clin Cancer Res 2019,*DOI:10.1158/1078-0432.CCR-18-2466) have contributed to developing international regulatory science and policy for the use of new medicines in combination with radiotherapy.

1.7. Open research

1.7.1. Principles and support

UOA3 are committed to open research and benefit from UoM and faculty initiatives to promote open research (REF5a, Section 2v). This includes: pre-registration; transparent research methodology; public availability and reusability of research data and analysis code; public accessibility and transparency of research communication; and using web-based tools facilitating collaboration. To support these expectations, we provide:

- Guidance and training for all researchers, from expert teams including the Library, Research and Business Engagement, and the Open Research Working Group.
- Access to systems facilitating open research, including Pure, the Library's OA Gateway, ORCID, and the UoM Data Repository.

- Support for sustainable open access options include UKRI (£1.2m) and Wellcome (£170k) block grants and UoM's Open Access Fund (£300k).

UOA3 staff are committed to the UoM's open research principles evidenced by:

- 100% of submitted staff have an ORCID identifier.
- 90% of papers published since April 2016 are open access.
- New commitment to pre-register >90% of future studies (with exceptions only for commercial confidentiality).
- Our clinical studies are pre-registered.

1.7.2. Open Research Working Group

The University-wide Open Research Working Group established by Stewart (UOA4) and Jay (UOA11) (**Plack** is a core member) meets quarterly to arrange training events and workshops around open and reproducible research. Stewart (UOA4) represents Manchester within the UK Reproducibility Network while the Manchester node forms part of a broader NW Open Research Hub, connecting equivalent groups at Lancaster, Keele, Sheffield, Manchester Metropolitan University, Leeds, and Chester. The School of Health Sciences hosts a fortnightly open science journal club (RepoducibiliTea), for all staff and students.

1.8. Research integrity

UOA3 are committed to the highest standards of research conduct and integrity, reducing research waste, and improving research quality. The Vice President oversees research governance ethics and integrity (RGEI) supported by an Academic Director and a dedicated Office of RGEI.

All researchers and staff supporting research are required to conduct their research and disseminate findings according to UoM policies and Code of Good Research Conduct (REF5a, Section 2v). All individuals undertaking research are required to take an online course on research integrity and data protection. UOA3 staff are involved in research integrity policy. **Glenny** was a member of a working group (with representatives from Lancet, JAMA, BMJ, World Medical Editors Assoc) developing core competencies for Scientific Editors.

1.8.1. Studies involving human participation

Research conducted by UOA3 staff or students involving human participants must receive approval from a recognised research ethics committee, either the University Research Ethics Committee (UREC) or HRA approval / NHS REC. UREC has 32 meetings a year, and instigated an expedited response for COVID-19 studies.

1.8.2. Animal research

Animal research is subject to the Concordat on Openness in Animal Research. This pledges transparency and public engagement on research involving animals. We have a culture of care among our staff working with animals, based on a strong collaborative environment and a shared collegiate philosophy.

2. People

2.1. Staffing strategy and staff development

UOA3 researchers benefit from a continuum of researcher development to support progression along clinical and non-clinical researcher career pathways, providing co-ordinated support from pre-PhD to senior academic research leadership, strategically aligned to our Faculty Research and Innovation Strategy (REF5a, Section 3).

UOA3 academics are provided with comprehensive support through Faculty researcher development teams and UoM's professional services including library, careers, research IT, and staff learning and development. UoM has been a signatory of the Concordat to Support the Career Development of Researchers since 2009, alongside our concordat implementation plan to continually enhance policies and practice overseen by the University Research Staff Strategy Group (URSSG).

URSSG have developed open-ended contracts carrying additional benefits for researchers with four years or more continuous service. In addition to the statutory notice period of three months, this includes an extra three months' salary. Research staff benefit from a redeployment scheme (being registered for a further six months) bridging gaps between funding. UoM developed a statement of expectations for research staff supporting 10 days development per annum. We have a robust induction, including our online Research Staff Handbook, the Researcher Development Planner, and the sector-wide Researcher Development Framework as a tool to map and guide career development.

UoM structures facilitate integration into the research culture at divisional, school, faculty and university levels. UOA3 staff attend an annual Research Staff Conference, a broadening career horizons 'Pathways' event for PhDs and research staff, 'Writefest' (a month of events devoted to supporting academic writing, publishing and grant writing), and an accredited 'Researchers into Management' development programme. All staff and PGRs have access to the Manchester Gold mentoring schemes and coaching; the further education and external training fund; our 'Investing in Success' funding scheme; the International Conference Fund and Research Collaboration Research Staff Funding Scheme. We have a policy for research/sabbatical leave which includes both fixed-term and part-time staff. Academic staff from probation onwards are encouraged to have a mentor, and training/mentorship needs are identified and monitored during annual performance and development reviews (P&DRs). To enhance effectiveness we have an online system. In 2020, 99% of UOA3 staff had a P&DR.

2.1.1. Appointments

UOA3 follow a common recruitment strategy and have targeted and recruited external research-active academic staff in priority areas.

Professors:

Briggs, **Dillon**, **Dowding**, **Lawrence**, **Moore**, **Robinson** (4 female / 2 male)

Readers/Senor Lecturers/Senior Research Fellows:

Edkins, **Butterworth**, **Campbell**, **Chen**, **Heinrich**, **Mistry**, **Saunders**, **Wykes (**4 female / 4 male)

Lecturers/Fellows:

Burgoyne, **Carr**, **Cruikshank**, **Hadjidemetriou**, **Leach**, **Millman**, **Mok**, **Renwick**, **Schlittenlacher**, **Vranic** (7 female / 3 male)

2.1.2. Promotions

Staff are recognised and rewarded through annual promotions, which account for career breaks and part-time working. Faculty, school and divisional promotion champions and workshops support researchers. UOA3 have seen 54 promotions since the last REF period.

Professors:

Aslam, **Bee**, **Bobola**, **Dobson**, **Dumville**, **Edge**, **Galetin**, **Glenny**, **Kirk**, **McBain**, **Morgan**, **Murray**, **Schafheutle**, **Silikas**, **Walsh**, **Yorke** (10 female / 6 male).

Readers/Senior Lecturers:

Bee, **Bichenkova**, **Radhakrishan**, **Silikas**, **Stanmore**, **Ward**, **Aojula**, **Bedwell**, **Brooks** (Jane), **Brooks** (Joanna), **Dawes**, **Demonacos**, **Galetin**, **Harris**, **Harte**, **Hicks, Kluk-de Kort**, **Leach**, **Ledder**, **Mills**, **Ogungbenro**, **Penny**, **Pluen**, **Renwick**, **Smyth**, **Willis** (17 female / 9 male).

Lecturers/Fellows:

We have nurtured and supported our ECRs, both clinical and non-clinical, to UoM baseline academic posts including: **Cooke**, **Finnegan**, **Hancock**, **Harris**, **Pedley**, **Phipps**, **Price O**, **Ogungbenro**, **Tirella**, **Scotcher**, **Latif**, **Jacobs** (8 female / 4 male).

2.1.3. Training and development

UOA3 researchers enjoy a range of training and development opportunities. The Centre for Academic and Researcher Development (CARD) delivers training, development, mentoring and coaching for clinical/non-clinical researchers, academics and NHS partners. CARD delivers the new academics and fellows programme, leading to Fellow of the Higher Education Academy. CARD convenes the Faculty Research Staff Representatives Forum which promotes the interests of clinical and non-clinical research staff ensuring their training needs are met and works with the N8 research partnership to enhance their experiences.

UOA3's early clinical academic researchers have access to all training and development courses and are supported through the Manchester Integrated Clinical Academic Training (ICAT) programme, hosted by MAHSC. ICAT facilitates and supports the academic development of both undergraduate and postgraduate clinical trainees who aspire to follow a clinical academic career path. ICAT is managed as a partnership between UoM and Health Education North West and in close liaison with the NIHR Trainees Coordinating Centre, which oversees 'Integrated Academic Training'.

The Fellowship Academy

UoM's Fellowship Academy identifies and supports clinical and non-clinical researchers to gain externally funded pre- and post-doctoral fellowships, providing support through CV clinics, mock interviews, pump-prime funding and the Presidential Fellowships, providing three years' salary to secure external fellowships.

The Fellowship Academy runs events and workshops attended by funders including MRC, Wellcome, CRUK, BHF, BBSRC, and NIHR. The Academy manages the MRC Skills Development Fellowships and the Wellcome Clinical PhD Programme (4ward North Clinical PhD Academy). The Fellowship Academy has close links with NHS Trusts, providing support for clinical academics from PhD through to Clinician Scientist Scheme, including the 6-month pump-priming fund for clinicians rolled out in MFT.

All schools have a mid-term Fellowship Review Committee for all extant Fellows which reviews progress at 18-24 months to agree strategies and plan forwards. Frequently this results in Fellows being offered extensions in order to advance their research programmes to be in an optimal position for applying for follow-on funding or more senior fellowship applications. We offer a tenure track position if performance is strong (examples in Section 2.1.2).

Additional support

UOA3 researchers (**Dumville**, **Harris**, **Lovell**, **Stratford**) lead initiatives to support and develop our staff. These initiatives were shaped in close and iterative consultation with researchers. In response to 'fragmentation of time' being flagged as a major barrier to grant development, we established and embedded six-monthly two-day residential Grant and Fellowship Retreats for 30-40 researchers. Retreats offer one-on-one sessions facilitated by up to 10 senior academics and professional staff. Feedback from the retreats has been overwhelmingly positive, specifically around providing 'protected time' and one-on-ones with facilitators. Similar to Grant Retreats; residential Fellowship Retreats provide intensive support for pre- and post-doctoral, intermediate and senior applicants. Across UOA3 we embedded a robust peer review system to ensure the highest quality applications are submitted. Post-award we provide workshops for first-time PIs.

We work with researchers submitting their first PI grant through intensive one-on-one mentoring (e.g. **Pedley**, NIHR RfPB, £150k; **Jeyasingham**, ESRC New Investigator Grant, £148k; **Renwick**, MRC, £148k). Staff undertaking their first PI role are supported by a senior academic in a Co-PI role (e.g**. Finegan**, **Williams**, Friends of Rosie, £67k). We also include costs for intensive grant mentoring from senior academics into grant applications with researchers who are submitting their first grant ensuring protected resource to support development (e.g. **Price O,** NIHR HTA, £520k).

UOA3 staff (**Luker**, **Neill**, **Stratford**, **Dumville**) provide regular workshops focussing on 'abstract writing'; 'what a high quality paper looks like' (~300 staff attended 2016-2020), and 'enhancing research reach and impact' (Section 1.6.1). In response to ECR feedback, **Milman**, **Dumville**, **Lovell** run a one-day 'building your research career workshops' for ECRs.

Fellowship success

In UOA3, we have identified and mentored ECRs to successful fellowships. For example, during this REF period (those in bold are REF eligible, not bolded indicates those who have moved to other institutions / returned to the NHS): **Cooke**, Jones, **Hancock**, Krishnamoorthy, Richens, **Rogers**, Wilberforce, **Price O**, Kemp completed NIHR Doctoral Research Fellowships/NIHR Clinical Doctoral Research Fellowships; and Dwyer, Griffiths, Lamph, Lees, Mitchell, Jones, Watson, Faulkner were awarded NIHR doctoral Fellowships. Searle (now in UOA1) and Pendharker secured CRUK/MCRC/AstraZeneca Clinical PhD Training Fellowships. NIHR post-doctoral/Clinical Academic Training Lectureship/Clinical Scientist Fellowships that were successfully completed include: Aggarwal, **Burden,** Brocklehurst. Awarded NIHR Post-doctoral Fellowships/Clinical Academic Training Lectureships include: **Hawley-Hague**, Hartley, Gibbons and **Rogers**. Other NIHR fellowships include: Ravi (NIHR In Practice Fellowship), Farquhar (NIHR Career Development Fellowship), Hyde (NIHR Translational Research Fellow), Britteon, Foley, Riley, Liu (NIHR Research Methods Fellowship and Internship), Jung-Yin (NIHR in Practice Fellow), and two Royal Society Newton International Fellowships (Chickale, Islam).

Doctoral fellowships funded from charities include: CRUK (Tessyman), Stroke Association (Plant), Alzheimer's Society (**Ferguson-Coleman**), PRUK (Magola, Greenwood), James Tudor Foundation (Lui). Examples of charity funded post-doctoral fellowships include: CRUK (Smith, Tessyman, Warrington), Breast Cancer Now (Khan), BHF (Camacho-Munoz), Wellcome (Sanz, Jones), Marie Curie (DeClerck), GCRF Fellow (Mdoe), Daphne Jackson Fellow (Sarginson), Dunhill (Kindle), Leverhulme (Halsall), UKRI/Rutherford Fund Skills Development (Hassan, **Lindner**), and Deafness Support Network (Littlejohn).

2.1.4. Support for exchanges between academia and business, industry, public, and third sector bodies

We stimulate and facilitate exchanges between academia and business, industry, public and third sector bodies, for example, through the secondment of research staff. UoM promotes industrial-entrepreneur-in-residence-like projects; for example, Will Goundry from AstraZeneca was hosted by NoWCADD in 2019. Staff are actively supported to participate in translational research and to collaborate with industry; not only via standard iCASE awards, but also via BBSRC Impact Acceleration Awards, the MRC CiC and Proximity to Discovery Industry Engagement Funds, and the Wellcome Access to Expertise (A2E) and Projects for Translation (P4T) schemes. Successful internal applications to these schemes include **Aojula**, **Freeman**, **Finegan**, and **Butterworth**. In addition, the NIHR-i4i scheme supported linking **Stanmore** to MIRA Rehab Ltd.

The Faculty and University Business Engagement and Knowledge Exchange teams work with partner organisations including HInM, the BRC, and the UoM Innovation Factory to understand and appreciate the external industrial landscape and proactively link academics with potential industrial partners. UoM has strategic partnerships with, among others, AstraZeneca, GSK, ThermoFisher, Smith & Nephew, and Unilever, and members of UOA3 have benefitted (e.g. UoM/AZ funding for NoWCADD). In addition to their strategic role, the Business Engagement and Knowledge Exchange teams take responsibility for contracts and pricing negotiations and provide supporting activities from consultancy, student and staff exchange through to larger contracts and strategic partnerships.

2.1.5. Health and safety

We are committed to the Health and Safety of our staff, and as well as standard inductions provide health and safety training in all laboratory areas. For UOA3 fieldwork staff we provide Suzy Lamplugh Trust training and have robust protocols for fieldwork using either 24/7 Lone Worker Technology (Skyguard) or mobile phone-based protocols.

2.2. Category C staff

Our Category C staff add additional vibrancy to UOA3's NHS multidisciplinary research and leadership activities. All hold MAHSC Chairs, and include: **Duncombe** (Pharmacy); **Lenney** (Nursing); described in Section 1.6.2. Dentistry has three category C members of staff (**Ashley, Barclay**, **Pemberton**). All hold clinical posts locally and are nationally networked and provide an important link to frontline services, informing decisions around the research we undertake, supporting its operationalisation, and facilitating dissemination and implementation.

2.3. Research students

UOA3 recognise the importance of research students to the future of our disciplines, and building research capacity to contribute to the future research success of the UK by providing

the highest quality research training. Our culture ensures that students are fully integrated into the research culture and provides an environment which actively supports progression of our undergraduate students to Masters and PhD level, post-doctoral positions, independent fellowships, and ultimately academic/clinical positions. We provide high quality research training, consistent with successful capacity building and maintenance of our researcher sustainability strategy.

UOA3 currently has a diverse collection of MSc, MRes, MPhil students, and 261 current doctoral students. Of these 203 are full-time / 58 part-time; 51% female / 49% male; ethnicity: White 122 (47%), Arabic 81 (31%), Chinese 17 (6.5%), other 41 (15.5 %). Our doctoral students come from 39 countries with 105 (40%) UK.

During the REF period, 307 PhDs were awarded in UOA3, compared to 221 in REF2014, with home (54%): international (34%) and EU (10%). In REF2014, the number of completed doctoral students by FTE was 1.96 which has increased to 2.45 per FTE. Since 2014, UOA3 has held: 67 UKRI studentships (26 from MRC); 15 CASE awards; 16 NIHR doctoral fellowships (pre- and post-doctoral NIHR fellowships are reported in Section 2.1.4). PhD students are encouraged to publish; of competed UOA3 PhDs in the period, 78% had published at least one paper from their theses (by 25/01/21).

2.3.1. Research student recruitment

We recruit PhD students from the UK and internationally including clinical and non-clinical. MAHSC Trusts are committed to research capacity building and release staff for part time PhD study. We have developed flexible approaches, e.g. the development of online research methods courses and online supervision and progress monitoring techniques. The EPSRC funded North-West Nanoscience Doctoral Training Centre (NowNano) was run by **Tirelli** until 2014, and was renewed as the Graphene NowNano DTC (2015 to date, funded by EPSRC and industry) with both **Kostarelos** and **Bussy** sitting on the management board. During the REF period, 20 students (with UOA3 supervisors) have graduated or have been recruited into this Centre. **Tirelli** was Deputy Director (2014-2016), then Director (2016-2017) of the EPSRC/MRC CDT in Regenerative Medicine (EP/L014904, £4.4m; now led by Kimber, UOA1). Eight students with UOA3 supervisors have come through this program.

UOA3 developed MRes and MSc provision in health and social care, community pharmacy public health services, advanced audiology, and oral implantology. Our Masters programmes operate under an ‘alliance’ structure to support interdisciplinary training. Our MClinRes and MRes programmes for nurses, midwives and AHPs had 46 NIHR funded places 2014-2017, when the scheme ceased. Pharmacy and Dentistry attract large numbers of overseas students to their postgraduate programmes. UoM is the only UK Dental School offering a 4-year Clinical PhD, allowing clinical development alongside research.

International students

UOA3 are committed to supporting international collaborations and study opportunities. PGR students in Nursing and Pharmacy practice are able to undertake their PhD as distance learning, enabling home and international students with caring or other responsibilities to study without compromising their family life. Pharmacy and Dentistry have collaborations with overseas universities enabling exchange visits and providing a rich source of PhD students. These include the Universities of Indonesia, Boston, Sao Paulo, Wuhan, Hong Kong, the Nippon Dental University (Japan), the Jordan University of Science and Technology and the Al-Zattoonah University of Jordan. In Nursing, close links have been established with Lugina Africa Midwives Research Network, supporting midwives from a range of African countries to undertake PhDs. As part of our social responsibility programme we have provided fee and living expense support to talented students from low- and middle-income countries.

2.3.2. Monitoring and support mechanisms for postgraduate students

FBMH has a Doctoral Academy (DA; REF5a, Section 3.3) to support postgraduate research from pre-admission to post-viva. The academic requirements of PGR students are supported by an Associate Dean for the Faculty and two PGR Directors. Each division has a senior tutor who support admissions, training requirements and examinations of all PGR students.

Primary PhD supervision is provided by experienced supervisors in the cognate area of study. PhD progress is monitored and supported through eProg, our online system which maps students' progress, flags key assessment milestones and allows continual supervisory feedback. Students are integrated into the research culture of the divisions and schools and encouraged to attend regular seminars. Each School has postgraduate prizes, as well as PGR student of the year awards at divisional, school, faculty and university level. There are funds and bequests available supporting travel, research expenses, and hardship (when required).

All PGR students attend the induction week at the beginning of their programme. Students can access a range of training sessions and courses (discipline-specific and generic), organised between CARD and the DA. All UOA3 PGR students engage in research and cultural environments. Student showcases run annually allowing students to gain experience of oral and poster presentations. The DA dedicates funds for conferences for all PGRs. Students are mentored to join appropriate learned societies in order to help secure support for meeting attendance, which is then supplemented by the UoM. The DA supports student well-being with a dedicated student experience officer and an academic lead for student experience. A dedicated team supports students with disabilities.

2.4. Equality, diversity, and inclusivity

UOA3 aligns with UoM's commitment to the principles of Equality, Diversity, and Inclusivity (EDI) strategy (REF5a, Section 3.4). The FBMH EDI committee, chaired by the Associate Dean for Social Responsibility, meets quarterly, including wide-ranging representation. Our commitment to EDI is demonstrated by our active engagement in the career advancement of female and BAME academics, and through our participation in Athena SWAN and Project JUNO.

UOA3 has taken an intersectional focus to address the additional barriers faced by BAME women staff and students. UoM currently holds six Silver and eight Bronze Athena SWAN awards. Both the School of Health Sciences and the School of Medical Sciences achieved Athena SWAN Silver status (2018). Our commitment to the career advancement of BAME staff is evidenced through our Race Equality Charter Mark Bronze. We are a Disability Confident employer and a Stonewall top-100 employer for LGBTQ inclusion.

UoM has made substantial progress delivering the equality agenda, evidenced by women now accounting for 32% of senior academics and 27% of professoriate, 56% of Professional Services staff in senior grades, 44% of Heads of School, 50% of Faculty Leadership Teams, and 36% of Senior Leadership Teams. We also secured increased numbers of women students progressing onto postgraduate programmes.

Coaching provision for FBMH staff

Our staff are actively engaged with the coaching provision available via Staff Learning and Development. An evaluation demonstrated that 100% of participants would recommend the coaching to colleagues.

BAME advocacy and working group

FBMH launched the pilot flagship Inclusive Advocacy Programme, designed to ensure high-performing researchers from under-represented groups are supported which aims to increase diversity in leadership positions and promote inclusivity within academic culture.

Support for women

Women in FBMH provides a support network, organising events and courses promoting EDI, e.g. confidence and personal impact workshops and International Women's Day events. Athena SWAN teams have held a number of events to promote flexible working and wellbeing.

Support for carers

Caring commitments can be a barrier preventing career development activities. A carer's fund provides PGRs with caring responsibilities additional financial support (up to £300) to attend conferences and workshops.

2.4.1. Examples of equality, diversity, and inclusivity in UOA3

We have invested in the development of a research workforce that reflects EDI. UOA3 takes an intersectional inequalities approach whilst highlighting people with specific protected characteristics. Examples include:

- **Inclusive workforce:** in UOA3, women head all of the divisions. **Young** and **Edge** have University-wide academic lead roles addressing disability equality and race equality. Our workforce is enriched by employment of, or consultancy with, people with specific protected characteristics including deaf young people, people with severe mental health disorders and both carers of, and people living with, dementia. In the Social Research with Deaf People group (SORD), all staff and students are fluent in one signed and one written language (whether they are hearing or Deaf). SORD's research practice and outputs in language(s) and culture(s) reflect the diversity of Deaf community nationally / internationally. The group includes the first Deaf sign language user to win NIHR doctoral and postdoctoral fellowships (**Rogers**) and the first Deaf signer to secure an Alzheimer's Society doctoral scholarship (**Ferguson-Coleman**).
- **Inclusive research practices:** UOA3 facilitates joint working and co-authorship between lead researchers and service user and carer team members. For example, two papers led by service user and carer co-applicants: Cree/**Bee** *BMC Psychiatry 2015*,DOI:10.1111/jpm.12275; Grundy/**Lovell** *J Psychiatr Ment Health Nurs 2016*,DOI:10.1111/jpm.12378.
- We take a structural approach to understanding inequalities in specific communities, for example unequal access in service delivery including Afro-Caribbean people with severe mental health (**Edge**), remote delivery of psychological interventions for people with common mental health problems (**Bee**), Deaf signers' IAPT (Improving Access to Psychological Therapies) outcomes (**Young**, **Rogers**). Other research highlighting people with specific protected characteristics include older adults with sensory issues (**Todd**, **Plack**, **Munro**), carers and people with dementia (**Keady**), and young carers of parents with severe mental health problems (**Bee**).

Our REF2021 Code of Practice complies with equality and diversity legislation and provides a transparent explanation of our approach for our REF2021 submission.

2.5. Staff wellbeing

In 2016, UoM set out a Wellbeing Strategy with a mission "to promote and enhance wellbeing for all staff through the development of a proactive and enabling culture" *(*REF5a, Section 3.3.2). This involves responsibility at university, managerial, and individual levels. Actions included the launch of the Manchester Ways to Wellbeing Campaign, with six ways identified: Connect; Be Active; Take Notice; Learn and Discover; Give; and Be Healthy, promoted via a 'wellbeing champion's network' with 12 champions within FBMH. Guidance on engaging with wellbeing is given to all staff through lectures and a host of online materials. UoM's Counselling and Mental Health Service provides a range of well-being workshops, and is partnered with the GM Health and Social Care Partnership to offer an integrated approach to supporting students. UoM provides dedicated space ('Wellbeing Rooms') for wellbeing activities. UoM's Dignity at Work policy for staff and students implements our commitment to zero tolerance of discrimination, harassment or bullying, supported by our specialist team and reporting channels.

Further activities that support implementation of the Wellbeing Strategy for UOA3 staff include:

- FBMH policy to avoid sending emails outside 0700-1900 on workdays.
- The formation of small staff groups and timetabling of virtual lunch/coffee meetings in divisions during the pandemic with a team leader responsible for the wellbeing of staff.

3. Income, infrastructure and facilities

3.1. Research income

Our total research income in REF2021 is £99.7m including REF4c funding (or £94.9m without REF4c funding) compared with £42.7m in REF2014. To account for differences in submitted staff FTE and the differing length of each REF period, we summarise this as annual research income per submitted and eligible staff FTE. In REF2014 we submitted 90% of eligible staff and the mean annual income per submitted staff FTE was £75,834. The income per eligible staff FTE was £67,558. The REF2021 mean annual research income per submitted/eligible staff is £113,427 (an increase of 68%).

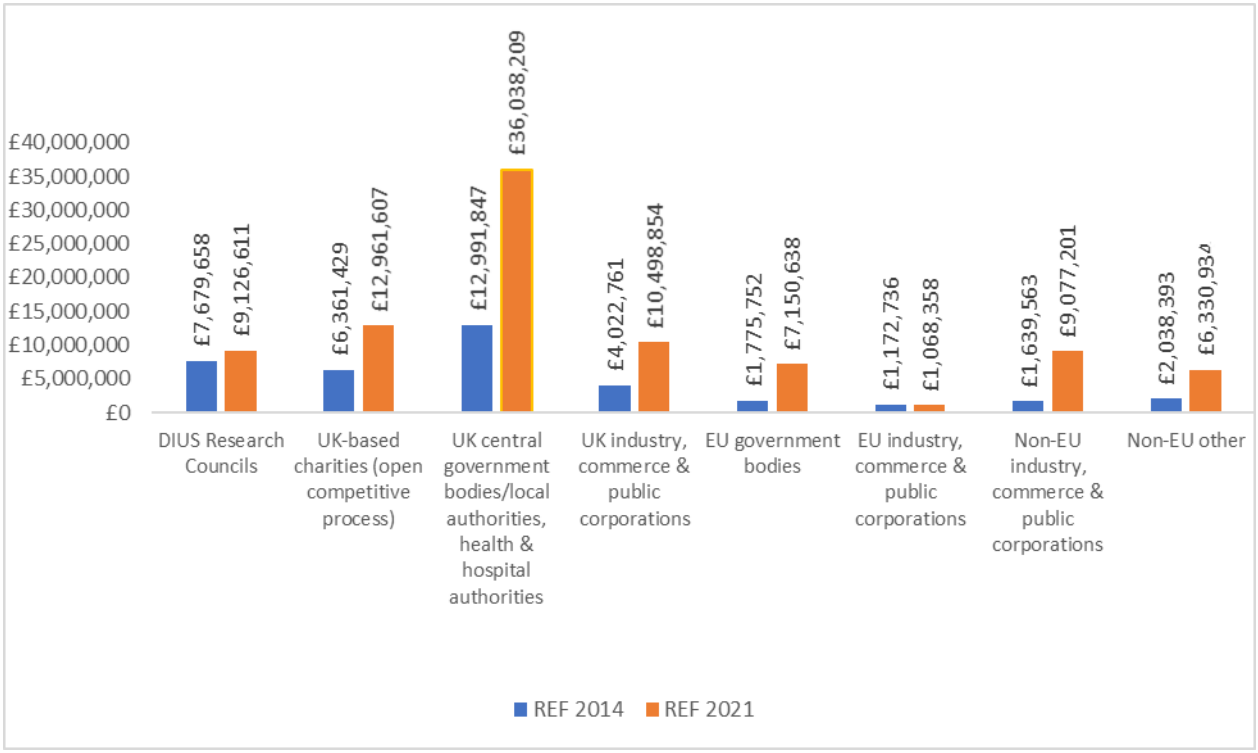

Figure 5. Research income for key HESA categories in REF2014 and REF2021

Figure 5 shows a large funding increase from UK central government and related sources, largely due to successes with substantial NIHR grants including infrastructure funding. We have maintained income from research councils and, after focused efforts to diversify funding, we have increased our funding from UK-based charities. Our efforts to increase industry and EU funding are also evidenced with large relative increases in income from these sources; e.g. UK industry and related funding increased from £4m to £10.5m. There has also been a general increase in EU government-based funding from £1.8m to £7.2m.

3.1.1. NIHR funding

UOA3 have been successful in NIHR grants awarded to UoM and NHS Trusts, with 130 awards (80 awards led by UOA3) during the REF period (Table 1). This equates to a total award value of £161m with award value to UoM of £64m of which £29m is to UOA3.

Table 1. Major and prestigious NIHR grant awards led by UOA3 staff

Funder and title	Dates	Total award	Led by
NIHR: Collaboration for Leadership in Applied Health Research and Care (CLAHRC)	2014-2019	£20m	Co-lead **Luker**
NIHR: Applied Research Collaborations (ARC-GM)	2019-2024	£11.3m	**Cullum**
NIHR: Policy Research Unit (PRU) for Older People and Frailty	2019-2024	£5m	**Todd**
NIHR BRC (Hearing Health Theme)	2017-2020	£4.5m (theme award)	**Munro**
ESRC/NIHR: Neighbourhoods and Dementia Mixed Methods Study	2014-2019	£4.2m	**Keady**
NIHR: Global Health Research Group on Stillbirth Prevention and Management in Sub-Saharan Africa	2016-2020	£2m + £500k extension	**Lavender**
NIHR Programme Grants for Applied Research: Enhancing the Quality of Psychological Interventions Delivered by Telephone (EQUITy)	2018-2023	£2.3m	**Bee**
NIHR HTA: The Effect on Relapse of Culturally-Adapted Family Intervention (CaFi) Compared to Usual Care Among African and Caribbean People Diagnosed with Psychosis in the UK: A Randomised Controlled Trial.	2019-2023	£2.3m	**Edge**
NIHR HTA: A Randomised Controlled Trial to Evaluate the Clinical and Cost Effectiveness of Prescribing High Concentration Fluoride Toothpaste in Preventing and Treating Dental Caries in High-Risk Older Adults (REFIeCt Trial).	2017-2022	£2.1m	**Tickle**
NIHR Programme Grants for Applied Research): Enhancing the Quality and Purpose of Care Planning in Mental Health Services (EQUIP)	2012-2017	£1.9m	**Lovell**
NIHR HTA: A Randomised Controlled Trial of Compression Therapies for the Treatment of Venous Leg Ulcers	2020-2024	£1.9m	**Dumville**
NIHR HTA: Evaluation of Water Fluoridation in Cumbria (CATFISH)	2014-2021	£1.2m	**Pretty**

3.1.2. Industry funding

UOA3 researchers led on 145 individual industrial grant awards (total: £17.8m). Taking account of credit share given to researchers in UOA3, as PIs and Co-Is, total income to UOA3 from all industrial grants was £20.6m. An example of substantive income to staff acting as Co-Is in grants led by other UOAs is **Nicolaou** (£193k) leading the lipidomic discovery theme on the £3.9m Boots-funded dermatology framework grant (Griffiths, UOA1).

Building on our industrial collaborations, UOA3 staff, acting as PIs, have secured £6.9m funding from Innovate UK. These include **Neill** and **Harte** (£2.2m; Autifony Healthcare, overcoming cognitive defects in animal models of neurological diseases) and **McBain** and **Cullum** (£843k; two projects: Archbiocides; wound antibiotic development). Examples are shown in Table 2.

Table 2. Major industry awards led by UOA3 staff

Funder and title	Dates	Total award	Led by
AstraZeneca: Modelling and Simulation Framework	2013-2017	£1.5m	**Aarons**
AstraZeneca: North West Centre for Advanced Drug Delivery	2014-2020	£1.5m	**Marshall**
Shire (3 projects): Nutrition and short bowel syndrome	2016-2022	£1m	**Burden**
Biocomposites Ltd (2 projects): diabetic foot infections and antibiotic use in vitro and in vivo	2018-2021	£890k	**Price B**
DSM Nutritional products/Kemin Foods (2 projects): Effects of lutein on visual function	2016-2018	£650k	**Murray**
Johnson and Johnson: Contact lenses and end of day discomfort	2018-2020	£526k	**Moldonado-Codina**

3.1.3. Other major awards

Examples of successful awards led by UOA3 staff are detailed in Table 3, and Table 4 highlights examples where UOA3 staff have been co-investigators.

Table 3. Other major and prestigious awards led by UOA3 staff

Funder and title	Dates	Total award	Led by
National Institute for Health: Timing of Primary Surgery for Cleft Palate Trial Follow-On (TOPS)	2015-2020	£5.8m	**Walsh / Munro**
EPSRC: 2D Materials for Next Generation Healthcare Technologies (2D Health). Graphene	2016-2021	£5.3m	**Kostarelos**
MRC GCRF: South Asia Self Harm Research Capability Building Initiative (SASHI)	2017-2021	£4.3m	**Robinson**
Wellcome Trust: Structure Based Discovery of CaMK1D Kinase Inhibitors with In Vivo Activity as Targeted Therapeutic Agents for Breast Cancer.	2016-2020	£2.6m	**Butterworth**
MRC Programme Grant: The Physiological Bases and Perceptual Consequences of 'Hidden' Noise-Induced Hearing Loss	2014-2019	£1.2m	**Plack**
MRC: Deciphering the role of p63 in secondary palate development using systems biology	2015-2018	£695k	**Dixon (M)**
BBSRC: Guided Activation as a Model for Transcription Factor Networks Determining Cell Fate	2019-2022	£693k	**Bobola**

Table 4. Examples of major awards in which UOA3 staff are co-investigators

Funder and title	Dates	Total award	Led by UOA3 contributor
EU graphene flagship (four rolling grants)	2013-2023	€18m	Falko (UOA9) **Kostarelos** (22% average across 4 grants credit share)
CRUK Radnet award	2019-2024	£16m	Bristow (UOA1) **Williams** (12% credit share)
NIHR Greater Manchester Patient Safety Translational Research Centre (NIHR PSTRC)	2017-2022	£5.9m	Campbell (UOA2) **Ashcroft** (20% credit share)
Horizon 2020: SENSE-Cog: Promoting Health for Eyes, Ears, and Mind	2016-2020	€6.5m	Leroi (UOA4) **Dawes** (20% credit share)
CRUK/EPSRC Imaging Award	2014-2019	£5m	Jones (UOA1) **Williams** (10% credit share)
Wellcome Institutional Strategic Support Fund (ISSF) **Two awards**	2014-2021	£4.5m	Rothwell (UOA5) **Dixon M** (50% credit share)

3.2. Infrastructure and facilities that support UOA3 research

UoM operates an investment strategy that enables excellence through facilitating interdisciplinary research (REF5a, Section 2iii). It is within this context that the investment in buildings and facilities supports our environment and UOA3 researchers.

3.2.1. Research Services Team

UoM's Research Services Team is responsible for leading an integrated and effective research service that maximises our ability to attract researchers and research income, undertake high-quality research, and exploit research outcomes. The team provides cross-faculty support for research, including a specialist EU office, compliance and risk management, research governance and data protection.

3.2.2. Research and Business Engagement Team

FBMH Research and Business Engagement Team provide advice and guidance on funding opportunities, costing and submitting applications.

3.2.3. Strategic Funding Team

FBMH's Strategic Funding Team supports and coordinates large strategic grant proposals; facilitates themed workshops that help collaborations prosper; performs strategic analysis of outputs and impact from funded research to inform strategy.

3.2.4. University Library

UoM's Library has the most extensive digital collections in the UK and enables UOA3 researchers seamless access to extensive discipline-specific collections. The library supports the researcher from initial research data management planning to open access compliance.

3.2.5. Manchester Clinical Trials Unit

The Manchester Clinical Trials Unit (MCTU) transferred from the Christie Hospital to UoM to maximise our ability to conduct high-quality research. MCTU has 55 staff, is registered by the UK Clinical Research Collaboration, and receives funding from NIHR, CRUK, UoM and HInM.

3.2.6. IT support

UOA3 researchers and students benefit from centralised IT support covering routine user support through to data storage and high-performance computing. The dedicated Research IT Team comprising ~50 FTEs provides support for a broad range of activities, including HPC platforms, a dedicated Research VM Service, cloud-based resources, and research software engineers. UoM provides a secure centralised data storage system.

Much of our computational work uses the Computational Shared Facility (CSF). The CSF is integrated with the Research Data Storage platform providing ~8PB of resilient storage. A working group (**Bryce**, board member), meets regularly with Research IT staff to discuss computing and storage needs, ensuring user requirements are fed into the central team.

3.2.7. Research facilities

The vision for the research infrastructure in UoM is to provide state-of-the-art research facilities operated by skilled staff, delivering key technologies and generating a skills repository, essential

to maintain research competitiveness (REF5a, Section 4.2). These facilities engage with the research community within FBMH, other UoM faculties, and with partner healthcare Trusts.

FBMH hosts eight Core Research Facilities: Bioimaging, Biological Mass Spectrometry (BMS), Biomolecular Analysis, Electron Microscopy, Flow Cytometry, Genomic Technologies, Genome Editing and Histology. UOA3 researchers have complementary bespoke facilities where expertise can be called upon from the Core Facilities including: **Nicolaou** for lipidomic BMS; **Rostami, Barber**, **Galetin** for proteomic BMS; and **Williams** for in vivo PET and MR imaging. Facilities embedded within UOA3 include:

- Audiology has nine bespoke double-walled soundproof booths, including equipment for evoked potential, behavioural, and audiometric testing. There are vestibular, hearing aid, and dry bench laboratories. Clinical research is also conducted at NHS sites.
- Optometry has five ophthalmic consulting rooms exclusively for clinical research, larger clinical suites with a wide range of high-end research-orientated examination instrumentation, and laboratories set-up for the conduct of psychophysics, physiological optics, and other research with human subjects. Research is also conducted within designed clinical spaces shared with undergraduate training.
- The NoWCADD consortium has a suite of equipment, including the Asia flow reactor, the LV1 high pressure microfluidizer, and the CF2000 centrifugal field flow fractionation, dedicated to the preparation and characterisation of advanced complex medicines, particularly particulate nanomedicines.

A key FBMH resource is the Biological Services Facility (BSF) providing a range of model organisms. UOA3 researchers take advantage of the rodent and zebrafish facilities with 56 of our 314 submitted outputs involving the use of the BSF. The BSF has 9000m^2 of usable space, a turnover of £2.5m, and 42 FTE staff, making it one of the largest in Europe. There has been £1.4m investment since 2014, including a new, state-of-the-art germ-free facility. To ensure liaison between the academic community and staff involved with animal care, the BSF has a Management Advisory Group (including **Stratford**).

Investment and growth in facilities

Core research facilities have grown substantially (REF5a, Section 4.2). Over £28m has been invested by UoM in the equipment base in FMBH, with associated staff increasing from 33 (2014) to 49 (2020). The increased size and capacity are reflected in turnover, increasing from <£2m (2014) to ~£3.5m (2020). We operate a transparent and equitable charging policy, facilitated by an online system, allowing charges to be levied uniformly with discounts applied to support postgraduate training. Dentistry has benefitted from a £50m capital programme renovating the Coupland 3 building, adjacent to the University Dental Hospital and the Colgate Palmolive Dental Health Unit 100 metres away in Manchester Science Park. Renovations include: a bespoke Dental Biomaterials laboratory providing key facilities for researchers at the clinical/basic science interface (**Silikas**, **Watt**, **Chen**); laboratory space for PGR students; and a 33-desk postgraduate computer suite.

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

Here we highlight our collaboration and contributions nationally and internationally, to our disciplines, and to the wider economy and society.

4.1. Research collaborations

Here we describe our collaborations internationally and with UK universities.

In the REF period, 1,142 UOA3 authorships have been identified for journal papers with international collaborators (Figure 6), a mean of 9.9 per individual. Examples across our Research Areas include:

- **Kluk** Vestibular receptors contribute to cortical auditory evoked potentials. *Hearing Res 2014,*39064258.
- **Aarons**, Analysis of the impact of controlled release formulations on oral drug absorption, gut wall metabolism and relative bioavailability of CYP3A substrates using a physiologically-based pharmacokinetic model. *Eur J Pharm Sci 2015*,46998824.
- **Bobola** Hoxa2 selectively enhances Meis binding to change a branchial arch ground state. *Dev Cell 2015,*51323477.
- **Cullum** The effect of a patient centred care bundle intervention on pressure ulcer incidence (INTACT): A cluster RCT. *Int J Nurs 2016,*64196396.

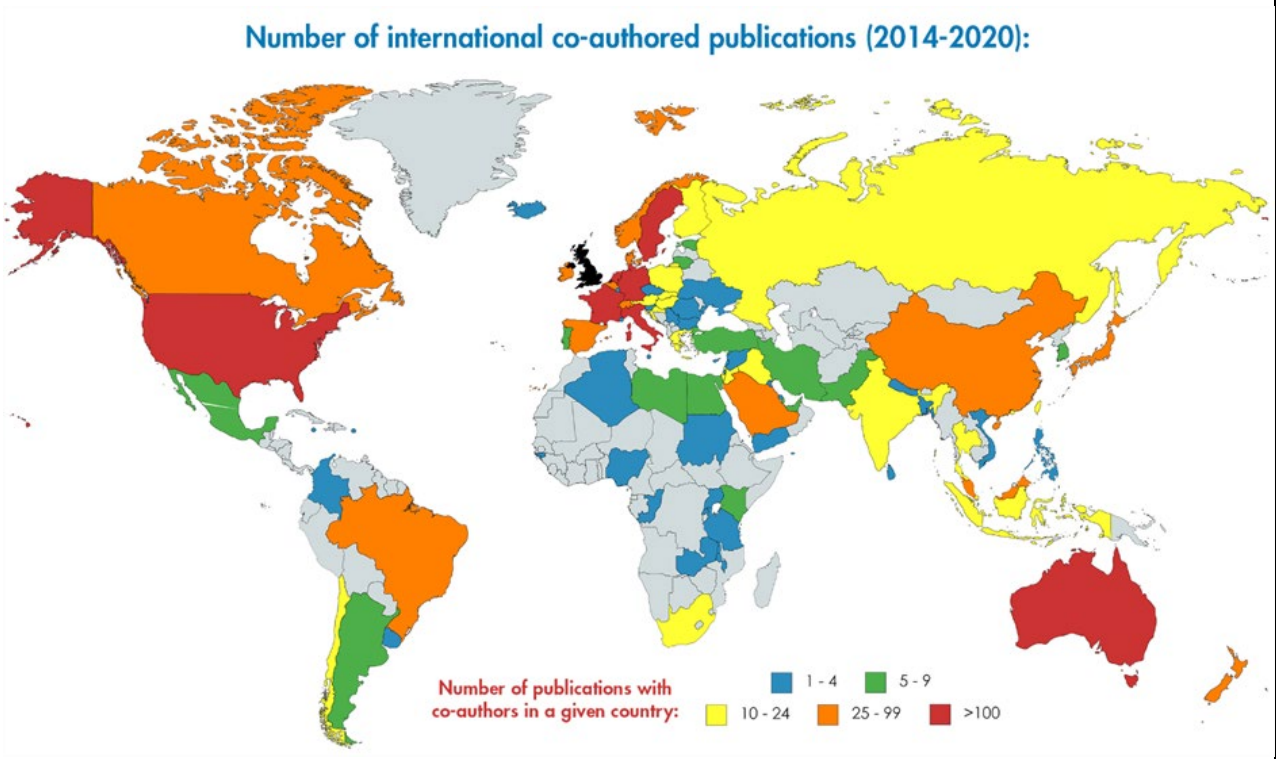

Figure 6. Number of international co-authored publications with UOA3 staff (2014-2020)

4.1.1. Links with other institutions

Links between UOA3 staff and academic institutions contribute to the wider UK and global research environment. **Cullum** is recipient of a Manchester-Melbourne Research Fund award, a joint fund to deepen and extend collaborative research links between the universities. Nineteen staff have held/hold honorary chairs. Four are UK: King's College London (**Lawrence**), Heriot-

Watt University (**Aslam**), University of York (**Cullum**), and Leeds Beckett University (**Briggs**). Four hold/held positions in European institutions including: the Catalan Institute of Nanoscience and Nanotechnolgy (**Kostarelos**); Complutense University of Madrid (**Dickinson**); Eotvos Lorand University, Budapest (**Campbell**); and University of Boras, Sweden (**Kirk**). Five hold honorary chairs in North American institutions: the Oregon Health Sciences University (**Watts**); New York University (**Glenny**, **Walsh**, **Worthington**); and the University of Toronto (**Luker**). **Cullum** and **Yorke** hold honorary chairs at the Universities of Queensland, Melbourne and Griffith. **Edge** in Central and South American universities (Universidad Nacional de San Marcos (and INDICASAT, Panama); **Luker** and **Ashcroft** hold honorary chairs at University of Hong Kong; **Young** at the University of the Witwatersrand; and **Lavender** University of Nairobi. **Kostarelos** leads the Manchester/Memorial Sloan-Kettering Cancer Centre Research Collaboration in Cancer Nanotechnology and the £1.6m EPSRC grant (*EP/S030719/1, 2019-2023)* International Centre-to-Centre Collaboration between Manchester, Harvard University and NU Singapore.

4.1.2. Conferences and other events

UOA3 researchers are active in national and international events, including keynotes worldwide (Figure 7). Sixty-eight staff have held organiser/adviser roles in national/international conferences, and 104 staff have been invited as plenary/keynote speakers at national/international conferences (Table 5). Invitations to present plenary sessions have come from 44 countries.

Table 5. Numbers of staff performing key roles at national and international conferences

Role	National conferences	International conferences
Organiser role	24	26
Scientific advisor	9	24
Other conference roles	10	18
Plenary/keynote presentations	43	53
Invited (non-plenary presentations)	66	68

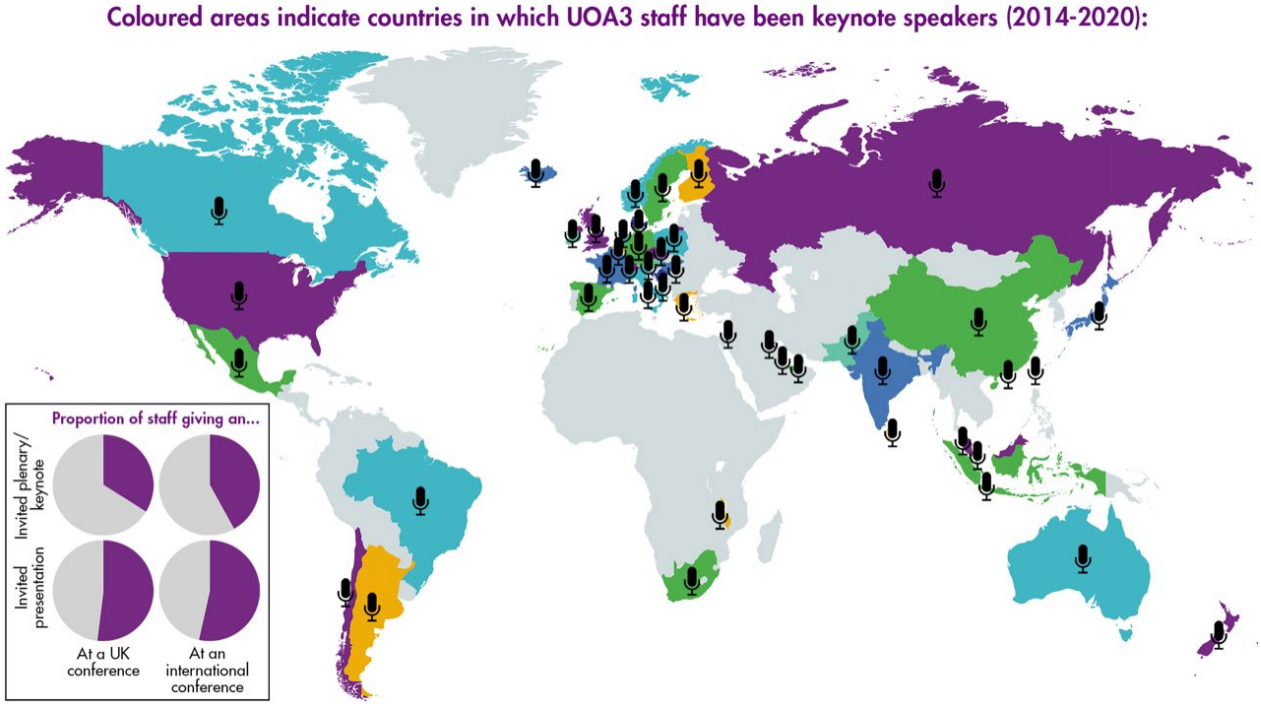

Figure 7. Countries in which UOA3 staff have delivered keynotes. Different countries are indicated by different colours

4.2. Awards and recognition

4.2.1. Awards

Our staff hold major accolades, demonstrating UOA3's contribution to the sustainability of the discipline, e.g. DBE (**Cullum**, **Lavender**); OBE (**Luker**); MBE (**Lawrence**); Officer of the Order of Australia (**Dillon**); Fellow of the Academy of Medical Sciences (**Cullum**, **Luker**); NIHR Senior Investigator (**Cullum**, **Lavender**, **Lovell**, **Munro**, **Todd**); Fellow of the Academy of Social Sciences (**Keady**, **Robinson**, **Young**); Fellow of Academia Europaea (**Luker**, **Lovell**). **Stratford** was awarded the Weiss Medal for services to Radiation Research in 2015, and **Butterworth** holds the 2019 American Chemical Society award for the discovery and development of Tagrisso.

4.2.2. Contributions to the sustainability of disciplines and role in professional and academic societies

Thirty-nine UOA3 staff have held/hold (since 2014) positions in professional or academic societies, with seven holding prestigious Presidential/Chair (including Vice) positions for professional societies: Evidence-based Dentistry, International Association for Dental Research (**Walsh**); Lipidomics Division, European Research Organisation (EuroFedLipid) (**Nicolaou**); Molecular Graphics and Modelling Society (**Bryce**); International Society for Contact Lens Research (**Morgan**); British Society of Audiology (**Munro**); British Association for Psychopharmacology (**Neill**); Academy of Pharmaceutical Sciences (**Lawrence**); and the National Cancer Research Institute CTRad RadCom group (**Williams**, **Stratford**).

4.2.3. Roles on funding panels

Forty-eight UOA3 staff have sat on over 50 funding panels (Table 6).

Table 6. Examples of UOA3 staff roles on funding panels

Role	Supporting examples
Membership of NIHR funding committees (including pre-doctoral, doctoral and fellowship awards)	Research for Patient Benefit (**Bee**, **Dumville**, **Kirk**, **Walsh**, **Munro** - Chair) NIHR Clinical Academic Training Fellowship Programme (**Lavender**) MRC/NIHR Global Maternal and New-born (**Lavender**) NIHR Advanced Doctoral Fellowship Panel (**Lovell**) NIHR Health Technology Assessment general committee (**Dumville**). Integrated Clinical Academic Doctoral Award panel (**Briggs**) HEE/NIHR Pre-doctoral Clinical Academic Fellowship Selection (**Marshall**)
Membership of overseas and other funding committees	European Research Council (**Plack**) Science and Technologies Facilities Council Science Board (**Lawrence** - Chair) Institute Laue Langevin (ILL), College 8 France (**Lawrence** - Chair) German Federal Ministry of Education and Research (**Grande**) National Health & Medical Research Council, Australia (**Keady**) Norwegian Research Council (**Williams**) National Institute of Health (**Saunders**, **Dowding**) Breast Cancer Campaign / Breast Cancer Now (**Williams**)
Research Assessment Exercise Panels	UK REF2021 **(Lavender**, **Lawrence**) Hong Kong REF (**Cullum**)

4.2.4. Editorial activities

Sixty-six UOA3 staff (51%) have held at least one editorial role for a scientific journal since January 2014 (Table 7).

Table 7. UOA3 editorial roles

Role	Number of staff	Supporting examples
Editorial Board	45	British Dental Journal; Oral Surgery; Journal of Oral Rehabilitation (**Yates**) Progress in Biomaterials (**Watts**) Nature Scientific Reports (**Bobola**) BMC Public Health (**Tickle**) Thorax (**Yorke**) Palliative Medicine; BMJ Supportive & Palliative Care (**Grande**) Journal of Pharmacy and Pharmacology (**Ogungbenro**) Drug Metabolism and Disposition (**Galetin**)
Journal Associate Editor	27	Clinical Pharmacology & Therapeutics: Pharmacometrics & Systems Pharmacology (**Campbell**) Translational Vision Science and Technology (**Radhakrishnan**, **Dickinson**) Molecular Human Reproduction (**Harris**) Journal of Human Nutrition and Dietetics (**Burden**) BMC Pediatrics (**Kirk**) Ear and Hearing; Hearing Research; Trends in Hearing; Journal of the Association for Research in Otolaryngology (**Plack**)
Journal Editor	12	Guest Academic Editor for PLOS ONE; Topic Editor for the International Journal of Environmental Research and Public Health (**O'Malley**) Dental Materials (**Silikas**) Dementia: the international journal of social research and practice (**Keady** – Founding Co-Editor) Cochrane Bone, Joint and Muscle Trauma (**Riley**) Nanomedicine (**Kostarelos** – Founding and Senior Editor)
Editor-in-Chief	4	British Journal of Midwifery (**Lavender**) Cochrane Oral Health (**Worthington**, **Glenny, Clarkson**) Cochrane Wounds (**Cullum, Dumville**) Dental Materials (**Watts**)

4.3. Contribution to the wider economy and society

4.3.1. Consultancies and expert contributions

UOA3 contribute to a research environment that links with wider stakeholders to generate and disseminate our research. Fifty-nine (47%) of UOA3 staff had external consultancy roles during the REF period (Table 8).

Table 8. Examples of UOA3's consultancies and expert contributions

Role	Number of staff
Consultancy with industry	32
Consultancy with NGOs and Charities	13
UK Government Committees	11
EU committees	3
Other types of consultancies **Including NHS; Public Health England; NICE; US FDA; World Dental Federation; local governments; UK and international universities; and as a reviewer for the Nobel Prize in Physiology or Medicine.**	15

Forty-two UOA3 staff have a recognised role within the NHS, and 35 have an honorary contract with an NHS Trust. Five staff hold clinical roles including medics, nurses, optometrists, dentists, and allied health professionals. One staff member chairs a clinical commissioning group.

Staff have key roles in Clinical Guidelines, guidance and monitoring including: Public Health England Monitoring Report (**Pretty**); International Guidance on resin composites (**Silikas**); NICE Guideline NG98 (**Munro**); ISO 532-3 Acoustics Methods for calculating loudness (**Schlittenlacher**); NHS England guidelines for translation and interpreting in Primary Care (**Young**); Royal College of Psychiatrists guidelines for commissioning mental health services for deaf people (**Young**); Expert Adviser for NICE Centre for Guidelines, DH/NIHR Translational Research Working Group for the 'Framework for Mental Health Research' (**Lovell**); Clinical Consensus Panel on the use of lissamine green in clinical practice (**Maldonado-Codina**); Joint report with National Data Guardian based on citizen juries (**Tully**).

4.3.2. Patents

UOA3 staff have produced 15 patents in the REF period and include:

- **Rostami-Hodjegan**, **Barber**, Achour, Rothman (2018). Methods for quantifying protein abundance in tissues via cell free ribonucleic acids in blood. US Patent 62648984.
- **Murray**, Carden (2016). Method and apparatus for measuring a property of an eye of a subject. US patent no 9526413.

4.3.3. Contribution to community engagement

UOA3's research is directed towards the health, social care and mental health of our local and wider communities). We engage with our public both in the form of specialist patient groups (Section 1.6.3), and public engagement activities. Examples include:

- ManCAD (led by **Munro**) published '100 Years of Audiology and Deaf Education at UoM' and curated an exhibition of audiology artefacts, and organised evening talks, at the Manchester Central Library (2019).
- The Prevention of Falls Network for Dissemination (ProFouND), a consortium of 11 EU countries led by **Todd**, delivered annual campaigns to raise awareness of falls prevention. This was supported by a comprehensive media and featured an EU wide flash mob involving 500 people from nine EU countries to increase uptake of local strength and balance classes.
- **Edge** organised free public mental health conferences with key stakeholders attracting >2,000 delegates, and received the Distinguished Award for Services to Community Mental Health by the Black Health Agency and African and Caribbean Mental Services (2017).
- **Bee** with 42nd Street (a GM mental health charity for young people) co-produced 'HIDDEN', an immersive theatre show, to raise public awareness of young carers. Partnership with Queen's University enabled performances of HIDDEN to be supplemented with the LiveShout! App, reaching 350,000 people. HIDDEN was shortlisted for best fringe production at the 2017 Northern Soul Awards.
- Co-ordinated by **Lovell**, NIHR CLAHRC GM collaborated with over 20 NHS Mental Health Trusts and organisations to hold a week-long festival raising awareness of physical and mental illness. Over 900 people attended various creative arts, sports events, public lectures and a theatre performance. The event was awarded the 2015 GM Clinical Research Award for public engagement.
- **Neill** has developed strategies, via open public meetings, to reschedule some psychedelic drugs from class I to class II.
- To widen participation, researchers led by **Munro** designed a bespoke transit van with a soundproof booth that travels into local communities to increase uptake of hearing tests, especially in vulnerable groups
- **Bee** and **Lovell**'s Indonesia/UK collaboration ran a 6-day mental health public engagement with 18 events with over 700 participants in Indonesia (2018).
- **Freeman**, **Humphreys**, **Ledder**, **McBain**, **Tirella** have made a sustained contribution to the education of the public, schools and UoM students on AntiMicrobial Resistance (AMR), including invited public engagement events e.g. Café Scientifique, annual World Antibiotic Awareness Week events, 1500 secondary school pupils taught by UoM students and signed as antibiotic guardians, 200 primary school children taught about AMR through handwashing, annual interactive stalls at UoM British Science Week, Science Spectacular and Community festivals (footfall >1000/event).