

**Institution: Cardiff University**

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

## **1. Unit context and structure, research and impact strategy**

### **1.1 UNIT STRUCTURE AND MISSION**

UOA3 comprises a critical mass of researchers (138.95FTE) from five Schools in Cardiff University's College of Biomedical and Life Sciences: Dentistry; Healthcare Sciences; Medicine (Division of Population Medicine); Optometry and Vision Sciences; Pharmacy and Pharmaceutical Sciences. This rich interdisciplinary research environment facilitates the **Unit's mission**: creation of new biomedical and health knowledge recognised to be internationally excellent, which realises societal benefit by advancing individual and population health in Wales, the UK and worldwide.

#### **1.1.1 Interdisciplinary research strands**

Since REF2014, the Unit's research has coalesced around three interlinked interdisciplinary research strands, enhanced by cross-UOA collaboration (e.g., Clinical Medicine; Psychology, Psychiatry and Neurosciences (hereafter Psychology); Biological Sciences; Engineering).

- 1. Biological Systems, Diagnostics and Therapies (BSDT)** focuses on pathobiological mechanisms and development of new and improved diagnostics and therapeutics, with a focus on infection and immunity, cancer and neuroscience. The strand exploits strengths in basic science (predominantly within Dentistry, Optometry and Pharmacy), as well as translational capacity in pharmaceuticals and biomedical engineering. Pathways to improved health outcomes involve the commercial sector and practitioners/professional bodies, developing new products, diagnostics and therapies.
- 2. Rehabilitation, Advanced Materials and Devices (RAMD)** builds on strengths in patient rehabilitation, technologies and biomaterial products, supporting clinicians and patients to better manage ill-health and compromised capabilities (with strong collaboration between Dentistry, Healthcare Sciences, Optometry, Population Medicine, as well as Engineering). A major focus is musculoskeletal conditions, eye disorders, biomedical and tissue engineering, enhanced by significant capability in clinical trials. Pathways to improved health outcomes involve personalised patient management, via practitioner-focused tools and guidelines, as well as new technologies and products with the commercial sector.
- 3. People-centred Care and Health Systems (PCHS)** involves all UOA3 Schools, and unites researchers working on determinants of ill-health, healthcare inequalities and the impact of health and social care organisation. Core methodologies include qualitative, mixed methods research, use of large-scale record-linked health-related datasets and innovative clinical trials. Research foci include infection and immunity, cancer, children and families, and health services organisations. Pathways to impact include evaluation of new therapeutic interventions, as well as new healthcare policies, clinical practice guidelines and services reform.

#### **1.1.2 Summary achievements**

Successful delivery of the Unit's strategy post-REF2014 was enabled by investment in new Centres, facilities and infrastructure (**Section 3**) and a strong focus on equality, diversity and inclusion (EDI), alongside targeted career support, from postgraduate research students (PGRs) through to senior academics (**Section 2**). Involvement in extensive external networks ensured our researchers contributed innovative disciplinary advances nationally and worldwide (**Section 4**). Core achievements included:

- Almost a doubling in size (138.95FTE in REF201 versus 74.95FTE, REF2014).
- Increased staff diversity (50% female staff in REF 2021 versus 33%, REF2014).
- £142M in research awards and £99.2M of research income, the latter a 131% increase from REF2014 (£42.9M).
- Transition to independence of 23 ECRs (65% female); increased PhD awards: 302.5 versus 222, REF2014.
- Significant investment in new facilities and technologies (£15M).

## 1.2 RESEARCH STRATEGY

We delivered, and exceeded, our REF2014 strategic research aims. Note, UOA3 staff (former and current), postdoctoral researchers and PGRs are in *italics*; staff from other UOAs are non-italicised.

### 1.2.1 Aim 1: Prioritisation of interdisciplinary working

Closer integration with Population Medicine (31.30FTE) expanded our population health and clinical trial expertise; this was accompanied by significant infrastructure and facilities investment (**Section 3**). For example, the **Centre for Trials Research** (CTR, Director *Hood*) is a UK-registered Clinical Research Collaboration Unit, established in 2015 with core funding from Health and Care Research Wales (HCRW, £13.3M) and Cancer Research UK (£5M). It conducts ~30-40 clinical trials annually, e.g., CTR's expertise in clinical evaluation of infection-related biomarkers (*Brookes-Howell, Gillespie, Hood, Phillips, Thomas-Jones*) underpinned the PACE Trial (2014-2017, NIHR £918K). This showed that primary care CRP point-of-care tests for chronic obstructive pulmonary disease reduce unnecessary antibiotic prescribing without compromising patient safety. It led to a 2020 NICE surveillance decision and updated guidelines for over-16s (further examples provided in **Section 3.2.1A**).

Research Centres, such as **The Centre for Development and Evaluation of Complex Interventions for Public Health Improvement** (DECIPHer, **Section 3.2.2B**), further facilitated UOA3's interdisciplinary research, e.g., *Robling's* £500K Big Lottery 'Confidence in Care' trial defining how training of foster carers and kinship carers impacts outcomes for the fostered child. DECIPHer also enabled our REF2021 impact case studies, e.g., 'Protecting children's health through new tobacco and e-cigarette laws' [*G.Moore*]; 'New public health measures to reduce harm from excess alcohol consumption' [*S.Moore*].

Cardiff's new £12M **Medicines Discovery Institute** (MDI, **Section 3.2.1B**) brought substantial industrial and new technical drug discovery expertise (e.g., on structural biology and drug target validation), as well as knowledge taking drug candidates from concept to clinical trial. Access to MDI's state-of-the-art protein crystallography facility and structural biology expertise (e.g., *Bax, Biosciences*) facilitated *Mehellou's* research on novel brain penetrant SPAK/OSR1 kinase inhibitors for ischemic stroke (£49K, MRC Confidence in Concept).

Cardiff's **Versus Arthritis Biomechanics and Bioengineering Centre of Excellence** (hereafter Versus Arthritis Centre) advances treatment and rehabilitation of patients with arthritis and other musculoskeletal conditions, via collaboration between biomedical, healthcare and pharmaceutical scientists, engineers and clinicians. This Centre is an important driver of UOA3's interdisciplinary working, exemplified by *Prokopovich* and *Birchall's* collaboration with Evans (Engineering) on a patented drug delivery technology for preventing infection in joint and bone implants (funded by £800K from NIHR, Dunhill Medical Trust and Life Sciences Research Network). *Sparkes* and *Button* collaborate with Chambers (Psychology) on corticospinal mechanisms driving lower-limb activity during walking. Welsh Government Sêr Cymru funding (£116K) to *Sparkes*, Holt (Engineering) and Gibson (NHS) supported research on clinical acceptance of technology in remote rehabilitation (further examples **Section 3.2.1C**).

Three of Cardiff's **University Research Institutes** (URIs, **REF5a**) enable delivery of UOA3's research and impact objectives (e.g., Systems Immunity; Neuroscience and Mental Health; Crime and Security), see examples, **Section 3.2.2D**. UOA3 also leads the **Cardiff University Research Network on Health and Social Care Improvement** (*Allen*), which brings together researchers from 13 Cardiff Schools, across Colleges, to develop innovative, interdisciplinary, patient-centred equitable healthcare. The **GW4 Alliance** (**REF5a**) further enriched UOA3's research, e.g., *Paljarvi's* mHealth Network workshop (2017) brought together GW4 researchers working on health technology assisted interventions for health promotion and disease management; *G.Moore* is Cardiff-lead for the GW4 Health Related Behaviour Change Interventions Initiator; CTR is involved in the South West Research Hub, which brings together GW4 applied trial methodology researchers.

**1.2.2 Aim 2: Increase the proportion of research informed by non-academic users**

A vital focus of activity during the REF period was co-development of research with patients, the public, health professionals, policy makers, professional bodies and commercial partners. We also committed to increasing membership and strategic influence in research-user networks (evidenced in **Section 4**). Working with primary care practitioners, patients and their families, the NIHR (2017, £278K) multinational mixed-methods study by *Carson-Stevens* (with Clinical Medicine) characterised patient safety incidents involving sick children in primary care. The work quantified rates of harmful events (30%) and led to new recommendations to reduce iatrogenic harm and avoidable child deaths. In collaboration with Public Health Wales, NHS partners and the National Childbirth Trust, the Welsh Study of Mothers and Babies (2013-2016, Phase 2, £118K Welsh Government/MRC, *Paranjothy, Hurt*) remains the largest (n=30,000) prospective cohort study of pregnancy outcomes associated with non-structural markers in antenatal ultrasound scans. The work directly informed new Antenatal Screening Wales guidelines on ultrasound observations for NHS Wales health professionals (implemented August 2018 across Welsh Health Boards).

NHS employees as co-investigators were vital for the 'Freedom to Speak Up Guardians' project (2014-2020, NIHR, £625K, *Allen, A.Jones, Kelly*). This evaluated the 'Guardian role' in empowering workers to raise concerns, and how organisations responded to issues. The research informed the All-Wales *Raising Concerns Policy* and the *Freedom to Speak Up* NHS review. *Margrain's* collaboration with the charity Guide Dogs underpinned delivery of positive outcomes from the DEPVIT trial. This highlighted high levels of depression (43%) in individuals with visual impairment, the impact of which is now being addressed within NHS low vision services (accessed by ~155,000 patients annually). The research informed Guide Dogs campaign for early mental health screening and management, as well as mental health training of mobility instructors.

Complementing those examples, UOA3 researchers lead major industrial engagement networks (e.g., **Life Sciences Research Network Wales; Celtic Advanced Life Science Innovation Network**), and international research partnerships. For example, *Birchall* and *Coulman's* \$4.8M Bill & Melinda Gates Foundation project on a long-acting microneedle-based contraceptive for the world's poorest countries, with an international consortium of biomedical engineers, pharmaceutical and manufacturing scientists, family planning NGOs and clinicians. Further contributions to global partnerships, and sustainability of the discipline, are described in **Section 4**. Unit researchers also have long-standing commercial relationships, e.g., *Coulman* and *Birchall's* work with Qualicaps® Europe developing test methods which improved the performance of dry powder inhaler capsules [impact case].

Growth of partnership activities was evidenced by an increase in commercial, UK government and NHS income: £56M REF2021 (versus £14M in REF2014), representing 56% of our research income. This included £9.8M NIHR and £26.2M HCRW, as well as £11.2M commercial partners, income.

**1.2.3 Aim 3: Recruit, support and develop excellent researchers**

The Unit recruited 35 new researchers into Teaching and Research (T&R) roles over the REF period, additionally growing UOA3's staff diversity (see **Section 2**) and opportunities for interdisciplinarity. **Section 2** provides the full details, with some examples outlined here. Medicinal chemists *Mehellou* (Senior Lecturer) and *Pertusati, Nannetti, Ferla, Serpi* and *Slusarczyk* (all early career researcher (ECR) academics) enhanced the Unit's strong drug discovery track-record. Immunologist ECR *Heurich* enhanced linkage with the Systems Immunity URI. She obtained a collaborative Wellcome Trust Innovation Award (£162K) to explore complement and coagulation biomarkers in psychotic disorders. *Bowen* also strengthened collaboration with the Systems Immunity URI, and grew our commercialisation expertise (e.g., via Cardiff spin-out Cotton Mouton Diagnostics, focused on rapid point-of-care diagnostics for infection, see **Section 4.4**). Additional appointments strengthened capacity in the Versus Arthritis Centre (and Systems Immunity URI), specifically in drug delivery technologies, biomaterials, biofilms and microbial infection (e.g., *Hill* develops multi-species biofilm models designed to support product-derived antimicrobial therapies for cystic fibrosis). Targeted appointments in vision sciences enhanced collaboration with the Neuroscience and Mental Health URI (e.g., funding from The Dystonia Society and Fight for Sight

supported ECR *Mcilreavy's* research using eye-tracking to investigate visual function and motor perception in aging, with Peall, Psychology). *Mander* strengthened CTR's expertise in statistics, particularly in the development of novel adaptive trial designs.

### 1.3 IMPACT STRATEGY

Delivery of outstanding impact was core to our post-REF2014 strategy. We empowered our researchers to understand the translational potential of their work and develop active partnerships and synergies with external stakeholders. Alongside increased research income with healthcare and clinical partners (**Section 1.2.2**), we saw an increase in collaborative research user partnerships and delivery of meaningful benefits to research users, e.g., 49% of REF2021 outputs were co-authored with the NHS, health authorities, government, private and commercial sector.

#### 1.3.1 Impact support

Impact activity is recognised, supported and rewarded through annual Performance Development Reviews (PDRs), workload allocations and promotion benchmarks (**Section 2**). UOA3 has a mature impact network, led by School Directors of Research (DoRs) and strengthened by six 'impact champions', specifically academic and professional services staff with considerable impact expertise. These individuals facilitate training and translational activities; identify gaps and relevant funding opportunities; define key indicators of success; and promote engagement with cognate users. Mentoring of those undertaking impact is also provided by staff with a track-record of successful impact (e.g., *Allen, Busse, Gumbleton, Margrain, G. Moore*). Complementary support is available through the University's Research and Innovation Services, from early-stage training to protection of intellectual property and commercialisation (see **Section 3**, and **REF5a**).

As well as key networks (described in **Section 4**), Unit researchers are supported by our new **Joint Clinical Research Office** with NHS Wales (**REF5a**) and the Health Board **Clinical Innovation** multi-disciplinary team (MDT, established 2014; *Gumbleton* member). These entities facilitate effective clinical translation between the NHS and the University, including direct support for technical, clinical and regulatory matters; financial expertise for translational projects; and development of effective external collaborations with users and beneficiaries, including access to Welsh SMEs developing new healthcare and medical diagnostics and technologies. Capacity was further expanded by the University's new Clinical Innovation Accelerator (**ACCELERATE**; *Gumbleton, Westwell, Co-Is*), a £24M (Cardiff £8.4M, 2018-2021) European Regional Development Fund project with Swansea and University of Wales Trinity St David (see **Section 4.4** for example projects). UOA3 Research Centres also have excellent user and patient-public involvement (PPI) networks (e.g., DECIPHer's Public Health Improvement Research Network and School Health Research Network, the latter involving 300 young people across Wales in the co-creation of research). Our PPI networks ensure that UOA3 research is developed aligned to the needs of key beneficiaries and other research users; details in **Section 4.3**.

#### 1.3.2 REF2021 impact case studies

Facilitated by impact support, UOA3 staff delivered a large and diverse suite of impact activities during the REF period, across all three research strands (e.g., examples noted in **Section 1.2**, and throughout the statement). UOA3's nine REF2021 impact case studies were selected based on their maturity and reach, while ensuring that breadth of research impact was evidenced (see **Section 3.1** for details of REF2021 delivery). The cases cover (aligned to BSDT) new diagnostic and therapeutic processes and products (*Brancale, Coulman, Maillard*); (aligned to RAMD) clinical practice and practice guidelines (*Busse, Joseph-Williams*); and (aligned to PCHS) health and welfare policy (*Chestnutt, Shepherd, G. Moore, S. Moore*).

*Maillard's* research demonstrating the ineffectiveness of clinical antimicrobial wipes led to a new protocol adopted as an American Society for Testing and Materials International Standard. Further, working with a leading UK wipe manufacturer (GAMA Healthcare), *Maillard* facilitated the development of new products delivering £8M in new revenue, as well as a new £4M research and development facility. *Brancale* and colleagues' research on cellular barriers to nucleoside drugs delivered new clinical-experimental anti-cancer candidates which allowed a UK SME (NuCana plc) to raise £189M investment in the REF period, and progress three Cardiff ProTide compounds

through Phase I to Phase III clinical studies, with encouraging outcomes for a range of advanced tumour types (e.g., biliary tract cancer, which currently has no approved drug treatment).

Researchers in Dentistry worked with NHS practitioners, patients and the wider public to provide evidence to the Welsh Government on their £3.1M per annum (p.a.) *Design-to-Smile* national oral health programme for young children (*Chestnutt*). Cardiff's finding led Welsh Government to change its policy and practice, specifically moving away from fissure sealants to fluoride varnish, as well as targeting oral health in children under-five. The research also provided the evidence base for a NICE guideline for Public Health England, focused on improving oral health initiatives.

Co-creation with patients and NHS practitioners was key to *Joseph-Williams* and her team's work on barriers to shared decision-making (SDM). Cardiff's new 'three-talk' SDM model was embedded within a national training programme in Wales, also informing UK SDM healthcare policies and international guidelines on minimum standards for patient decision aids. *Busse's* research partnership with Rosser (Biosciences) on physiotherapy and supported physical activity led to revised international guidelines for Huntington's Disease, which have been utilised by international Huntington's Disease Associations (e.g., in Europe, China, United States). Further UOA3 impact outcomes are described in **Sections 3 and 4**. UOA3 researchers working on early-stage impact development continue to be provided with ongoing support and investment, via the mechanisms outlined in Section 1.3.1, as well as early-stage funding (see **Section 3**).

#### 1.4 FUTURE RESEARCH AND IMPACT STRATEGY

UOA3's future research and impact strategy builds on the success of our REF2014 strategic mission, with the aim of further accelerating discovery of new knowledge able to deliver major healthcare benefits in Wales, the UK and internationally. It will be revisited regularly, ensuring consideration of COVID-19 impacts on research, and UOA3 researchers.

**Aim 1. Continue to develop an inclusive research environment which supports, attracts and retains the very best staff, both established academics and early career researchers.**

Specific objectives include:

- i. Expansion of our ECR community through mentorship of promising young researchers, alongside strategic external recruitment to capture prestigious independent fellowships which strengthen collaboration across research strands, and with other synergistic disciplines. Key growth areas include: precision medicine, specifically integrating basic and molecular sciences with population and clinical sciences; pre-/non-clinical *in-vivo* experimentation aligned to drug discovery; advanced therapies (cells and genes) and bio-responsive therapeutics and diagnostics; research in practice and service change across health and health-related social care, further enhanced through epidemiology, health economics and qualitative/mixed-methods research expertise.
- ii. Continue to build a sustained clinical academic pipeline, through active participation in NIHR Fellowship Schemes; via disciplinary expansion of our joint GW4 Clinical Academic Training programme; and the Wales Clinical Academic Training Scheme. This will be complemented by enhanced support for allied health professionals through the Research Capacity Building Collaboration (RCBC) Wales programme (see **Section 2**).
- iii. Continue to deliver positive EDI initiatives which promote inclusion, including leadership mentoring of individuals from underrepresented groups, alongside a coordinated external appointment strategy which advances diversity, while maximising opportunities for interdisciplinarity and impact. Build on our School Athena Swan action plans, sharing best practice as part of a coordinated EDI approach.

**Aim 2. Grow our portfolio of large-scale research projects by capitalising on our interdisciplinary Centres and Institutes and continue to nurture and increase our network of external research collaborators.**

- i. Invest in, and successfully compete for, new funding aligned to growing collaborative research across UOA3's new Centres and facilities. Aligned to national research needs, we will develop an Advanced Therapies (cells, genes and viral) GMP manufacturing facility enhancing our researchers' ability to develop and evaluate new therapies for patients,

linked to Cardiff's strengths in infection and immunity, cancer and neuroscience. New cross HEI collaborations will further foster growth, for example, via collaboration with the new £130M London-based Oriel Eye Care Hub (2021, Research England/Department of Health) and UK Vision Research Institute.

- ii. Through mutually beneficial partnerships, we will further develop our translational activities (e.g., Cardiff's Medicines Discovery Institute and UK Dementia Research Institute Centre provide a unique opportunity for UOA3 to align its current drug discovery strengths to neuroscience). We will also grow PCHS's strengths in child development and adolescent health aligned to Cardiff's new £56.5M Social Sciences Research Park, as well as the University's recently awarded £10M Wolfson Centre for Young People's Mental Health (REF5a).

**Aim 3. Support our staff to continue to address major global healthcare-related challenges and the unmet needs of our stakeholder communities.**

- i. Continue equitable and transparent use of research and impact funding, workload allocations and mentoring to ensure all Unit researchers have the time and resources to develop the translational potential of their research, enhanced by Cardiff's planned investments in University Innovation Institutes and professional support for impact (REF5a).
- ii. Expand the Unit's Impact Support Network (**Section 1.3**) and ensure provision of funding for proof-of-concept impact activities. Sustain the Unit's strong success with external funding in partnership with networks, and grow commercial and licensing success, aligned to Aim 2 (see **Section 3**).
- iii. Promote and grow public and patient involvement within the UOA3-linked Research Centres, ensuring co-creation of research and impact aligned to the needs of our stakeholders and beneficiaries (see **Section 4.3**).

**1.5 OPEN RESEARCH, RESEARCH INTEGRITY AND ETHICS**

The Unit is committed to open research practices, and is fully compliant with, and in some areas exceeds, Cardiff University's policies (REF5a). All UOA3 Schools have Open Access (OA) coordinators who oversee OA staff training and ensure compliance with funders' requirements (Green or Gold). All post-print files and bibliographic details for outputs are held in Cardiff's OA repository. Following Research England's guidance, 100% of Category A staff have ORCID iDs. The Unit follows the principles of the San Francisco Declaration of Research Assessment (DORA) e.g., in recruitment, promotion and assessment of research quality. UOA3 goes beyond the Concordat on Open Research Data (e.g., via collection and reporting of primary data to governments and other stakeholders aligned to healthcare delivery and policy initiatives). For example, *Sivarajasingam* coordinates the National Violence Surveillance Network, which works with the Office for National Statistics and informs the *Crime in England and Wales Statistical bulletins*. This underpins our research on violent crime, e.g., *Shepherd's* [impact case].

Rigorous governance around research integrity and ethics is fundamental to the conduct of high-quality research, with staff and PGRs required to complete the University's mandatory online research integrity training (REF5a). The Unit's Schools each host a Research Ethics Committee (SREC) that considers discipline-specific issues in the design and conduct of research studies. SRECs meet monthly to review applications and report to the University's Open Research Integrity and Ethics Committee. The CTR Director (*Hood*) and College Dean of Research and Innovation (*Westwell*) sit on this Committee. The College Human Tissue Act Officer (*Stephens*) is lead for the **Cardiff University Biobank (Section 3.3)**. Research involving human-derived materials is conducted under Human Tissue Authority licences and research involving animal species is regulated under the Animals (Scientific Procedures) Act 1986.

## 2. People

### 2.1 EQUALITY, DIVERSITY AND INCLUSION

We are committed to recruiting and developing excellent researchers. EDI is embedded within our people strategy, evidenced through our senior leadership teams and extensive staff development initiatives. EDI was also firmly embedded in our REF2021 delivery (**Section 3.1**).

Highlights since REF2014 include:

- An increase in Unit size to 147 staff (138.95FTE) from 84 (74.95FTE, REF2014)
- Increased staff diversity, with 50% female staff (versus 33% in REF2014)
- Improved promotion opportunities (e.g., 60 promotions since REF2014, of which 53% were female)
- Success supporting ECR transition to independence (23 researchers, 65% female)
- Increased PhD completions, 302.5 (a 36% increase from 222 in REF2014)

Our commitment to EDI begins at the top. Since REF2014, UOA3 had nine female Heads (or Deputy Heads) of School (HoS) or Division (e.g., *Votruba*, *Paranjothy*, *Waterman*, *Hood*, *Nelson*), two female DoRs (*Albon*, *Allen*) and five female Directors of PGR (e.g., *E.Lane*, *Knauper*). At the census date, 50% of Senior Management Team Leaders were female. The College's current Deans of Research and Innovation (*Westwell*), Postgraduate (*Kidd*) and International (*Stephens*) are UOA3 researchers, evidencing significant contributions to University research leadership. Unit researchers also lead research strategy at College level (e.g., *Sheeran*, *Brain* and *Purcell* are Theme and Associate Theme Leads for Population Health). Former colleague *Paranjothy* was the first female and BAME individual to hold the prestigious Mansel Talbot endowed Chair; she was also Director, Division of Population Medicine. Since REF2014 all six new HoS completed Cardiff's bespoke Heads of School training programme (**REF5a**); College Deans also completed Cardiff's Deans' Development Programme (established 2018).

Each of UOA3's Schools has continuously held Bronze or Silver Athena Swan awards since 2014, with renewal pending for Healthcare Sciences. EDI is embedded within the agendas of Research Committees and Senior Management Team, with regular reports on initiatives and progress aligned to each School's EDI strategy. Initiatives since REF2014 include: a maternity, paternity, adoption and surrogacy scheme, providing funding for individuals on leave where a grant-funder does not cover costs; safe environments for expressing breast milk; a more inclusive focus on match-funding for Fellowship applications (benefitting *Bassetto*, *Serpi* and *Slusarczyk*); gender-balanced inclusion of ECRs on Research Committees; job-sharing initiatives for research staff following maternity leave; a revised academic recruitment approach (developed with an external agency, Diversity by Design), which aimed to increase engagement of applicants from diverse backgrounds, identities and experiences.

### 2.2 STAFF RECRUITMENT

Since REF2014, UOA3 grew by 63 staff, of which 23 were ECRs. This was achieved through (a) new T&R recruitment (35 new staff, 57% female); (b) R-only staff moves to independence (15, 66% female); and (c) integration of 34 staff from the Division of Population Medicine (including 19 (12 female) CTR researchers). The latter supported our strategic goal to grow our PCHS research strand. Our staff cohort moved from 33% female in REF2014 to 50% in REF2021 (74 of 147 staff). Support for BAME staff facilitated new leadership roles (*Paranjothy*) and successful promotion (e.g., *Wei* to Senior Lecturer; *Sivarajasingam* to Professor). We increased our BAME researchers to six, from one (REF2014).

#### 2.2.1 New appointments

Appointments strengthened capacity across UOA3's research strands, aligned, where possible, to increased linkage with UOA3 interdisciplinary Research Centres and Institutes (**Sections 1.2 and 3.2**). Applications were encouraged from underrepresented groups (e.g., Harvey Nash Consulting supported recruitment of a new Dentistry HoS, with the brief to generate an inclusive short-list; this led to appointment of *N.Innes* (initially honorary, full move 1/08/20), bringing new expertise in clinical dentistry augmenting PCHS). Five further female appointments into PCHS

focused on: patient and healthcare decision-making, specifically medicines management (*Weiss*, Professor); applied psychology and behavioural change (*Bundy*, Professor); cognitive neuroscience of motor control and movement (*Purcell*, Reader); palliative care in advanced cancer, including patient experiences of immunotherapy (*Watts*, Senior Lecturer); midwifery clinical trials (*Sanders*, a joint NHS-University Professorial appointment, who also holds senior NIHR leadership roles). These positions also supported cross-College interdisciplinary research (e.g., *Purcell's* collaboration with Psychology on motor control in Developmental Coordination Disorder). Recruitment of *Mander* as CTR Professor of Statistics brought new expertise in novel adaptive trials and accelerated UOA3's ability to translate fundamental research into population-level interventions and policy formation.

Research in our BSDT and RAMD themes benefitted from new drug delivery and biomaterials expertise aligned to combating complex infections [*Hill*, *Pritchard*] and *Farnell's* applied mathematical research, bolstering UOA3's leading position in 3D facial imaging and genetics. *Whitaker's* research on sensory time (how we perceive the duration and temporal order of events), and recruitment of *Mcilreavy* (an ECR clinician), enabled new research on visual function in patients with nystagmus. New clinical lecturer *Terry* uses artificial intelligence to study choroidal vasculature in age-related macular degeneration, with *Koudouna* focusing on cell-matrix interactions defining tissue structure and function. *Pertusati* moved into his first lectureship, and alongside recruitment of senior lecturer *Mehellou*, strengthened delivery of UOA3's promising pro-nucleotide (ProTide) drug discovery work (see **Section 1.3.2**).

Recruitment of *C.Thomas* and *Heurich* to their first lectureships bolstered expertise in oxidised lipids, complement cascade and coagulation biology (building links with Cardiff's Systems Immunity URI, **Section 3.2.2D**). Appointment of *Bowen*, who researches point-of-care diagnostic devices aligned to sepsis and infection, further enhanced links with the URI. As Director and co-founder of Cotton Mouton Diagnostics Ltd (see **Section 4.4**), *Bowen* also augmented UOA3 expertise in commercial development. *Newland's* research on nano, micro and macroscale materials supported closer partnership with Cardiff's Neuroscience and Mental Health URI and grew international partnerships (via his collaborations with Max Planck Institute of Molecular Cell Biology and Genetics, Dresden; University of Antwerp).

Cardiff's Disglair Lectureship Scheme (**REF5a**) recruited *Nannetti* and *Mead* into BSDT. *Nannetti* augmented capability on new antiviral drugs, with *Mead* bringing new expertise, and key US collaborations, on treatment of eye diseases. *Mead* notes of Disglair, "*The gap between a post-doctoral researcher and lecturer can often seem wide and the scheme has been very helpful in making the crossing of this gap smoother and less daunting without reducing the research potential and independent success that comes with being a lecturer*". Facilitated by his Disglair award, *Nannetti* obtained a £50K Wellcome Trust ISSF grant to study development of innovative anti-fever compounds.

### 2.2.2 Fellowships

*Bassetto*, *Ferla*, *Nannetti* and *Pritchard* obtained fellowships from the prestigious Welsh Government Sêr Cymru II scheme. All continue to build successful academic careers (e.g., *Pritchard* was awarded further funding from industry (Venture Life Group, £73K), Welsh Government (Sêr Cymru Accelerator Award, £5K) and KESS2 (PhD studentship, £88K); *Bassetto* obtained a Chemistry lectureship at Swansea). *Koudouna* is a current Marie Skłodowska-Curie Fellow, with *Slusarczyk* and *Serpi* holding research fellowship positions, involving commercial partner NuCana. This supported *Serpi's* move into her first lectureship (Chemistry, Cardiff, 01/10/20).

Healthcare and clinical ECR investment included five Research Capacity Building Collaboration (RCBC Wales) postdoctoral fellowships (e.g., *Davies*, *J.Baillie*, *Sheeran*, £459K). *J.Baillie* previously worked as a staff nurse in Nephrology and Transplant at Cardiff and Vale University Health Board. She undertook a RCBC PhD in Healthcare Sciences, prior to obtaining an RCBC postdoctoral fellowship on patients' and families' experience of dialysis-associated peritonitis. *Sheeran's* RCBC postdoctoral fellowship supported her work with BACK-on-LINE™ (**Section 4.4**). Other fellowships included: Versus Arthritis (*Adamczyk*), Fulbright Scholar (*Taussig*) and four HCRW Fellowships (e.g., *Gillespie*, *Latchem*). *Latchem's* collaboration with Kitzinger on patient-

centred care for those in vegetative or minimally conscious states led to a REF2021 impact case (Journalism). Her current project FEAST identifies how mealtimes and food-based activities can enhance quality of life for young people with neurological conditions in long-term care.

## 2.3 STAFF DEVELOPMENT

### 2.3.1 Staff wellbeing

Staff wellbeing is afforded the highest priority, supported by Cardiff's Wellbeing Team, services, resources and policies (**REF5a**). UOA3's has 23 Dignity and Wellbeing contacts across all staff categories. Trained in mental health first aid (e.g., "i-act"), they help staff identify appropriate support services within and outside the University. The Unit's wellbeing strategy is informed by Cardiff's biennial staff survey and direct staff consultation. Initiatives developed from staff suggestions include: Staff Forums, covering presentations on wellbeing, work-life balance and coaching; drop boxes for feedback and improvement ideas; staff training on mental health first aid.

11 UOA3 staff (across four Schools) have formal flexible working, with many others benefiting from informally agreed flexible arrangements. In Optometry, for example, 26% of research active staff work part-time. Seventeen staff took maternity leave during the REF period (across all Schools), with staff actively supported in their return to work, through keeping-in-touch days, phased returns and reduced teaching/administrative workloads. For example, *E.Lane* was provided with a research day per week for a year, plus support from a research assistant. She has been promoted twice since her maternity leave, and successfully obtained a £217K MRC grant on hESC-derived transplants in Parkinson's disease. *Heurich* did not undertake teaching for a year after her maternity leave and is now a successful co-PI on a £1.3M Wellcome Trust Innovation Award with the Irish Royal College of Surgeons. *Brookes-Howell*, *Dewitt*, *Ferguson*, *Pritchard* and *F.Wood* were also provided with reduced hours and flexible working after maternity leave. *F.Wood* now holds a research leadership role as Director of PGR for Population Medicine, with *Ferguson* acting as Impact lead in Dentistry.

All Schools have core working hours and schedule meetings to avoid the beginning and end of the day providing flexibility to drop off and pick up children. Seminars are scheduled to facilitate staff attendance (e.g., 2pm on Wednesdays in Pharmacy; or rotated across days to support clinicians with set commitments, Population Medicine). Funding is also available for e-conferences (e.g., *Brain's* attendance, Cancer and Primary Care Research International Conference).

All Schools transitioned to e-seminars during the COVID-19 epidemic and provided mechanisms for staff to keep in contact with each other, maintaining staff wellbeing. Staff also benefitted from enhanced University support (**REF5a**), particularly off-site working, dependency leave, facilitated access to laboratory and clinical research facilities. University-funded PGR student extensions and campus study spaces were provided, and particularly relevant to UOA3, support where staff served the NHS or national research effort (e.g., *Maillard's* work on personal protective equipment; *Brain's* research on early cancer diagnosis; *Bundy's* role on the Technical Advisory Group, informing the Welsh Government's COVID-19 Scientific Advisory Group, as well as rapid review of COVID-19 research applications). In the first lockdown, the University Dental Hospital also operated as the sole regional Dental Care Centre, seeing over 10,000 patients, supported by university clinical staff.

### 2.3.2 Promotion

Annual PDRs provide staff with input on promotion and career ambitions, including discussion of training needs, and institutional academic and performance expectations (Cardiff Academic and Cardiff Professional). Based on his PDR, *A.Wood* was supported to attend an MRC accredited course 'Improving Health by Improving Trials' at Liverpool University. This enhanced his knowledge of clinical trials and led to co-investigator status on an application for a multicentre clinical trial of a novel therapeutic for early-stage macular disease (£753K, AltRegen Ltd., with City University and UK Astronomy Technology Centre). Unit staff also benefit from participation in Cardiff's new Academic Promotions Development Programme (for Readers who identify as BAME, female or both and who aspire to promotion to Professor).

60 Unit staff (53% female) were successfully promoted since REF2014, of which 15 were promoted twice (indicated with a \*), e.g., **promoted to Senior Lecturer: Acton, Albon, Castell,**

*Courtier, Coulman, Ferguson, Gale, Hemming, Hurt, J.Lewis, Joseph-Williams, Mehellou, Prokopovich, Rozanowska, Segrott, Wei; Reader: Anstey\*, Blain\*, N.Evans\*, E.Lane\*, Moseley, Button\*, Featherstone, Boote\*, Knupp, Farewell, Heard, Hiscox, Sakellariou\*, Sheeran\*, Simons, Purcell, Playle, White; Senior Research Fellow: Gillespie; Townson; Brookes-Howell; Al-Amri; Thomas-Jones; Cannings-John; Principal Research Fellow: Mcnamara; Chair: Brain\*, Brancale\*, Busse\*, Erichsen, Hannigan, Hughes, A.Jones\*, A.T.Jones, G.Moore\*, Margrain, Marshall, Mason, Moseley, Nelson, Robling\*, Ryan, Sivarajasingam, Sparkes, Westwell, F.Wood\*.*

Cardiff's R-only promotion route to Principal and Senior Research Fellow are an important route to equality in UOA3, where Research Centres (e.g., CTR) have a large proportion of staff on R-only contracts, compared to T&R.

### 2.3.3 Career development

A Workload Allocation Model ensures equitable, flexible and transparent allocation of academic activities, aligned to PDR discussions. Staff are given time to pursue research and impact goals, with inclusion of at least 0.4FTE for research, complemented by further allocations aligned to impact, external research activities (e.g., REF or grant funder panellists), civic mission and public engagement (e.g., for staff supporting UOA3's Pharmabees project, see **Section 4.3.2**). As noted in **Section 1.3.1**, UOA3's impact champions, and staff working on impact projects, are provided with workload allocations (e.g., 60 hours dedicated to impact activities in Optometry). Early, and less-developed impact, which was not submitted to REF2021 continues to be supported via continuing workload allocations, impact funding (see **Section 3**) and secondment opportunities.

Complementing School research leave schemes, five UOA3 staff benefited from the **University Research Leave Scheme** (between 2015-2019). *Brain's* leave in 2015-2016 catalysed successful awards on cancer screening and early diagnosis and supported promotion to Professor of Health Psychology. She was named Chwarae Teg's (Fair Play's) Wonderful Welsh Woman of the Year Award finalist, 2018. Research leave linked to the Disglair Lectureship Scheme supported three UOA3 staff (*Erichsen, Redmond, Brancale, 2019-2020*). During his research leave, *Redmond* wrote a £1.8M MRC DPFS grant with Ulster University and UCL on glaucoma, and novel visual field acuity measures for use in clinical settings (awarded post-REF2021 census date).

All new UOA3 ECR academics are supported to achieve research excellence through training following an integrated academic induction programme designed to achieve HEA Fellowship status. Seventeen Unit staff undertook further Cardiff leadership training (e.g., Moving into Leadership; Practical Leadership for University Management; Professorial Leadership). Eight took part in the Vice-Chancellor's **Cardiff Futures** programme (supporting promotion for *Ferguson* and *Playle*). The award-winning **Welsh Crucible** programme involved five Unit participants (*Bowen, Castell, Ferguson, Newland, Redmond*), and facilitated *Ferguson's* successful £400K MRC New Investigator grant on antibiotic polymer conjugates. **GW4 Crucible** brings together future research leaders across the Alliance, with three UOA3 staff participating since REF2014, e.g., *Pritchard* and *Serpi* participated in the 2020 GW4 Interdisciplinary Approaches to Antimicrobial Resistance programme. This catalysed *Serpi's* collaboration with Laabei (Bath), Duggan (Bristol), Malavia and Stappers (both Exeter) on antimicrobials to treat human pathogens.

**Pitch-to-peer sessions**, led by senior researchers, supported those applying for grants, with provision of feedback at an early-stage helping deliver increased success with funding (**Section 3.1**). This approach supported *E.Lane, Redmond* and *A.Wood's* grant successes (mentioned earlier). Mentorship is provided to staff writing grants and outputs, especially those less experienced in applying for funding, and all Schools have peer-review processes providing grant feedback from expert reviewers. Researchers are provided with funding to support their research needs, whether training, conferences, fieldwork or collection of pilot data. Pharmacy, for example, provides funding from overheads into holding accounts, while CTR has pooled funding into a single development account, supporting training and conference attendance. Staff and PGRs can apply to Research and/or Staff Development Committees for funding for training, conferences or to generate pilot data (e.g., Optometry supports early-stage research ideas via a £15K per annum seed-corn funding scheme). Annual research away days ensure staff actively contribute to the development of UOA3 research and impact strategies.

The Cardiff University Research Opportunities Programme (**REF5a**) supported 82 undergraduate research placements, e.g., Harvey, from Engineering, built a 3D printer speeding up creation of microfluidics with *Castell*, leading to funding on COVID-19 point-of-care tests (Sêr Cymru, £142K, awarded post-REF census date).

#### 2.3.4 Postdoctoral researcher development

176 (R-only) postdoctoral researchers were recruited since REF 2014, with all UOA3 Schools committed to applying the Concordat to Support the Career Development of Researchers (**REF5a**). As well as supportive PDRs, grant application peer review and mentorship schemes (as described in **Section 2.3.3**), our R-only researchers benefit from targeted funding, leadership and training schemes.

For example, Cardiff's **Wellcome Trust ISSF** has specific R-only and ECR academic career development schemes. UOA3 received 43 ISSF awards (£1.57M, over 25% of the total available), including seven early-career Consolidator Awards. For example, *Baxani's* Consolidator Award with *Castell* resulted in a REF output (on artificial cells from compartmentalised droplet networks) and a subsequent postdoctoral position (Imperial Molecular Sciences Research Hub). The Unit received two ISSF Reconnect with Science Awards, providing tailored support for individuals to undertake research after a career break. *Elbetany* used the scheme to publish first author research outputs, and obtain proof-of-concept pilot data, designed to support grant applications in antimicrobial resistance and wound healing. Other UOA3 ISSF beneficiaries included ECR academic *Hamana* who co-produced a walking (physical therapies) programme for people with Huntington's disease with *Busse*. ISSF Consolidator, *Shologu*, who moved from Ireland to Cardiff after her PhD, was funded to develop **Science Pirates** (2019), a pirate-themed 'Escape Room' engaging the public on exercise and bone health (over 200 attendees). Cardiff R-only staff, and ECR academics, observe ISSF grant panels, enhancing understanding of grant assessment (**REF5a**).

Many R-only staff benefitted from Cardiff's Research and Innovation Services' portfolio of dedicated research support programmes, including an 'ECR Pathways to Impact' course, as well as training and support around translation and commercialisation (**Section 3.3**). The University also runs a structured **Fellowship Support Programme**, comprising interactive six-monthly workshops focused on grant funding, grant writing and peer review, and additionally providing an informal peer-to-peer fellow network. Unit ECRs were supported via externally facilitated research grant writing workshops, such as those run by Parker Derrington Ltd., a company supporting training and mentoring on writing research grant and fellowship applications. Twenty ECRs and PGRs also attended an external fast track impact workshop, covering the generation, evaluation and evidencing of impact, and working with external stakeholders. Our R-only staff also accessed training opportunities provided by GW4 partners (e.g., the GW4 RCUK mock panel grant training, including NERC, MRC and BBSRC, *C.Thomas, Koudouna*).

The Cardiff University Research Staff Association (CURSA), open to all research staff, independent of career stage, provides a voice to influence the University's research and innovation strategy. *S.Morgan* (Optometry) serves on the CURSA executive team. R-only and ECR academics are involved in UOA3 Research and EDI Committees allowing them to contribute to School strategic decision-making. Publication policies ensure that ECRs are appropriately credited and encouraged when writing as first authors. ECRs are also fully involved in supporting seminar series and given the opportunity to meet leading figures in the field. For example, RCBC Wales PhD students and postdoctoral fellows have a regular interdisciplinary Community of Scholars meeting, involving discussions of scientific disciplines, research methodologies and opportunities for mentoring and peer support. The strong distribution of ECRs across the Unit's three research strands provides a further opportunity for the development of interdisciplinary research approaches, ensuring translation of research knowledge to clinical benefit. This varied and supportive approach to UOA3 R-only staff enhances their future research careers, whether by transition into fellowships (**Section 2.2.2**), new T&R positions (**Section 2.2.1**) or a move into other sectors (e.g., *Wymant* became public engagement officer for the charity Shine; *Piggott* worked initially for Cancer Research Technology, before being appointed as a senior scientist at Debiopharm, a Swiss biopharmaceutical company).

### 2.3.5 Developing research clinicians

UOA3's research is grounded on clinical foundations, with some staff joining as expert clinicians or teacher-practitioners on Teaching and Scholarship (T&S) contracts. *U. Jones* (T&S), for example, worked with *Busse* on physiotherapy interventions in Huntington's Disease and is now lead of the European Huntington's Disease Network physiotherapy working group. Support is provided for career pathway change to T&R, including PhD enrolment (via a tuition fee waiver, research expenses, and allocated research time). RCBC (Wales) First into Research Awards also help clinicians and practitioners develop a competitive PhD funding application; UOA3 received 11 of these awards since REF2014 (£76.7K). For example, *Smith* (T&S) used the RCBC First into Research Award to secure a funded PhD studentship on diagnostic ultrasound imaging of shoulder disorders (£170K, Versus Arthritis). In total, eight staff in Healthcare Sciences completed PhDs during the REF period (one funded by RCBC, £62.5K).

Mentorship and an agreed workload reduction ensure delivery of research outcomes designed to support a career pathway change, and since REF2014, four UOA3 staff successfully transferred from T&S to T&R. For example, *N. Evans*, secured a Health Foundation award to undertake a PhD, focussing on child adolescent mental health. She subsequently obtained funding for three NIHR studies, a Florence Nightingale Travel award and a Global Opportunities Research Fund grant (in total, £379K). In 2017, she was awarded the RCN (Wales) Research in Nursing award and was promoted to Reader in 2018. Flexibility within the workload model allows T&S staff to contribute as expert clinicians (e.g., *Delport* brought their clinical expertise in autistic spectrum disorders to an £1.2M NIHR project (SenITA, 2016-2021) focused on a randomised controlled trial of sensory integration therapy in autism (with *Brookes-Howell*, *Busse*, *Gillespie*, *McNamara*).

## 2.4 POSTGRADUATE RESEARCHERS

PGRs form a core element of UOA3's research community, further developed in this REF period, with particular success in recruitment and development of new tailored support. Postgraduate programmes are aligned to disciplinary requirements and managed by the Directors of PGR, supported by an administrative team. Postgraduate Research Committees meet regularly to oversee formal monitoring processes. Student-staff panels operate to represent the interests of the postgraduate community, reporting to Boards of Study and Research Committees.

### 2.4.1 PGR Recruitment

We are committed to an inclusive approach that promotes EDI, achieves disciplinary excellence and supports our diverse PGR community. Our funded programmes have specific recruitment approaches, which include measures to promote inclusive recruitment (e.g., anonymised applications, unconscious bias-trained interviewers, diverse interview panels and interview slots for students who self-report as BAME and disabled). Formal recruitment involves advertising through [www.findaphd.com](http://www.findaphd.com) and the University website. After triage, a consistent interview process is implemented, with at 2-3 interviewers, including brief research presentations followed by questions about research, projects and careers.

UO3 currently has 213 PhD and MD students (134 female; 79 male), with international students making up 41% of the PGR student body (mostly recruited across Europe and Asia). PhD completions since REF2014 were 302.5 (versus 222, REF2014).

Financial support for PGRs included University DTEs (e.g., GW4 MRC BioMed); KESS (additionally involving 18 companies and NGOs); China Scholarship Council; RCBC, HCRW and NIHR; Life Sciences Research Network. The Unit also secured studentships from charities and NGOs, e.g., British Heart Foundation, Versus Arthritis, Abbeyfield Research Foundation, College of Optometrists, Fight for Sight UK, British Skin Foundation, Macular Society, Council for At-Risk Academics and Russian Federation. Industry studentships were provided by Unit partners (e.g., Qualicaps; Reckitt Benckiser). PhD funding was also provided for displaced international scholars (e.g., *Al Dalaty*, Council for At-Risk Academics).

The Welsh Government Academic Fellows Scheme provides initial support for clinicians to undertake research, placing them in a competitive position to obtain PhD funding (e.g., *Sanyaolu*, from the Wales Centre for Primary and Emergency Care Research Centre, obtained a HCRW

Doctoral Fellowship focused on antimicrobial resistance via this scheme). The Unit's current 231 externally funded studentships were complemented by 79 UOA3-funded studentships.

#### 2.4.2 PGR support

PGRs are allocated personal desk-space and a computer with printer access. They receive support from their PhD supervisors' research funds and can apply to School Research Committees for additional funding (e.g., for conferences and external training events), e.g., *Diani* (£689) for EMBL PhD Symposia, Heidelberg, Germany (2018); *Lamborne* (£1200) two-week visit to MRC Protein Phosphorylation Unit, Dundee (2019); *Ogle* (£1500) presentation International Society for Zinc Biology, Kyoto, Japan (2019). PGRs also obtained external funding for conference attendance (e.g., *Davies* and *Hodges*, Brocher Foundation Scholarships to travel to Geneva).

PhD students are supported to self-evaluate their training needs. While there is variation in training associated with different PhD schemes, Cardiff expects all PGR students to have six-monthly and annual monitoring meetings, including ongoing training needs analysis. Mock vivas are designed to ensure a successful outcome. Every PhD student benefits from a supervisory team which includes a designated main supervisor; many students also benefit from larger interdisciplinary research teams. Supervision is managed strategically across UOA3 to enhance interdisciplinarity and facilitate development of supervisory skills in junior staff (e.g., 18 current PGRs are jointly supervised across UOA3 disciplines). PGRs are also given a mentor, from outside the supervisory team, who provides guidance and pastoral care.

Annual PGR 'return to studies' workshops help identify challenges students might experience at different stages of their research. This is complemented by: involvement in research groups, journal clubs, seminars, quantitative and qualitative research methods training; UOA3 research strand events and ECR workshops linked to College research themes; URI and the Cardiff Institute of Tissue Engineering and Repair annual meetings; and cross-Wales networking through UOA3's HCRW Centres.

Students are encouraged to contribute to internal symposia and conference organisation (e.g., the RCBC Wales Community of Scholars meeting, and annual student-led *Speaking of Science* interdisciplinary event, with 15 UOA3 PGRs involved 2018-2019). Unit PGRs participate in the Unit's varied PPI and public engagement activities (**Section 4.3**), the University's heat of the Three Minute Thesis (3MT®) competition (*Lowthian* was shortlisted in 2020) and Cardiff's Doctoral Academy *Images of Research* event (*Williams* won in 2019).

Students' training needs are enhanced by our Doctoral Academy's extensive training programme (**REF5a**); topics include academic writing, thesis and viva preparation; public engagement and science communication; careers and employability; networking; wellbeing; resilience and mental health.

Our successful approach to supporting future generations of allied health professionals is further evidenced by over 90% of PhD students submitting within four years, our successful training of both fundamental and clinical/allied health professionals (e.g., **Section 2.3.5**) and the broader contributions UOA3 students make to the Unit's research outputs, impact and stakeholder engagement. Unit PGRs frequently win prizes (e.g., *Hodges* won paper of the day at the 2017 RCN International Nursing Research Conference in Oxford; *Moseley* won the RCN Wales Safeguarding Award 2018; *Pickering*, a poster prize from the Association of Paediatric Chartered Physiotherapists; *Nasser* first place in the UAE Senior Category Hatton Award; *Lowthian* the Advanced Quantitative Research Method Award from the ESRC Wales Doctoral Training Centre).

Cardiff's careers service ensures ongoing support for PGRs, and postdoctoral staff, enabling successful transition to careers in academia, industry, scientific writing, policy organisations, NGOs and the NHS (e.g., *Breger*, Project Manager (University of Paris) SMARTS-UP €21M PhD training consortium across 21 Paris Institutes; *Francies*, Senior Scientist Wellcome Sanger Institute Translational Cancer Genomics; *Gutteridge*, Senior Scientific Advisor (Biomarker Liaison) Q<sup>2</sup> Solutions; *Sim*, UK Government Intellectual Property Office).

### 3. Income, infrastructure and facilities

#### 3.1 RESEARCH SUPPORT, AWARDS AND INCOME

The Schools' DoRs, with HoSs, oversee delivery of UOA3's research and impact strategies, working via their Research Committees, with impact champions, Directors of PGR and UOA3's network of professional research facilitators (15 staff). This promotes Unit cohesion and collaboration, aligned to our strategic objectives (**Sections 1.2-1.3**). Grant application and impact best practice is shared across UOA3, with our interdisciplinary research strands providing access to a breadth of experienced academic and professional research support. This is further facilitated by funding initiatives, infrastructure and facilities, within UOA3 and across the University, and through partnership with external UK and international networks (**Section 4**).

This collaborative approach underpinned our **REF2021 delivery**, led by HoS and DoRs, supported by professional staff. A cohort of UOA3 staff reviewed outputs, all of whom undertook Cardiff's mandatory EDI training, aligned to the REF2021 Code of Practice. Impact case studies were identified in consultation with Schools, aimed at demonstrating impact aligned to our BSDT, RAMD and PCHS themes. Staff consultation and communication was embedded in all REF2021 processes, aligned to Cardiff's focus on inclusivity, transparency and consistency (**REF5a**).

As noted in **Section 2**, UOA3's constituent Schools use a variety of initiatives to help staff obtain grant funding, delivered with equity and transparency (e.g., **pitch-to-peer**; **mock interviews**; **School funding**; **research leave**; **workload allocations**). These are further complemented by:

- **promotion of internal and external funding opportunities**, e.g., *Sheeran's* successful Wellcome Trust ISSF Award with Engineering, IBM Power Vision and IT Meridian on machine learning for classification of patients' motor control based on smart phone videos;
- **peer-review grant processes, monthly grant writing surgeries and ECR mentoring from experienced academics**, e.g., *Allen* and CTR's pre-application support of *Strange*, when applying for her first independent grant on non-invasive prenatal testing (£247K, HCRW);
- **financial support, including development of partnerships with external stakeholders**, e.g., MRC Proximity to Discovery funding supported *E.Lane* and *Lelos'* (Biosciences) early-stage commercial work involving transplantation of hiPSC-derived patient cells in rodent models of Parkinson's disease, which led to a commercial project with Aspen Neuroscience (£360K, 2020-2021);
- **liaison with Cardiff's Research and Innovation Services around translation and commercialisation**, e.g., Knowledge Transfer Partnerships (KTP) support (**Section 3.3**), such as *O'Brien-Waddington's* project on novel implant surfaces using additive manufacturing with Renishaw (2016-2019, £212K, Innovate UK);
- **PPI activities and support for 'Lay Faculty' (see also Section 4.3)**, e.g., end-user involvement supported *Button's* development and evaluation of an online portal (TRAK) for patient self-management in knee injury rehabilitation, being developed for implementation in outpatient and virtual musculoskeletal physiotherapist services in Wales' Health Boards and six NHS England trusts (2015-2016 £55K, Health Foundation).

**UOA3's REF2021 research income was £99.2M:** £38.6M (aligned to BSDT); £13.4M (RAMD); £47.2M (PCHS), a total 131% greater than REF2014 (£42.9M), and a 67% increase in p.a. income (£14.2M versus £8.6M REF2014). Income per FTE grew by 25% (£714K).

Aligned to our strategic Aims 1-2 to realise greater interdisciplinary clinical research (**Section 1.2**), we saw a 4.5-fold increase in government and health-related agencies income (to £7.9M p.a.).

£142M of new grant awards were secured since REF2014 (versus £60M, REF2014): £60M (aligned to BSDT); £26M (RAMD); £55M (PCHS), with a concomitant increase in grant applications (value £325M). License income totalled £778K, with 19 new patent families granted. Benefits-in-kind were £1.4M (e.g., access to the Diamond Light Source National Synchrotron, **Section 4.1**).

### 3.2. INFRASTRUCTURE AND FACILITIES

UOA3 occupies ~32,000m<sup>2</sup> floor space, excluding clinical research facilities shared between NHS Wales and Cardiff University. Laboratory research is predominantly undertaken in buildings at Cardiff's Cathays campus, close to the city centre. Clinical and PCHS-aligned activities are facilitated by UOA3's Research Centres, located at the University Hospital of Wales and Velindre Cancer Centre (close to Cathays). Optometry hosts an **eye clinic**, providing access to patients for Cardiff's vision scientists. UOA3 researchers regularly utilise **Cardiff's Central Biotechnology Services** and **Advanced Research Computing@Cardiff** (ARCCA) facilities (REF5a). Access to infrastructure and resources for staff and students is equitable and transparent, taking into account EDI requirements. UOA3's dedicated technicians and facilities managers (16 staff in Optometry, Pharmacy and Dentistry) provide training and support.

#### 3.2.1 New infrastructure investments

Infrastructure investments since REF2014 included major Centres, coalescing Unit expertise around key methods (clinical trials) or research themes (drug discovery, musculoskeletal disorders, children and families, see **Section 1.1.1**). Smaller-scale equipment purchases or upgrades further enhanced research strengths and external collaborations.

#### A. Centre for Trials Research (CTR)

As noted in **Section 1.2.1**, the new CTR, comprising ~160 research and professional support staff, accelerated clinical trials collaboration. CTR's annual research awards (excluding core funding) average £6.29M, with 17.85FTE UOA3 CTR staff reflecting its central contributions to the Unit's research and impact. The 'PRINCESS trial (2015-2018 NIHR £2.2M, *Butler*) assessed whether daily probiotics in care home residents would reduce systemic antibiotic administration for acute infections and found no positive benefit. UOA3's strength in Health Services organisation and delivery underpinned PUMA (2014-2019; NIHR, £1.9M *Allen, Hood, C.Powell*), a multi-centre UK-wide mixed-methods intervention trial testing a novel early warning approach designed to identify hospitalised paediatric patients at risk of deterioration; this approach has now been adopted in Qatar.

*Busse's* innovative clinical trials in Huntington's Disease, in collaboration with academic physiotherapists (*Hamana, van Deursen*), changed international guidelines, supporting early referral to physiotherapy services [impact case]. They were supported by CTR's strong PPI (**Section 4.3**) and Cardiff's Huntington's Disease Centre (2019) and its HCRW-funded (£2.76M) **Brain Repair and Intracranial Neurotherapeutics Unit** (supporting interdisciplinary collaboration with Psychology).

CTR is a major partner in clinical oncology trials for the **Wales Cancer Research Centre (WCRC, HCRW, £10M 2015-2025, Director Chester, Medicine)**, many of which involve UOA3 researchers. UOA3's CTR-led cancer research awards amount to £25.2M, e.g., the NIHR trial CONSCOP2 (2019-2025 £2.2M; *Dolwani (Medicine), Daniel, Brain, Hood*) assessed new contrast-enhanced colonoscopy imaging for bowel cancer screening, whilst also utilising UOA3's epidemiological expertise (*Cannings-John*) to understand demographic and lifestyle factors influencing polyp incidence. WCRC also supports UOA3's drug discovery and palliative care programmes. As part of early-stage work on an anti-metastatic Bcl3 inhibitor (*Brancale, Westwell, Clarkson (Biosciences)*), WCRC funded development of a new patient xenograft model (2014-2019, £250K), complementing CTR's preparation for a first-in-class Phase 1 trial of the new agent. *Nelson* leads WCRC's 'Palliative and Supportive Care' and PPI work-packages; the latter supported a successful UKRI-ESRC award exploring COVID-19 impacts on health and health behaviours in relation to cancer (£690K, 2020, *Brain, Robling, Townson*).

#### B. Medicines Discovery Institute

The **Medicines Discovery Institute (MDI)**, involving Clinical Medicine, Biosciences and Pharmacy, was established in 2019 via Welsh Government's competitive Sêr Cymru scheme (£5M). This was matched by £7M Cardiff investment, including £5.5M for equipment/capital infrastructure (e.g., new medicinal chemistry facilities). The MDI significantly increases Cardiff drug discovery expertise, facilitating the move of drug candidates into clinical trials, and is key to

UOA3's future research plans (**Section 1.4**). *Gumbleton* and *Brancale* serve on the MDI Advisory Board.

Since 2019, the MDI has grown rapidly, now accommodating ~40 staff working on interdisciplinary drug discovery science. UOA3 ECR medicinal chemistry lecturer (*Pertusati*, **Section 2**) works with Waller-Evans (MDI, Biosciences) on glycosylation drug targets for lysosomal storage disorders, in a new research avenue designed to diversify early-career success in rare disease drug discovery (2017-2019, £263K, Cerecor Inc USA, *Pertusati*, *Brancale*). MDI further enabled *Aeschlimann*, Bax (MDI, Biosciences) and Buurma's (Chemistry) successful application for a new SwitchSENSE facility for analysis of biomolecular interactions in support of drug discovery activity (EPSRC, 2020-2022, £228K, starting 01/11/20). Further investment, via the University's Research Infrastructure Fund (RIF, **REF5a**), supported upgrade of Pharmacy's 500MHz NMR spectroscopy (£250K, 2017, *Westwell*). This enables delivery of high value external partnerships, exemplified by the £2M award with NuCana plc on anticancer ProTides [*Brancale*, impact case].

### C. Versus Arthritis Biomechanics and Bioengineering Centre of Excellence

**Cardiff's Versus Arthritis Centre** was renewed in 2016 (£2.2M). This interdisciplinary Centre hosts state-of-the-art research facilities, novel *in-vivo* models and clinical samples for bioengineering research (including 3,600 orthopaedic samples, facilitated by Cardiff's Biobank, **Section 3.3**). Involving Clinical Medicine, Engineering and UOA3 researchers, the Centre enables an interdisciplinary approach, e.g., *Mason's* work linking engineering and biology to investigate mechanical loading, pain and pathology in skeletal disease (NC3Rs; £100K, 2017), as well as projects with Novartis based on her patented research on glutamate receptor antagonists in protecting against inflammation in injury-induced arthritis. UOA3 staff play key leadership roles: *Sparkes* (Director, since 2018); *Aeschlimann*, *Dewitt*, *Mason* (Lead, WP1: Preclinical); *Al-Amri*, *Button*, *van Deursen* (Co-Leads, WP4: Lower Limb Rehabilitation); *Sheeran* (Lead, WP5: Spine Rehabilitation); *Birchall* (WP6: Bone Cements and Coatings). The Centre also supports interdisciplinary postdoctoral and PGR training (e.g., 17 PGRs since REF2014). Focused particularly on ECRs, the linked **Cardiff Institute for Tissue Engineering and Repair**, led by UOA3 (*Maillard*), provides bursaries and networking events designed to promote cross-University interdisciplinary collaboration on stem cell and tissue engineering research, aligned to joint and bone diseases, microbial infections in tissues, and rehabilitation.

A new Musculoskeletal Biomechanics Research Facility (£2.5M, 2015 Welsh Government, £2.5M Cardiff) enhanced the Centre's capacity to undertake human movement studies. Located in Engineering (Director, Holt, Engineering), this facility helps deliver innovative work on transformative technologies, e.g., *Button* (co-lead, Sensor Physiotherapy Intervention Research Group) and *Al-Amri's* (ECR clinical engineer) €10M Early Warning Wearable Device 'EWW'D' Interreg project (£320K Cardiff) applying virtual reality, machine learning, and wearable electronics for the remote monitoring of lower limb injuries. The Centre's Gait Real-time Analysis Interactive Lab (established 2012; Director, *van Deursen*) was enhanced by upgrade of its instrumented motion capture treadmill, equipped with mechanical sensing and virtual reality projection (2020 £82K, Sêr Cymru). This laboratory supported Bisson (Psychology), *van Deursen* and *Hannigan's* Phase II trial (2017-2019, £200K, Forces in Mind Trust) on memory desensitization and reconsolidation therapy in British military veterans experiencing treatment-resistant post-traumatic stress disorder.

### D. Enhanced Imaging Capacity

£2.92M was invested in UOA3's **imaging capacity**. Supporting *Castell* (ECR recruited 2014), University RIF funding (£120K) enabled the build of a bespoke **dynamic multi-colour single molecule TIRF-imaging system**. This facilitated further funding: (a) on novel bio-diagnostic platforms from the Sêr Cymru National Research Network in Advanced Engineering and Materials (2016-2018, £143K); (b) a £980K HORIZON2020 project with Barrow (Engineering, see **Section 3.3**); and (c) a key £5M EPSRC research network (CAPITALS, 2014-2019, led by Imperial College) where *Castell* is a collaborator. The TIRF-imaging platform also facilitated ECR *NL Thomas's* first independent grant on physiological ligands and hierarchical clustering of cardiac ryanodine receptors (British Heart Foundation, £223K, 2016-2020, with *Castell*).

Investment in UOA3's vision research (2017, RIF/ISSF, £287K) established a new **pre-clinical Optical Coherence Tomography** facility supporting successful grant awards: (a) combined retinal imaging and phenotypic characterisation of mouse retina and efficacy endpoints for studies on new therapies for optic atrophy (*Votruba*, £161K, Fight for Sight, Academy of Medical Sciences) and (b) agents against mitochondrial targets (*Brancale, Heard, Votruba*, 2017-2018; 2020-2021, National Eye Research Centre, £129K). RIF funding (£403K, matched MRC £220K) supported acquisition of a **volume electron microscope** (the only such facility in Wales); this enables study of cornea ultrastructure in unprecedented detail over large tissue volumes and supported two five-year MRC Programme Grants and three BBSRC Project Grants (*Meek, Quantock*, total £7.8M).

A **clinically approved Optical Coherence Tomography** imaging system (£88K; 2014; Innovate UK/EU Commission) was acquired by *Birchall* and *Coulman* to visualise *ex-vivo* and *in-vivo* human skin in their microneedle research. This technology was vital for their impact case on dimensions and morphology of puncture characteristics of pharmaceutical capsules. £1.8M of University investment in 2015 enhanced radiochemistry capability in Cardiff's **Positron Emission Tomography (PETIC)**, Director *Marshall*, with *Bradley*). This advanced UOA3's preclinical PET research, including development of synthetic radiochemical routes to F-18 nucleoside pro-nucleotides (*Westwell*) and acceleration of *in-vivo* biodistribution profiling of clinical stage anticancer ProTides (necessary for *Brancale*'s impact work).

### E. Population Health resources

The **National Centre for Population Health and Wellbeing Research**, involving Cardiff, Bangor and Swansea Universities (created 2018, £2.5M HCRW; UOA3 PIs, *Paranjothy, G.Moore, Robling*) facilitates delivery of large-scale epidemiological analyses to inform health improvements (30 studies to-date). This is complemented by HCRW funding for **HealthWise Wales** (HWW; established 2015, £2.5M, *Paranjothy, Hurt, Robling, Townson*). HWW is a flagship Welsh initiative supporting longitudinal population cohort studies on health and lifestyle factors through a database of research-ready patient and public participants (40,000+). For example, *Nelson* and Byrne's (2018) HWW-enabled study on 'Attitudes Towards Death and Dying' was presented to Welsh Government's 'End of Life Care' Board shaping future service provision and priorities for public education.

### 3.2.2 Interdisciplinary Centres and Institutes

#### A. Children's Social Care Research and Development Centre (CASCADE)

**CASCADE** was launched in 2014 (£2.5M, HCRW) and renewed in 2020-2025 (£2.4M). The Centre develops public health responses for children in need of protection, bringing together practitioners and policy makers from the children's social care sector. It is a leading UK Centre, with UOA3 researchers contributing through their expertise in randomised controlled trials, data-linkage and qualitative/mixed-method research. CASCADE secured over £10M in funding since REF2014, including the '*What Works Centre for Children's Social Care*' (£7M; 2017-2020, UK Government Department of Education). This Centre involves UOA3 researchers *G.Moore, Robling, Kemp*, alongside Forrester (Social Sciences), Evans, Scourfield (both Education). Other CASCADE projects, involving UOA3 staff include: (a) Family Recovery after Domestic Abuse (FRoDA): A feasibility trial and nested process evaluation of a group based psychoeducational intervention for children exposed to domestic violence and abuse (2020-2023, £272K, NIHR, *G.Moore*, Evans, Education); (b) Impact of local authority care on children's futures (2015-2021, £155K, ESRC, *G.Moore*); and (c) The restorative approaches veterans and family service project (2015-2021, £71K, from Tros Gynnal Plant, involving Williams (Social Sciences), Rees (Education), *Segrott*).

#### B. Centre for Development, Evaluation, Complexity and Implementation in Public Health Improvement (DECIPHer)

**DECIPHer** is a UKCRC Public Health Research Centre of Excellence. Established in 2009, DECIPHer received further funding in 2014-2019 (£4.5M) and 2020-2025 (£2.5M). UOA3 researchers fulfil key leadership roles, including *G.Moore* (Deputy Director); *Segrott* (PI: Family and Parenting-based Interventions) and *Robling* (PI: Population Health Trials). The Centre unites Cardiff's interdisciplinary public health expertise, providing evidence to policy makers via direct

working with the public. For example, the 'Building Blocks 2-6' trial (2014-2019, NIHR £860K *Cannings-John, Channon, Hood, Lugg-Widger, Robling, Sanders, Segrott*) was a collaboration between CTR, Healthcare Sciences midwifery researchers and DECIPHer. It used innovative clinical trial methodology to follow-up their prior work on the Family Nurse Partnership Programme, which involved specialist home visiting support for teenage mothers designed to promote child safety and development. At two to six years post-birth, while there was no observable benefit on maltreatment or maternal outcomes, benefits in school readiness and attainment at Key Stage 1 were evident. Research recommendations are being rolled out by the NHS in 2021, as part of the Family Nurse Partnership programme.

DECIPHer is one of the strategic drivers of UOA3's impact strategy, as evidenced by *Chestnutt's* dental public health impact case involving the 'Seal or Varnish' NIHR clinical trial, which resulted in improved child oral health in deprived communities, as well as *G.Moore's* impact on policy-making to protect children's health from tobacco and e-cigarettes. The latter was facilitated by one of UOA3's vital user networks, the School Health Research Network, involving 210 Welsh secondary schools, Welsh Government and Public Health Wales. DECIPHer was a key partner in Cardiff's new **£10M Wolfson Centre for Young People's Mental Health**, which built on our social science and biomedical research strengths in child development and mental health. DECIPHer, and the new Wolfson Centre, will be hosted in Cardiff's flagship **£56.5M Social Sciences Research Park (SPARK)**, opening Autumn 2021, **REF5a**). Research on children and young people is one of SPARK's strategic themes, providing a unique opportunity for UOA3 to grow its interdisciplinary research on children and families.

### C. Wales Centre for Primary and Emergency Care Research (PRIME)

UOA3's primary care research is strategically supported through **PRIME** (2015-2020 £5M; 2020-2025 £5M; HCRW), hosted in UOA3 (Director, *Edwards*, 17 UOA academics). PRIME is a multidisciplinary all-Wales network, generating the evidence base for change aligned to unmet policy and practice healthcare needs outside of the hospital setting. Six of eight PRIME work packages are led by Cardiff researchers, and like many of UOA3's Centres, PRIME has well-developed PPI networks (see **Section 4.3.1**), designed to actively facilitate outcomes of direct benefit for patients, e.g., *Joseph-Williams* and *Edwards* work on shared decision-making [impact case]. Further research examples include: a clinical decision support tool for primary care management of lower urinary tract symptoms in men (PRIMUS, NIHR £1.8M, 2017-2021; *Edwards, Hood, Joseph-Williams, Thomas-Jones*) and research on GP-Emergency Department models of patient care with the Involving People Network ('GP-ED' study NIHR, £1M, 2017-2022; *Edwards, Carson-Stevens*). PRIME is also now host to Welsh Government's £3M COVID-19 Evidence Centre (Director, *Edwards*, awarded post-REF2021 census date); this provides UOA3 researchers with a unique opportunity contribute to COVID-19 recovery in Wales, and the UK.

### D. University Research Institutes

UOA3 has strong collaborations with Cardiff URIs (e.g., **Neuroscience and Mental Health URI**, **Section 1.2.3**). Additionally, *D.Thomas* plays a senior leadership role in Cardiff's **Systems Immunity URI**, which facilitated his project (with *Hill, Ferguson*) on characterisation of novel polymer therapeutics to disrupt mucus and bacterial biofilms in cystic fibrosis and multi-drug resistant infection. Polymer candidates gained FDA orphan drug designation and entered Phase 2b trials during the REF2014 period (sponsored by AlgiPharma AS, with USA Cystic Fibrosis Foundation, \$11M, and European funding, €6M).

The interdisciplinary **Crime and Security URI** (£2M, *S.Moore*, Co-Director) undertakes research on police, security and defence, enabled by well-established partnering with local and national government, police, health, defence organisations. UOA3-led research included: ELASiC (2015-2018, ESRC, MRC and Alcohol Research UK £470K, *Farewell, Fone, S.Moore, Paranjothy*), a record-linked longitudinal study identifying pathways into, and impacts of, alcohol use on health and wellbeing. EDARA (2016-2019, NIHR £930K, *Allen, S.Moore, Sivarajasingham, Shepherd*) was a large mixed-method multicentre study, demonstrating the transformative potential of night time alcohol intoxication management services in reducing harm. These studies shaped new policies on violent crime [*Shepherd*, impact case] and excessive alcohol consumption [*S.Moore*, impact case].

### 3.3. CLINICAL, TRANSLATIONAL AND COMMERCIAL SUPPORT

Established in 2018 by £1.5M of Cardiff University investment (ongoing support £280K p.a.), the **Cardiff University Biobank** (CUB, Lead, *Stephens*) provides infrastructure, governance support and coordination for Welsh research involving human-derived samples. CUB can store up to 900,000 biological samples (e.g., blood, urine, tissue, saliva), procured for research under accredited quality management ISO standards. The facility supports Cardiff researchers and other research organisations that need high quality samples (e.g., CUB hosts the only Welsh cystic fibrosis bio-sample collection, jointly curated between Cardiff University and Cardiff and Vale University Health Board).

To further accelerate clinical research collaboration between Cardiff University and the Cardiff and Vale University Health Board, a new single research service, the **Joint Clinical Research Office**, was established. This supports human and patient research across both organisations and facilitates the patient-facing and clinical trials work of Cardiff clinical researchers. The Cardiff University Innovation Network (**REF5a**) also facilitates NHS and Cardiff collaboration, complemented by partnership funding initiatives, e.g., KTP's supported nine UOA3 projects since REF2014 (versus four, REF2014), including *Maillard's* work on antimicrobial wipes which improved international standards [impact case]. Cardiff's Commercial Development team also provided extensive support for UOA3 researchers in obtaining patents: 162 patents, from 10 patent families since REF2014 (e.g., *Stephens* (priority-date 2015) adult progenitor cells and wound healing of oral mucosa; *Gumbleton* (priority-date 2018) polymer nanoparticles for oral delivery of biologics).

Since REF2014, UOA3 researchers successfully secured £2M of internal funding for early-stage translational and commercial projects. Awards included: 3 ESRC Impact Accelerators (£36.2K); 17 MRC Confidence in Concept (£781K); 16 MRC Proximity to Discovery (£333K); 18 Wellcome Trust ISSF Translational Kickstart and Cross-Disciplinary projects (£900K). For example, Confidence in Concept funding between Dentistry and Pharmacy (2014-2015 £45K *Sloan, Maillard*) supported innovative work on liposomal delivery of antimicrobials for dental tissue repair, with Proximity to Discovery enabling *Castell's* (2017-2018, £24.6K) collaboration with an SME, OxSyBio, on 3D printing of tissue-like materials. Alongside investment in our new TIRF-imaging system platform (**Section 3.2.1D**), this laid the groundwork for *Castell* and Barrow's (Engineering) £980K HORIZON2020 FETPROACT programme on 'Artificial Cells with Distributed Cores to Decipher Protein Function'. An ISSF Cross-Disciplinary award (£63K), on novel drug-loaded contact lenses and mucoadhesive films for controlled delivery of medications into the cornea, led to BBSRC funding between Dentistry, Optometry and Healthcare Sciences (2019-2021, £871K. *Quantock, Heard, Whitaker*). *Button* and *Al-Amri's* EU Interreg project (**Section 3.2.1C**) was facilitated by an ISSF Cross-Disciplinary Award (£49K, to *Sparkes, Button, Chambers, Psychology*). ESRC Impact Accelerator funding (2017-2018 £19.8K *Courtenay*) supported a Delphi study to develop a competency framework for the optimal use of antibiotics. The competencies were endorsed by professional bodies (e.g., Royal College of Nursing) and identified as an educational resource in the UK Government's five-year national action plan 'Tackling antimicrobial resistance 2019–2024'.

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

Local, national and international collaborations, involving both academic and non-academic partners, facilitated meaningful contributions to society. Illustrated by impact examples in **Sections 1-3** and below, UOA3's contribution to the discipline is further complemented by innovative PPI, public engagement initiatives, and contributions to industry, charity and government.

#### 4.1 ACADEMIC PARTNERSHIPS

77% of REF2021 outputs were co-authored with academics external to Cardiff. 65% involved national collaborations, most commonly (177 outputs): UCL, Oxford, KCL, Imperial, Liverpool, Nottingham, Manchester, Cambridge, Swansea and GW4 (the latter 34 papers). International collaborations featured in 50% of REF2021 outputs. National and international collaborations, from over 285 separate academic institutes, include:

**Aligned to BSDT:** *AT.Jones'* work with Nottingham on polymer therapeutics and bioresponsive materials stimulated commercial interest (Astra Zeneca; 2016-2017; £142K) and was the first demonstration of 'Endocytic Profiling' in nanomedicine development. Enabled by investigator status at the NIHR Sheffield Biomedical Research Centre for Neurology, *Aeschlimann's* collaboration with Hadjivassiliou and Sanders led to a new diagnostic (ELISA) kit, being developed by German biotech company, Zedira. Porch (Engineering) and *L.Baillie* (with GW4 colleagues) collaborated with Microsemi Ltd. to develop a new hand-held, rapid point-of-care diagnostic for *Clostridium difficile* infection. Working with Huttner (Max Planck Institute of Molecular Cell Biology and Genetics, Dresden) *Newland* developed a novel ultrasoft hydrogel enabling live imaging of human brain tissue cultures. Using Cardiff's high-performance computing facility (ARCCA, REF5a), *Guggenheim's* collaboration with the Consortium for Refractive Error and Myopia (involving ~100 geneticists, biostatisticians and ophthalmologists from 15 countries) led to a genetic test for high myopia. This work is now being translated for patient benefit (Fight for Sight; £196K; 2020, awarded post-REF2021 census date).

**Aligned to RAMD:** With Liverpool, Exeter and the Karolinska Institute (Sweden), *Boote, Hayes, Meek, Regini*, undertook research elucidating the structure and light transparency of biosynthetic corneal implants at the Diamond Light Source National Synchrotron (£1.4M facilities award). *Quantock, Meek, Boote's* extensive Japanese collaborations delivered new protocols for introducing hiPSC-derived cells into eye-like tissues (enabled by BBSRC-funded Japan Partnering Award (2018-2022, £48K) and research exchanges, e.g., ECR *Harrington*, 2018, Osaka University). This work contributed to the MRC-funded Cross-linking Consortium and National Keratoconus e-Registry, currently developing a code of best surgical practice with the Royal College of Ophthalmologists. Dentistry's Regenerative Biology Group have strong international collaborations on technologies for regeneration of epidermal tissue (North Carolina, *Stephens*); neuronal injury (China Medical University, Shenyang, *Song*); and wound re-epithelialisation (QIMR Berghofer, Brisbane, *Moseley*). *Mason* actively contributed to international multidisciplinary expert groups with UK (e.g., Oxford), European (e.g., Lund) and North American (e.g., Duke) Universities. Including patient representatives, these led to new recommendations for the conduct of efficacy trials of treatment devices for osteoarthritis.

**Aligned to PCHS:** Tenovus Cancer Care and Welsh Government funding (£186K) supported *Brain's* collaboration with behavioural scientists and public health physicians at UCL, King's College London, City and Belfast HEIs, on early warning signs for breast, colorectal and lung cancer. UOA3 fellow *Thomas-Jones* (with academic GP Francis) co-designed a NIHR-funded multicentre randomised controlled trial (involving 96 GP surgeries) with primary care and dermatology researchers at Southampton, Bristol and Nottingham Universities. This study found no benefit of emollient bath additives in children with eczema informing care management. The **Wales Centre for Evidence Based Care (WCEBC)** and the **Specialist Unit for Review Evidence (SURE)** support systematic and literature reviews in public health, clinical practice and health services delivery. They also advance methodological innovation and provide consultancy and training. For example, SURE supported three systematic reviews as part of the PUMA study, which laid the foundations for a novel paediatric early warning improvement programme (**Section 3.2.1A**). **WCEBC** is also part of the Joanna Briggs Institute's (Australia) international network, spanning 34 countries. This supports local to international training (e.g., systematic review training in Malawi; Global Evidence Summit, South Africa, *N.Evans*). The WHO Collaborating Centre for Midwifery Development (Healthcare Sciences, *Hunter*) generates evidence for midwifery practice, and provides expert advice and technical consultancy across WHO's 194 member states (e.g., resilience within midwifery practice, with Auckland University of Technology; Australian midwife experiences of workplace culture, with University of Technology Sydney). *Lewis'* influential trial work on tuberculosis involved collaboration with Africa, China and South America, utilising contacting tracing, text messaging and medication monitors to improve treatment uptake.

Cardiff's international strategic partnerships (**REF5a**) supported *D.Williams'* collaboration with PGR Cavalcanti (Campinas, now Adjunct Professor, Federal University of Paraiba), on *Clostridium albicans* virulence in biofilms; Cardiff (*Farnell, Richmond*) and Leuven (Claes) research exchanges focused on biological influences on human facial morphology, including orofacial clefts. *Hall* leads the Phoenix Project, Cardiff's civic mission partnership with University of Namibia. Shortlisted for International Collaboration of the Year (THE, 2017), the Phoenix Project hosts 40 projects (from

reducing road deaths to water research) which aim to reduce poverty, promote health and support UN Sustainable Development Goals. *Hall's* translational work (MRC DPFS/PHIND; £1.1M; 2017) on anaesthesia, post-operative recovery, and road traffic accidents also involve collaboration with Italian (IMT School for Advanced Studies, Lucca), Canadian (University of British Columbia), US (Virginia Tech) and New Zealand (University of Auckland) researchers.

#### 4.2 CONTRIBUTIONS TO THE SUSTAINABILITY OF OUR DISCIPLINES

Highlighted contributions, from amongst many, include:

**Keynotes:** World Health Organisation INSPIRE conference; WHO Child Protection Hub; Prime Minister's Summit on Serious Violence (*Shepherd*); Penn Stem Cell and Regenerative Dentistry Conference, Pennsylvania (*Sloan*); Gordon Research Conference 'Transglutaminases in Human Disease Processes', Spain (*Aeschlimann*); RCN Research Society and BMA Sociology Group Annual Conference (*Allen*); Senedd Cymru/Welsh Assembly presentation on alcohol harm (*S.Moore*); Global Conference on Pharmaceuticals and Drug Delivery systems, Spain (*AT.Jones*).

**Conference leadership:** Chair, Association for Research in Vision and Ophthalmology (ARVO) (2014; *Meek*); Chair, Myopia: Behaviour and interventions, ARVO (2019; *Guggenheim*); Chair, British Society for Oral and Dental Research Conference (2015; *Lewis*); Chair, International Conference on Microneedles series (*Birchall*); Chair, Gordon Research Conference Transglutaminases in Human Disease Processes (2018, *Adamczyk*).

**Funding bodies:** Multiple HCRW and NIHR panels (*Allen, Busse, Chestnutt, A.Jones, Hannigan, Hood, Gillespie, Thomas-Jones*); Chair, Macular Society Research Committee; Guide Dogs Strategic Research Advisory Committee (*Margrain*); National Eye Research Centre (*Votruba*); Fight for Sight (*Morgan, Guggenheim*); BBSRC-Innovate UK (*Williams*); NC3Rs (*Sloan, Stephens*); Deputy Chair, Coeliac UK Research Awards Panel (*Aeschlimann*); Research Foundation Flanders (*van Deursen*); NIHR HS&DR Commissioning Board; Canadian Institute for Health Research; French National Institute for Cancer Research (*Allen*); MRC DPFS Expert Group (*Birchall*); Alcohol Research UK (*Segrott*); Breast Cancer Now Scientific Advisory Board; Academic Lead, CRUK International Cancer Benchmarking Partnership public awareness module (*Brain*); CRUK Clinical Expert Review Panel (*Hurt*); Health Research Board (Ireland, *Hood, Robling*).

**Editorships and editorial boards:** Journal of Psychiatric and Mental Health Nursing (*Hannigan*); Antiviral Chemistry and Chemotherapy (*Brancale*); Journal of Cardiovascular Pharmacology and Therapeutics (*Baxter*); Advanced Drug Delivery Reviews; International Journal of Nanomedicine (*Gumbleton*); JDR Clinical & Translational Research (*Chestnutt*); European Journal of Orthodontics (*Richmond*); Journal of Dental Research (*Aeschlimann*); Scientific Reports (*Ferguson*); PLoS One (*Boote*); Sociology of Health & Illness; Journal of Health Services Research and Policy (*Allen*).

**Honours:** Queen's Anniversary Prize (2017); Association of Optical Practitioners Lifetime Achievement Award (2015) (*Woodhouse*); David Rich Lecture Award (*Meek*); Institution of Engineering and Technology Innovation Award (*Margrain*); International Association for Dental Research William J Gies Prize (2019) (*Chestnutt*); MediWales Innovation Award (2018) (Dentistry, *Advanced Therapies Group*); RCN Wales Nurse of the Year Research Award (*Evans, Hannigan, Jones*); Fellow, Academy of Social Sciences (*Allen*); European Society for Paediatric Endocrinology Outstanding Clinician 2018 (*Gregory*); OBEs (2020, nursing research (*Kelly*); optometry (*Woodhouse*); CBE (2018, midwifery and education (*Hunter*)).

**Professional bodies:** Chair, Mental Health Nurse Academics UK (*Hannigan*); President, European Tissue Repair Society (*Stephens*); President, British Association for the Study of Community Dentistry (*Morgan*); Chair, UK Association of Clinical Oral Microbiologists (*Wilson*); Children's Diabetes & Endocrinology Clinical Studies Group, British Society for Paediatric Endocrinology & Diabetes (*Gregory*); Scientific Foundation Board, Royal College of General Practitioners (*F.Wood*); Fellowship, Royal College of General Practitioners; Specialty Lead for Primary Care Wales, NIHR (*Edwards*); Council, Royal College of Anaesthetists (*Hall*); General Optical Council Expert Advisor (*Margrain*); Past President, European Oncology Nursing Society (*Kelly*); Councillor, International Psoriasis Council (*Bundy*); Board of Directors, International

Society for Antiviral Research (*Brancale*); Secretary General, European Association for Vision and Eye Research (*Votruba*); President, European Society for Prevention Research (*Segrott*).

**Health and clinical excellence bodies:** Chair, NICE Nurse Prescribers Advisory Group (*Courtenay*); NIHR and HCRC Ophthalmology Speciality Lead (*Margrain, Votruba*); Royal College of Obstetricians and Gynaecologists Wellbeing for Women Scientific Committee (*Sanders*); NIHR Cancer and Nutrition Collaboration Group (*Hopkinson*); HCRW Lead for musculoskeletal disorders (*Button*); Expert Advisor, British National Formulary for Children (*Gregory*); Topic Expert, NICE Public Health Advisory Committee (*Segrott*); Co-lead, Global Network of WHO Collaborating Centres (*Hunter*); Scientific Advisor, NHS Education for Scotland; WHO Primary Care Expert Group; OECD Working Group for Patient-reported Safety Outcomes (*Carson-Stevens*); Temporary Advisor to WHO on vaccine delivery; British Pharmacopoeia Expert Advisory Group (*Birchall*); Expert Advisor, United Nations Policy Group on Whistleblowing in the Health Sector; United Nations Office on Drugs and Crime Experts Group (*A.Jones*).

**Government:** Public Health England's Academic Network; National Substance Misuse Non-Medical Prescribing Forum (*Courtenay*); Home Office Science Advisory Council; Advisory Board on Violence against Women and Girls, Welsh Government (*Shepherd*); Chair, Advisory Panel on Substance Misuse, Welsh Government (*S.Moore*); Chair, Dental Caries Prevention Working Group; Delivering Better Oral Health; Public Health England (*Chestnutt*); All Wales Senior Nurse Advisory Group for Mental Health and Mental Health Nurse Academics (*Evans, Hannigan*); Freedom to Speak Up/Raising Concerns Welsh Partnership Forum (*A.Jones*); Chair, National Advisory Board, Care and Social Services Inspectorate Wales (*Hall*); Consultant, US Centers for Disease Control and Prevention (*Shepherd*).

#### 4.3 PATIENTS AND THE PUBLIC

##### 4.3.1 Patient-Public Involvement (PPI)

As evidenced throughout our REF5b statement, PPI is an integral part of our research strategy, enabled by UOA3's Research Centres (**Section 3.2.1**) and project steering groups (e.g., UK Imaging Retinal Densitometry study), ensuring critical feedback from those at risk from, or experiencing, the illnesses we aim to prevent and treat. Examples include:

CTR's **Public Involvement and Engagement (PIE) Hub** provides oversight of CTR's PPI work and supports implementation of the National Standards for public involvement in research across CTR's studies. Since 2017, CTR provided 400 opportunities for public involvement, e.g., free online training for researchers on engaging with the public on 'data projects', co-produced with stakeholders and patients (centrictraining.org). PPI strategy in the Brain Repair and Intracranial Neurotherapeutics Unit is led by *E.Lane*, ensuring involvement of people with neurological disorders in all aspects of research (e.g., *Busse's* impact case).

PRIME's key PPI driver is **SUPER** (Service Users for Primary and Emergency care Research), involving 40 lay people from diverse backgrounds. DECIPHER's **ALPHA** network (Advice Leading to Public Health Advancement) involved 84 young people over the REF period, who supported 101 research studies. ALPHA, and DECIPHER's School Health Research Network (**Section 1.3.1**) informed UOA3 research on alcohol advertising, drug prevention, school-based health promotion, sexual health, and suicide and self-harm (e.g., *G.Moore*, impact case). PPI is further embedded in co-development of patient reported outcome measures (PROMs) designed to improve care, e.g., *Nelson's* PPI work with the Wales Cancer Research Centre enabled clinical testing of a simple and effective screening PROMs (ALERT-B) for detection of gastroenterological effects after prostate cancer radiotherapy (2014-2018, EAGLE trial, Prostate Cancer UK, £448K, *Nelson*, Staffurth, Medicine).

##### 4.3.2 Public understanding

UOA3 has an active public engagement portfolio, from educational activities, to theatrical workshops and other engagement events. Examples include:

**Pharmabees** is an award-winning (Guardian University Awards 2017 Sustainability Project) public engagement project (launched 2014) based on UOA3's research on the antimicrobial properties of honey (*L.Baillie*). Since REF2014, Pharmabees (via £750K from Cardiff Council, Wellcome

Trust, HEFCW, Waterloo Foundation) has established new pollinator-friendly wellbeing gardens in hospitals and bee-friendly community green spaces (e.g., ‘*Greening Cathays*’; ‘*Grangetown Community Gateway*’, the latter linked to Cardiff’s Transforming Communities initiative, **REF5a**). Pharmabees is also part of the **Trio Sci Cymru** project (£810K), a Welsh Government National Science Academy STEM initiative, e.g., UOA3 ECRs delivered Trio Sci Cymru activities to 1,500 key stage 3 pupils in underprivileged areas of South Wales.

The **Written in Sand not Stone** theatrical event (2020; *R.Lane, Hannigan*) stimulated dialogue between the public and mental health providers on psychiatric diagnosis. A film of the performance was shown at the Green Ribbon Arts Festival (sponsor, Mental Health Foundation). UOA3 researchers participate in **The Cardiff Science Festival**, held annually; in 2020, *Moses*, a postdoctoral researcher, delivered **Busting Bacteria for a Superstar Smile**, highlighting UOA3’s dental research, and attracting over 10,000 social media impressions. *E.Lane* and *Kidd* co-lead **Brain Games**, an annual interactive event introducing children aged 7-11 years to psychology and neuroscience research, hosted by the National Museum of Wales (3,670 participants, 2019).

**Science in Health Live!** is an annual UOA3-led event reaching 1,000 Welsh Year 12 pupils, offering hands-on opportunities to explore the science behind disease and therapeutic interventions. The **Urdd Youth Eisteddfod** and **National Eisteddfod of Wales** attract 150,000 visitors. *AT.Jones* is science lead for the National Eisteddfod Steering Committee; with 50 Cardiff staff and students, he led Eisteddfod exhibits **Science of the Sea** (2018, Cardiff) and **Pharmabees** (2019, Llanrwst).

#### 4.4 CONTRIBUTIONS TO THE ECONOMY AND SOCIETY

Augmenting our REF2021 impact cases (described **Sections 1-3**), research with industry created new and improved technologies, e.g., *J.Morgan*’s software innovation enabled early computer screen detection of optic nerve damage by stereoscopic digital microscopy review; this software is now incorporated into Japanese company Kowa’s latest stereoscopic software release. Cardiff-based SME, Cotton Mouton Diagnostics Ltd. (*Bowen*, founded 2015, £2.5M private equity/Innovate UK) uses magnetic nanorod technology in point-of-care diagnostics. A new product, ‘CMD-alphabet’ for sepsis, is scheduled for launch (early 2022) in the US, in partnership with a global corporate. New technology (MacuMap™), providing unique outer-retinal imaging for diagnosis of age-related macular degeneration, was developed with the UK Astronomy Technology Centre (NIHR/STFC (£1.5M), Cardiff £285K, *Margrain, A.Wood*). MacuMap™ is currently being used in a Phase II clinical trial of a new therapeutic agent (*Margrain, Votruba, A.Wood*, with CTR’s *Playle*, 2020-2023, AltRegen Co. Ltd £753K); this trial will also support device CE marking. Industrial advisory roles further enrich our collaborations, e.g., Consultant, L’Oréal Paris (2015-current) and Grupo AC Marca (2014-current) (*Maillard*); Chair (2017-current) Novo Nordisk UK Research Foundation Research Selection Committee (*Gregory*).

UOA3 leadership of the **Life Sciences Research Network Wales** (LSRNW; 2013-2020 Welsh Government Sêr Cymru £7.3M, *McGuigan, Brancale*) supported 150 projects in Wales, leveraging a further £33.7M investment, e.g., LSRNW funding (£12K) supported *Moseley*’s collaboration with QBiotics Ltd. (2016-2020, £545K) on a wound healing candidate now in clinical development for veterinary applications and preclinical development for humans. Led by UOA3, the **Celtic Advanced Life Science Innovation Network** (CALIN) is a six-HEI Ireland-Wales European Interreg consortium (2016-2023, €19M, Cardiff, £1.9M, *AT.Jones, Birchall, Bowen, Gumbleton, Watson* (Biosciences)). Via consortium-funded consultancies and workshops, CALIN supported 125 companies. A further 43 SMEs benefited from laboratory research projects, 10 of which involved Cardiff (e.g., Mikota Ltd.’s work on new collagen-based products for wound care, *AT.Jones, Watson*).

UOA3’s T&S, T&R and honorary clinical staff support collaborations with the healthcare sector (**Section 2.3.5**). Other mechanisms include HCRW’s Research for Patient and Public Benefit (RfPPB), facilitating joint working between Universities and the NHS on healthcare practice and services. The **All Wales Research Design and Conduct Service** within CTR (2015-2023, HCRW, £1.4M, *Robling, Hood, Channon*) supports RfPPB proposal development (for both NHS and HEI researchers), with over 510 researchers helped since 2015. *Hopkinson*’s RfPPB study (£230K, 2016-2018), with third sector organisations (e.g., Carers UK), focused on specialist home

treatment intervention for people with dementia in the community, designed to prevent hospital admission

Sheeran's BACK-on-LINE™ digital platform is used by public and private-sector employers (e.g., NHS, Transport for London) to help staff self-manage their back pain (2018-2020, £168K Department of Work and Pensions Health Challenge Fund). This research informed the parliamentary consultation, *'Health is everyone's business: Proposals to reduce ill health-related job loss'* (July 2019). Carson-Stevens and Edwards PISA study on patient safety incidents, involving primary care practitioners, set priorities for systems improvement, including safer GP anticoagulation services (subordinate legislation 2017 Health and Social Care Act; Wales '1000 Lives Plus' quality improvement campaign). This research also informed clinical professional development (e.g., e-learning resources guides, WHO Patient Safety and Royal College of General Practitioners).

**ACCELERATE** (£8.4M, 2018-2021; **Section 1.3.1**) aims to expedite adoption of NHS healthcare solutions and provides commercial and public enterprises with research and development expertise (e.g., business project management, health economists) and proof-of-concept funding. Al-Amri's funded (£66K) collaboration with Ambiquire Ltd. and NHS physiotherapists is enabling development of wearable remote movement sensor technology to guide rehabilitation in individuals with knee pain. Another ACCELERATE UOA3 project (Ryan, Acton, J.Morgan; £150K), working with Welsh Government and Cardiff and Vale University Health Board, developed a new service framework allowing registered High Street optometrists to manage high-risk eye patients (e.g., new glaucoma referrals, diabetic retinopathy); the longer-term objective is an All-Wales roll-out as part of the NHS Wales Transforming Eyecare Services (benefiting 115,000 at risk patients).

Hannigan and A.Jones' research on care planning in mental health services (2014-2016) informed recommendations in the Independent Review *'Modernising the Mental Health Act 2018'*, a precursor to the recently published (January 2021) consultation on *'Reforming the Mental Health Act'* legislation in England and Wales. UOA3 research enhancing health and social care organisations response to employees' concerns (Allen, A.Jones, Kelly, **Section 1.2.2**) was used as primary evidence by Welsh Government (via the 'Freedom to Speak Up/Raising Concerns Welsh Partnership Forum'). This informed the new NHS Wales 'Speak Up' Service (launching summer 2021) and the 2020 UN (Office on Drugs and Crime) and UK Government guidelines, *Protecting Whistleblowers in the Health Sector*.

M.Morgan's research on dental treatment needs in care home residents (£19K, 2015-2019, GlaxoSmithKline Consumer Healthcare) was used by NHS England to generate health needs assessments, informed NICE (2015) oral health guidelines and prompted Welsh Government action on oral health in care homes. Research on electronic medication administration systems (2018-21 KTP £219K; Smith (T&S), Gumbleton), with care homes, community pharmacies and health technology company (Invatech) informed professional policy (e.g., Royal Pharmaceutical Society Wales, *Improving Medicines Use for Care Home Residents*), and was endorsed by other key bodies (e.g., Older People's Commissioner for Wales). The research received the Health Service Journal Excellence UK award (2016) and is cited as the evidence base for the Welsh Government's Digital Medicines Management programme (2019).

#### 4.5 SUMMARY

Successful delivery of our REF2014 strategy ensures we remain well-placed to continue to address key societal challenges, deliver new health products and technologies, and more effective healthcare policies, practices and services. Our research and impact contributions to Wales and the UK have strengthened, while our new research strands enhanced interdisciplinary research, enriched by our extensive national and international collaborations. Our Research Centres enabled co-creation of research addressing patient and public needs; they ensure our research will continue to deliver meaningful benefit to society. REF2014 and planned infrastructure investments, in University Innovation Institutes, CTR, MDI and SPARK (**REF5a**), provide exciting future catalysts for our diverse research community to expand their research ambitions, with a focus on identified strategic priorities (**Section 1.4**): advanced therapies, drug discovery, biomedical engineering, children and families, and public and population health.