Institution: Cardiff University

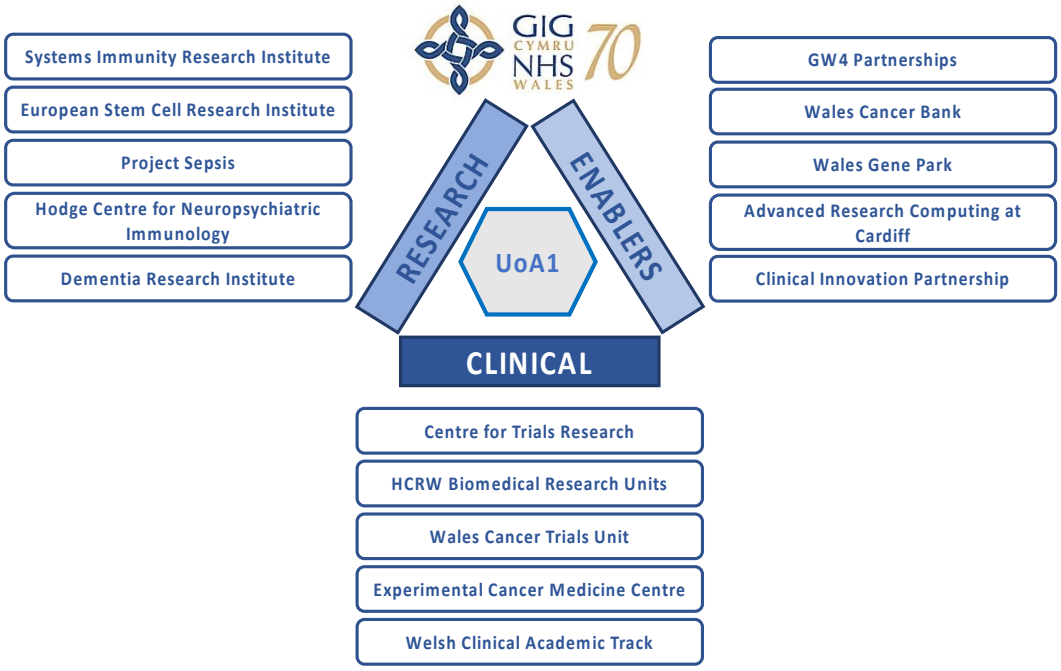
Unit of Assessment 1: Clinical Medicine

1. Unit context and structure, research and impact strategy

1.1. Context and structure

Cardiff University (CU) UOA1 staff reside within the **School of Medicine** (SoM), one of seven schools in the **College of Biomedical and Life Sciences** (CBLS). Prioritising support for discovery science, clinical translation and experimental medicine, UOA1 comprises research in cancer, immunology, infectious and immune-mediated diseases and genetic disorders. Initiatives introduced since REF2014 have catalysed the integration of computational methods in our research, fostering new interdisciplinary collaborations in precision medicine, neuroimmunology, immune-oncology, and neonatal infections.

Fig-1. *Infrastructures and enablers supporting our strategic priorities*



We work closely with the **Welsh Government**, **NHS Wales**, industrial partners and other stakeholders. University-led initiatives and inward investments from UKRI, the charitable sector, industry and international funding agencies have catalysed strategic investments in personnel, collaborations and enabling facilities and infrastructures (>£204M; **Fig-1**). These have energised our research environment, creating a multi-disciplinary identity for clinical research in Cardiff University that include collaborations with colleagues returned in UOA3, UOA4 and UOA5.

Examples include:

A. **UK Dementia Research Institute Centre** (2017; £23M with UOA4)
B. **Systems Immunity Research Institute** (2015; £4.5M)
C. **Hodge Centre in Neuropsychiatric Immunology** (2016; £1M with UOA4)
D. **Project Sepsis** (2018; £5.5M)
E. **Centre for Trials Research** (2015; £12.3M with UOA3)
F. **Medicine Discovery Institute** (2017; £14M with UOA4)
G. **Health & Care Research Wales** (HCRW; totalling £38.5M) funding NHS-linked resources

1.2. Delivery of research strategy from REF2014

Overarching strategic aims from REF2014 focussed on four key areas designed to strengthen interdisciplinary research within clinical medicine.

A. Increase research performance. Since REF2014, new initiatives have enhanced the scientific and career aspiration of our staff (**Section; S2**) and led to:

i. *Enhanced research productivity and quality.* We published 2,914 articles with a year-on-year increase in publication outputs since REF2014.

ii. *Increased competitiveness for extramural grant capture*. totalling £148.8 million since REF2014 (**S3**).

iii. *Recruitment of strategic academic appointments*. 24 new tenured appointments and an increase in REF returned staff (from 59.01 in REF2014 to 86.9 FTE).

iv. *Promotion of early-career researchers* (ECR). First academic appointments: 11; independent career fellowships: 5; initial early-stage career fellowship holders: 17 (**S2**).

v. *Increased matriculation of research students*. Sustainable postgraduate schemes have increased PGR numbers by >130 students (**S2**).

B. Enhance computational and mathematical expertise. Our submission includes 11 new appointments in bioinformatics, biostatistics or mathematics [All REF2021 outputs flagged as *interdisciplinary* in our submission showcase research with computational scientists] (**S3.2**). The **Systems Immunity Research Institute**, **Sêr Cymru Chair in Systems Medicine**, and **Wales Gene Park** (renewed; 2019) catalysed the use of computational methods in our clinically applied research. Membership of **ELIXIR UK**, which promotes best practices and analytical resources in bioinformatics, evidences our expertise in this area. Access to University supercomputing infrastructures (**ARCCA**; Advanced Research Computing@Cardiff, see REF5a), and **Supercomputing Wales** has provided bespoke training programmes for early career and postgraduate researchers (**MRC BioMed Doctoral Training Partnership**; **S2.4**) and accelerated international partnerships (e.g., Biomedicine Discovery Institute; Monash University, Australia).

C. Promote clinical translation and innovation. Cross-disciplinary research and training essential for clinical innovation and impact were prioritised through strategic investments. These included funding schemes *via* MRC and NIHR initiatives and dedicated support for all stages of translational research (**S3.3**). The SoM hosts a **Clinical Innovation Partnership** between CU and **Cardiff and Vale University Health Board** (CAVUHB) linking industry and the NHS. This partnership assisted over 170 projects, and in 2018 secured European Regional Development Funds (EDRF) to establish a Clinical Innovation Accelerator (**ACCELERATE**; totalling £24M with Trinity St. David's and Swansea University), providing development funding for novel clinical diagnostics. Our expertise in diagnostics is further evidenced by membership of a UKRI **Knowledge Transfer Network**, involving six other UK centres, and recognition as an Innovate UK **Centre of Excellence for Precision Medicine**. To foster links between academics, healthcare professionals and industry, CU and CAVUHB secured ownership of the **Cardiff MediCentre Business Incubator Facility** on the hospital campus (£3M; CU). The MediCentre currently houses twenty companies (e.g., Alesi Surgical, Q-Chip, Synexus Clinical Research) and provides the necessary infrastructure to support health research and co-production (**S3.3**).

D. Improve delivery for experimental medicine. Adhering to a '*patient pathway*' approach, we work with government agencies, academic institutions, healthcare professionals, industry and patient stakeholders to address societal challenges affecting the health and wellbeing of people (**S4**). Creation of the **Centre for Trials Research** (CTR) through the amalgamation of three UK registered Clinical Research Units has streamlined the delivery of clinical studies (**S3.4**). Enabling infrastructure funding from HCRW (£6.8M) and **Cancer Research UK** (CRUK; £5.5M) supports 161 members of staff offering professional services, data analysis, quality assurance and regulatory oversight. All clinical studies are conducted in partnership with the CAVUHB, and NHS Wales, and adhere to governance frameworks that guide clinical

trial design and the use of medical devices (**S3.5**). This framework enhanced the sustainability of our trial capability and resulted in an average of 32 new studies per year evaluating the prevention, diagnosis and treatment of diseases across the human lifespan.

1.3. Open research strategy and identification of societal impacts

Prioritising research addressing societal challenges affecting the health and wellbeing of people, our research strategy provides opportunities for all career stages (**S2**). Programmes introduced since REF2014 include enhanced support for grant development through a College of Experts comprising senior academics with relevant experience with major funders and initiatives designed for ECRs (**S2.5**, **S4.5**). Recognising the use of big data in clinical medicine we prioritised investments in people and resources to enable systems medicine approaches (**S2.3**, **S3**). This strategy secured external funding for new interdisciplinary initiatives, fostering several new areas of endeavour (e.g., neuroimmunology, neonatal infections).

To underpin our strategy, we endorsed policies and practices ensuring governance, ethics, and scientific integrity (**S3.5**), and embraced Open Science initiatives (e.g., the San Francisco Declaration on Research Assessment; DORA, see REF5a) that enhance our research impact (**S4.6**). These include submission of datasets to digital repositories (e.g., Gene Expression Omnibus), the preprint publication of articles in specialist archives (e.g., medRχiv) and our online library resource (**ORCA**). UOA1 researchers (*Clarke, Cooper, Fry, Sampson, O'Donnell*) also manage and curate open access resources (e.g., Human Gene Mutation Database) for practicing clinicians, patient groups and researchers. Recognising the importance of our research to society, we use staff development review processes (**S2**) to generate an overview of projects delivering societal or emerging societal impacts (31 projects were identified during this assessment period). Annual interactive workshops raised impact awareness and supported the early development of case studies including ways to articulate the impact of our research. These were open to all career stages and attracted 34 UOA1 staff in 2019.

Projects delivering impact were monitored by Local SoM Impact Champions, with support from the University's Research, Innovation & Enterprise Services (see REF5a). Requests for additional help in impact case development were reviewed at a monthly SoM REF committee (Female:10; Male:15). These included resources to gather health economic data, costs for open access charges for underpinning publications and dedicated administrative support for impact authors, many of whom perform extensive clinical duties.

The sections below highlight the key objectives prioritised for our research themes following REF2014. Descriptions evidence how each theme has met or exceeded these ambitions. Research delivering case studies in our submission are annotated **IMPACT CASE**.

1.4. Delivery of a research strategy for Cancer and Genetics

Research focuses on the prevention and early diagnosis of cancers, the discovery of new treatments, early-phase clinical trials of novel therapies, and advances in personalised interventions. With interests in haematological malignancies, solid tumours, and genomic medicine, researchers work with NHS Wales and the Wales Cancer Partnership and benefit from an overarching **CU Integrated Cancer Research** (CUICR) strategy. This initiative encourages interactions with commercial and third sector organisations and contributed to the **All-Wales Cancer Research Strategy** (CReST Cymru; 2019), which informs our continued strategic direction for cancer research.

Objectives for Cancer and Genetics

1. Align clinical and discovery science to enable interdisciplinary cancer research.
2. Enhance our research capabilities through closer integration of University and NHS infrastructures into an overarching organisation for cancer research.
3. Recruit and develop cognate groups to focus our research activity.
4. Enhance the infrastructure for translational research, including participation in major national and international programmes.

Achievements against the objectives for Cancer & Genetics

Inward investments from NIHR, MRC, CRUK, Marie Curie, Bloodwise, HCRW and other public and charitable funders support discovery research, clinical investigations, and studies in primary and community care. These activities are underpinned by strong infrastructures linking to the NHS and enabling facilities. Entities include the **Wales Cancer Research Centre** (*Canolfan Ymchwil Canser Cymru*; £7.5M), **CTR**, the **Marie Curie Palliative Care Centre** (£2.1M) (administered by UOA1; *Adams, Chester, Noble*) and the **PRIME Centre** prioritising the prevention and early diagnosis of cancers (linking to our UOA3 submission). These structures facilitate efficient patient care and therapy benefiting from major investments in the **Wales Research and Diagnostic PET Imaging Centre** (PETIC; £16.5M), and the **CU University Brain Imaging Centre** (CUBRIC; £44M, linking to our UOA4 submission) (**S3**).

The Wales Cancer Research Centre supports our research of **Haematological malignancies** (e.g., AML) [**IMPACT CASE**]. This centre nurture's interdisciplinary research involving nurses, clinical academics, pharmacists, pathologists and biomedical scientists from across Wales, employing 41 full and part-time staff members. Clinical trials benefit from the **Phase-1 Clinical Trials Unit** at Velindre Hospital, the NIHR **Experimental Cancer Medicine Centre** (Chester; >£1.5M), and the CRUK **Cancer Trials Unit** (renewed in 2018; *Adams*, £5.5M). These entities provide the necessary infrastructure to investigate molecular abnormalities associated with leukaemia and pre-leukaemia (*Baird, Darley, Fegan, Ruthardt, Tonks*) and the selection of drug candidates for fast-tracked testing in clinical trials (*Jones, R., Knapper, Ottmann*).

Researchers of **solid tumours** investigate the molecular and genetic basis of gastrointestinal, colorectal, breast, and urological cancers, and cancers of the head and neck (*Cheadle, Dolwani, Sampson*). These include studies of tumorigenesis, metastasis and tumour progression (*Clayton, Errington, Tabi*). Investments in enabling polyomic and imaging technologies support cancer research in UOA1. These include one of the most advanced PET imaging centres (PETIC) in the UK, which provides clinical assessments of cancers and brain disorders for the NHS, and novel imaging modalities for discovery research and innovative clinical trials (*Adams, Chester, Jones, R., Kynaston, Mason, Staffurth*). Collaboration with the **Rutherford Cancer Centre** (in Newport) also provides access to the UK's first high-energy proton beam therapy centre for cancer treatment (opened in 2019). These advanced technologies support the delivery of personalised care for patients with life-threatening cancers (*Barrett-Lee, Mason, Staffurth*) [**Objectives 1,2,4**].

Delivering societal benefits that impact the diagnosis of inherited disorders and cancer, colleagues in **medical genetics** contribute to the UK-wide CRUK **Stratified Cancer Medicine Programme**, and our facilities are a centralised Technology Hub for the genetic screening of cancer mutations. These include archiving genetic mutational datasets from patient cohorts involved in clinical trials and population studies. Examples include:

i. The 100,000 Genomes Project in Wales (*Sampson*)

ii. The Wales Cancer Bank (*Sampson, Mason*)

iii. The British Isles Rett Syndrome Survey (*Clarke*)

iv. International repositories dedicated to the monitoring of brain malformation (*Fry*), polyposis and gastrointestinal cancer syndromes (*Sampson*)

v. Annotation of disease-associated inherited genetic variation (Human Gene Mutation Database, *Cooper*). [**IMPACT CASE**].

Our research informed the implementation of the Welsh Government's £6.3M **Genomics for Precision Medicine Strategy** through leadership in translational genomics (**Wales Gene Park**; £6M, and MRC funded **100,000 Genomes Project in Wales**; £1M). The Wales Gene Park, providing essential infrastructures in next-generation sequencing and bioinformatics, deliver high quality genetic and genomic health research through the **NHS All Wales Medical Genomics Service**. [**Objectives 1,2**].

These resources have enabled pioneering advances in clinical innovation (**S3.3**). For example, assays for the study of global DNA repair (*Reed*), telomere assays in clinical diagnosis (*Baird*) and the use of oncolytic viruses in cancer therapy (*Parker*). Here, activities benefit from programme

awards from CRUK (*Baird, Parker*), grants from the BBSRC and National Institute of Health (USA), and leadership in cancer trials (*Adams, Chester, Mason*) with CRUK, MRC and international partners. [**Objectives 3,4**].

Our research has improved the standard of care for patients with rare diseases. In response to the **UK Strategy for Rare Diseases**, the Welsh Government outlined a plan, including £3.4M from the MRC and Welsh Government to establish the **Wales Genomic Medicine Centre**. This virtual centre links activities of the Wales Gene Park, the NHS All Wales Medical Genetics Service and expert academics across Wales supporting patients with rare diseases, their families, and the use of genomic data in healthcare. Working within the Welsh Implementation Plan for Rare Diseases, our researchers pioneered clinical advances in the treatment of tuberous sclerosis and mTOR signalling disorders (*Sampson, Tee*) [**IMPACT CASE**]. [**Objectives 2,4**].

1.5. Delivery of a research strategy for Infection, Immunology & Inflammation

UOA1 researchers investigate chronic diseases, persistent and resistant infections and mechanisms of immunity. Addressing global health challenges affecting both higher- and middle-low-income countries, we boast a broad research portfolio covering a diverse group of human diseases sharing common inflammatory or immune mechanisms. Founded on collaborations between discovery scientists and clinical academics, the theme received a strategic CU investment to establish the **Systems Immunity Research Institute** (£4.5M; 2015). This initiative transformed our research base, creating a bespoke, highly integrated platform delivering systems immunology and systems medicine research. Further international recruitment and collaborations involving the Wellcome Trust, Welsh Government, the EDRF, MRC and charitable benefactors increased our research capabilities and catalysed new partnerships in clinical neuroscience, psychiatry, and cancer.

Objectives for Infection, Immunology & Inflammation

1. Frame a distinctive identity for interdisciplinary research in Cardiff University.
2. Fully embed computational and mathematical expertise into our research framework.
3. Use genomics, lipidomics, metabolomics and proteomics to underpin discovery and translational science.
4. Build capacity in neuroimmunology, immune-oncology, viral infections, and multimorbidity.

Achievements against the objectives for Infection, Immunology & Inflammation

The Systems Immunity Research Institute attracted inward investments to support computational approaches. For example, the relocation of the **LIPID MAPS** gateway from UCSD to Cardiff University (co-hosted with the Babraham Institute, Cambridge) following the award of a **Wellcome Trust Biomedical Resources Grant** (£1.3M; *O'Donnell*), and the **Sêr Cymru Chair in Systems Medicine** (£5.5M; *Ghazal*) (**S3.2**). Capabilities in systems medicine benefit from a vibrant research partnership with the **Biomedicine Discovery Institute** at Monash University (led by *Rossjohn*). This university collaboration (established 2017) supported the integration of our in-house computational expertise with parallel resources in the Biomedicine Discovery Institute (e.g., Monash Bioinformatics Platform, the Medical Genomics Facility). This interaction led to staff exchange through a **Rutherford Fund Strategic Partner Grant** (Universities UK; £150K), and development of a joint PhD scheme between the Systems Immunity Research Institute and the Biomedicine Discovery Institute. Eleven co-authored outputs from the two institutions are evidenced in our submission. [**Objectives 1,2**].

Infection researchers investigate host-pathogen interactions, immune surveillance and the basis of anti-microbial resistance. Recognition of excellence includes two Wellcome Trust Investigator awards (*Price, Taylor*), a Wellcome Trust Senior Fellowship (*Humphreys*), and inward investments for viral immunology (*Humphreys, Ladell, Price, Stanton, Wang*), innate immunity (*Labeta, Raby, Taylor, Triantifilou*), the development of novel vaccines and diagnostics (*Stanton, Eberl, Humphreys, Parker*), and studies of antibiotic resistance (*Spiller, Toleman, Walsh*). These include national clinical trials of antibiotic therapy in premature babies (*Kotecha*; MRC, NIHR) and the monitoring of infections in mothers and infants in middle-lower income countries (*Walsh*–**BARNARDS**; Gates Foundation). We are also lead participants in the UKRI funded **COVID-19**

Immunology Consortium (*Gallimore, Humphreys, Morgan, Price, Stanton, Wang*) and employ computational methods to track sepsis in neonates (*Ghazal, O'Donnell*– **Project Sepsis**). [**Objectives 1,2,3**].

Immunology research includes studies of T-cell immunity (*Eberl, Jones, SA., Ladell, Moser, Price, Sewell*), autoimmunity (*Dayan, Wong*), cancer immunology (*Ager, Gallimore, Godkin, Martin, Sewell*), immune cell trafficking (*Ager, Moser*), and antigen recognition (*Rossjohn, Rizkallah, Sewell*). Evidence of excellence includes a renewed Wellcome Trust Investigator Award (*Sewell*), and leadership of a Wellcome Trust Collaborative Award with Imperial College London and the University of Reading to identify superior vaccines against infections and cancer (*Godkin, Gallimore*). [**Objectives 2,3,4**].

Investigators engaged in **inflammation** research explore the molecular and cellular basis of host immunity, tissue inflammation, and chronic disease progression. Funding supports research in cardiovascular disease, kidney disease, arthritis, diabetes, neuroinflammation, dermatological diseases and wounds. Research strengths include the complement system (*Morgan*), cytokine receptor biology (*Choy, Ghazal, Humphreys, Jones, SA.),* innate immunity (*Morgan, Taylor*), lipidomics, coagulation and immunometabolism (*Collins* [**IMPACT CASE**], *Ghazal, O'Donnell*). This group holds two Wellcome Trust Investigator Awards (*Martin, Taylor*), an ERC Advanced Grant (*O'Donnell*) and renewed programme grant funding from the British Heart Foundation (*O'Donnell*) and Versus Arthritis (*Jones, SA*). Support for neuroimmunology links our research to the **Neuroscience and Mental Health Research Institute** and the MRC **Centre of Neuropsychiatric Genomics and Genetics** (both UOA4). These interactions resulted in the **Hodge Centre of Neuropsychiatric Immunology** (£1M) and the award of our **UK Dementia Research Institute** (£23M), which investigates genetic traits of immune regulation that impact dementia (**S3.1**). Two immunology researchers hold UK-DRI programme grants (*Morgan, Taylor*; £3M). New staff recruitments in this area will continue to integrate neuroimmunology in our research portfolio [**Objectives 1,2,3,4**].

1.6. Delivery of a research strategy for Translational and Experimental Medicine.

As the largest academic group involved in clinical research in Wales, UOA1 colleagues work with NHS partners to deliver drug trials and complex interventions, cohort studies (e.g., the evaluation of disease mechanisms and treatments), and inquiries that inform policies and practice (**S3.4**). These include studies of solid and blood-borne cancers, infections and investigations in the young.

Objectives for Translational & Experimental Medicine.

1. Unite the management of clinical trials under one umbrella structure to maximise quality, reduce governance risk, and streamline procedural processes.
2. Align current clinical trial activity against our research strengths in the SoM and CBLS.
3. Enhance our study portfolio through increased numbers of UKCRN registered clinical trials.
4. Promote activities that encourage a broader integration of discovery science findings and methodologies into clinical trial design.

Achievements against the objectives for Translational and Experimental Medicine.

Creation of the CTR enhanced the sustainability of our clinical studies by maximising the use of existing data, improving trial efficiency and enabling innovative trial designs [**Objective 1,2**]. Examples include **AML18** (£2.64M) and **AML19** (£3.2M) (CRUK; *Adams*), the **FAKTION** (Astra Zeneca, CRUK; *Jones, R.*) trial of an aromatase inhibitor in postmenopausal women with breast cancer, the testing of cetuximab in oesophageal cancer (**SCOPE1** trial, CRUK; *Stafforth*), and interventions for prostate cancer (**ProtecT**, **Stampede**, CRUK, MRC; *Mason*) [**IMPACT CASE**]. Trials also benefit from multidisciplinary workings between basic, clinical and community-based researchers and include studies of under-researched conditions, e.g., in paediatrics, childhood health, and rare diseases (*Fry, Ingram, Kotecha, Sampson*). Examples include national trials of antibiotic therapy and lung function in premature babies (**AZTEC**; £2.1M, **RHiNO**; £1.45M; *Kotecha*) and the **THESUS** (£0.7M; NIHR Health Technology Assessment Programme; *Ingram*) trial of hidradenitis suppurativa management [**IMPACT CASE**]. [**Objective 2,3**].

Clinical impact arising from our pre-clinical research include immunotherapy interventions for type-1 diabetes (**MonoPepT1De** trial; *Dayan*), and a Phase II study, funded by the Experimental Cancer Medicine Centre (**TaCTiCC**; TroVax® and Cyclophosphamide Treatment in Colorectal Cancer), describing the first translational study in solid epithelial tumours to originate from our cancer immunology research (*Adams, Godkin, Gallimore, Jones, R.*).

Clinical research is enhanced by enabling infrastructures funded by HCRW and charities. These include links between the Wales Kidney Research Unit (led by *Fraser*) and the Kidney Research UK funded **National Unified Renal Translational Research Enterprise** (NURTuRE) in the University of Bristol. Through NURTuRE, UOA1 researchers are evaluating the basis of chronic kidney disease in 3,800 clinical samples (*Bowen, Fraser, Philips, Steadman, Meran*). We contribute to the **Type-1 Diabetes Immunotherapy Consortium** and the **INNODIA platform**, which advances clinical trials in adults and children with new-onset type-1 diabetes. We link with the **Diabetes Research Unit Wales** (Uned Ymchwil Diabetes Cymru) and SAIL (Secure Anonymised Information Linkage; Swansea University) to conduct immunology research within large scale epidemiological, genetic and data linkage studies (*Dayan, Taylor, Wong*). For example, the **INDUCE** study designed to inform antibiotic prescribing decisions for diabetic foot ulcer infections, the **EDDY** study implemented to enhance the early detection of type-1 diabetes in children and young people, and the **USTEKID** trial of biological drugs in type-1 diabetes and psoriasis (£0.85M NIHR EME Programme). Cohort studies are led through the **Early Arthritis Experimental Treatment Centre** (*Choy, Jones, SA*). This includes a six-centre UK consortium study (**MATURA**; led by Queen Mary University London) evaluating biological drug responses in rheumatoid arthritis (totalling >£5.5M; MRC and Versus Arthritis) and studies with industrial partners (e.g., Pfizer, Roche, NovImmune, Mestag Therapeutics). [**Objective 2,3,4**].

1.7. An integrated research and impact strategy for the next five years

We propose an ambitious programme to increase the delivery of transformative interventions relevant to the diagnosis, stratification and treatment of patients with chronic illness and related co-morbidities. Embracing interdisciplinary approaches, we will:

A. Enhance existing areas of excellence by prioritising activities that deliver impactful research for patients and the community. Specifically, we will:

i. Promote translational and reverse-translational research to identify mechanisms and potential new therapies relevant to pathologies that pose significant threats to global health in infectious and inflammatory diseases, cancer, mental health and associated multimorbidity.

ii. Synergise cross-disciplinary links between clinical and discovery science to catalyse improvements in health and care outcomes. We will focus on the causative links between chronic pathologies and multimorbidity to capitalise on new opportunities arising from our successes in psychoneuroimmunology, immuno-oncology and viral immunology.

iii. Align studies in population medicine with existing multi-disciplinary strengths in discovery research, clinical translation and precision medicine. Harnessing expertise in population medicine (*Adams, Ahmed, Dolwani, Wilheim-Benartzi, Noble*), we will increase engagement with HCRW infrastructures, SAIL, and **GW4 Alliance partners** in Bath, Bristol, and Exeter (e.g., ALSPAC, MRC Integrated Epidemiology Unit). We benefit from in-house resources (e.g., £1.4M; **HealthWise Wales**, *Dolwani*) including a new (December 2020) HCRW **COVID-19 Evidence Centre** (£3M in UOA3), evaluating the diagnosis, care and community-based procedures affecting patients with COVID-19.

iv. Enhance clinical impact and innovation *via* initiatives such as ACCELARATE, the **Joint CU/CAVUHB Research and Development Office** (Director; *Dayan*), and co-development of a new University Hospital of Wales campus (**S3.4**).

B. Foster academic-industry partnerships (exemplified by the Wales Cancer Partnership, ACCELERATE) to enhance clinical innovation and impact. CU recently purchased (£14M) a 10-acre plot of land adjacent to the university hospital campus. A planned redevelopment of the land is under review with the CAVUHB to provide new research, education and hospital facilities across the entire site. Benefitting from resources available through the UK

Government investment in the **Cardiff Capital Region City Deal** (£1.2bn), this initiative will harness essential expertise to advance the use of artificial intelligence in precision medicine.

C. Enhance the career opportunities of clinical and non-clinical ECR, postgraduate students and all colleagues involved in our team science research. Specifically, we will adopt equality, diversity and inclusion (EDI) initiatives to promote equity in career progression (**S2**).

D. Expand global networks and collaborations that enrich our research environment and are founded on existing working relationships. The links between the Systems Immunity Research Institute and the Monash Biomedicine Discovery Institute (Australia) exemplify this approach.

Increase stakeholder engagement with national and international government agencies, policymakers, charities, commercial partners, non-government organisations and public and patient insight groups (**S4**).

2. People

2.1. Promoting equality and diversity

CU offers a respectful and inclusive working environment for all (see REF5a). Adhering to these values, we adopt qualities and behaviours that extend beyond issues of gender and advocate support for staff irrespective of race, creed, disability, sexual orientation or socio-economic background. For example, we actively contributed to the formulation of the **BMA Racial Harassment Charter for Medical Schools**, and lead an all-Wales group, which ensures the dignity and wellbeing of BAME staff and students in higher education and during clinical placement. We continue to work closely with organisations including the BMA, Health Education and Improvement Wales and CAVUHB to embrace values that promote EDI amongst our staff and students.

2.2. Establishing a supportive workplace

The SoM promotes a positive working culture, supported by our **Athena SWAN Bronze Award** (2018, with plans to apply for Silver in 2021). Over 90% of staff and students believe the SoM provides a collegial and friendly workplace where people are valued and respected. A diverse, gender-balanced EDI committee (Chair; *Wong*) representing all career pathways oversee our SoM commitments to equal opportunities. New positive interventions include:

A. ***Cultural and attitudinal changes essential for sustainable gender equality***. These include:

i. Workshops for women (including mentoring circles), designed to increase awareness of, and confidence in applying for, the University's Personal Promotion scheme saw a 20% increase in successful applications. Moreover, senior female academics in UOA1 hold prominent leadership roles in the SoM (*Ager, Errington, Gallimore, O'Donnell, Williams, Wong*).

ii. The introduction of appropriately equipped family rooms for infant care and increased education around menopause in the workplace.

iii. Increased recognition of the challenges facing part-time staff (e.g., difficulties associated with caring commitments during the early morning, mid-afternoon and evenings). Directives ensure meetings are scheduled between 10:00 and 15:30 and are limited during school holidays (including half-term).

iv. New policies support EDI principles and commitment to a work-life balance. Application packs for all new appointments contain equal opportunity monitoring forms, with all vacancies considered for flexible working. We use gender decoding software in our recruitment advertisements and the composition of shortlisting and interview panels is always made with EDI in mind. Senior management and HR Advisors meet all new appointees to discuss the University's Positive Working Environment, which has gender equality and protected characteristics as core elements. These include signposting to

university networks (e.g., Black Minority Ethnic+; University Carers; Enfys LGBT+; disability & dyslexia support) (see REF5a).

v. To support colleagues with clinical commitments, all academic seminars are advertised two months in advance and scheduled between 12:00 and 15:00.

B. ***Establishing a caring society***. To safeguard mental health and individual wellbeing, we have introduced initiatives led by expert practitioners covering diet, physical activity, spirituality and mindfulness. The provision of wellness days during the COVID-19 pandemic helped reduce anxiety and unseen pressures from increased virtual communications. The importance of this approach was particularly evident following bereavement. During this REF cycle, we sadly lost two young colleagues. Their deaths had a significant and long-lasting impact on the research community. Staff counselling was offered and worked with the families to support memorial services and the naming of dedicated ECR and postgraduate awards.

Details of available programmes are accessible *via* the university intranet and tailored towards an individual's needs. For example, our ECR network offers a forum designed to share personal experiences and communicate the professional needs of ECR colleagues to senior management. These include HR guidance, grant opportunities, increased funder engagement, training, and career development schemes such as the MRC interactive career framework.

C. ***Adopting values that enhance EDI***. Adhering to national (Welsh Government, GMC, Academy of Medical Sciences, Royal Colleges, Right commissioners) and international (WHO, Nuremberg Code, Declaration of Helsinki) frameworks we have introduced practices to support flexible working and provide designated areas for prayer and quiet reflection. Additional schemes support postgraduate research (PGR) students with maternity, paternity and adoption leave, and staffing uncertainties arising through BREXIT. We are equally cognisant of the needs of staff returning from parental leave or other imposed absences and strive to ensure equity and enabling objectives in line with individual needs.

2.3. Staffing strategy and staff development

The SoM continually reviews University HR policies and procedures to ensure fairness and inclusivity. Adopting institutional Workload Modelling policies, we annually review workload allocations with staff and line managers to ensure transparency, consistency and fairness across all academic career pathways. Since REF2014 we have equally focussed on improving dignity in the workplace for those with protected characteristics (**S2.2**). All staff undertake mandatory online training in EDI and unconscious bias (2020, 80% of SoM staff had completed/renewed EDI training). Completion of these modules is essential for staff involved with recruitment panels, internal grant-awarding committees and membership of our SoM REF committee.

All research staff undertake an annual performance development review (see REF5a). Achievements based on publications, research funding, postgraduate supervision, teaching, leadership and management, and external peer esteem are reviewed with line managers to prioritise objectives and expectations for the following year. This ensures staff on T&R and R-only pathways have equitable allocations of time for research, grant development and appropriate recognition for managerial or citizenship activities (e.g., EDI, Impact, Innovation, and Engagement). This includes the identification of development courses that enhance research excellence, creativity and leadership. Courses are tailored towards all career stages and include the **Professorial Leadership Programme**, providing Professors with opportunities to influence the governance and strategic direction of the University.

Decisions on recruitment, retention and promotion are transparently adjudged using defined criteria. Adopting formal processes, applications are evaluated by a senior SoM review panel (female:5; male:5; including BAME:2) and transferred to the University's Academic Promotions Committee for external evaluation. Thus, ensuring the strategic fit with the research objectives of the School, support for research excellence and equity for all staff. Of the non-professorial staff returned as Lecturer or above in REF2014 (Female:9; Male:20), 86% have since been promoted to Senior Lecturer (Female:4; Male:0), Reader (Female:1; Male:5) or Professor (Female:4; Male:10).

Since REF2014, we prioritised new staff appointments (24 tenured positions including 13 ECR) in areas of emerging research excellence. To bolster our expertise in computational methods we appointed eleven new faculty (including five MPSS staff) with expertise in systems medicine (*Ghazal*), bioinformatics (*Angelopolous, Zhou*), biostatistics (*Watkins, Wilheim-Benartzi*), and mathematic modelling (*Szomolay*) (**S3.2**). We provided staff with opportunities to enhance our capabilities in clinical translation and innovation (e.g., ACCELERATE has invested in 26 research associates and 12 project management specialists, £3.1M). These include long-term secondments with external partners (e.g., **GSK Immunology Network** in Stevenage; *Triantafilou, K; Triantafilou, M*, and the Sanger Institute in Cambridge; *Humphreys*). Reciprocally, visiting scholars from Africa, Australasia, Europe, North America and South America further supported knowledge exchange (e.g., Rutherford Fund Strategic Partner Grant).

2.4. Postgraduate research training

The SoM delivers effective and sustainable doctoral training programmes. Currently, 170 (22 staff members) students are registered for higher degrees (152 PhD, 13 MD and five MPhil) in UOA1. Improvements in progress monitoring and academic mentoring transformed the overall experience with 97% student satisfaction with their supervision (2019 PGR student survey). Most PhD students are on three-year programmes, and on-time submission rates increased from 87% (REF2014) to 100% during this current REF cycle. We are increasingly investing in four-year programmes that build on existing schemes (e.g., Systems Immunity PhD Studentships provide advanced bioinformatics and computational training [totalling 12]).

New internal schemes and funding from external national and international programmes supported 226 PhD, 40 MD, and 14 MPhil students during the assessment period (see below). These increased UOA1 PGR numbers by more than 130 students (186% increase since REF2014) equating to 2.65 PGR students per academic FTE (greater than the Russell Group median of 1.56 for Clinical Medicine).

A. ***How we support non-clinical training.*** The SoM PGR Office oversees the recruitment, monitoring and assessment of our PGR programme, including:

i. Projects funded by UKRI, charity sector (e.g., British Heart Foundation), Welsh Government, NHS Wales, and university-led schemes.

ii. International programmes (e.g., Marie Sklodowska-Curie Actions schemes) currently support 14 students from across Europe and other parts of the world with the proportion of international students remaining consistent since REF2014 (8%).

iii. *MRC/GW4-BioMed Doctoral Training Partnership* (DTP)– in collaboration with the universities of Bath, Bristol and Exeter, we develop the next generation of medical researchers. Of the 76 studentships awarded to date, 15% were supervised by UOA1 staff.

iv. Industrial collaboration awards. Since REF2014, we saw a 40% increase in third sector studentships in science and engineering (three BBSRC) and European Social Funds (e.g., 10 Knowledge-Economy Skills Scholarships).

v. PhD allocations *via* an annual SoM studentship competition (typically six per year).

B. ***How we support clinical training.*** Training for the next generation of medical researchers and clinical academics is central to our UOA1 ethos. We host two clinical academic training programmes and support MD studies as follows:

i. *Welsh Clinical Academic Track* (WCAT). This programme equips clinical trainees to conduct translational research as independent investigators. Fellows study through a supernumerary lectureship programme. This framework provides a three-year PhD training scheme, dedicated research time (20%), and mentoring through to the completion of competency-based accreditation. The Unit hosted 19 WCAT fellows during this REF cycle (from 51 awarded in all medical disciplines across Wales).

ii. *Wellcome Trust GW4-Clinical Academic Training* (GW4-CAT). Supporting early-career medical, veterinary and dental graduates this programme provides multidisciplinary PhD training in population health, cardiovascular sciences, neuroscience, mental health,

infection, immunity and repair, cancer and molecular cell biology. A three-year fully funded PhD period is followed by intensive post-PhD support and mentoring towards intermediate/senior fellowships and career academic posts. Nine of twenty studentships are supervised by UOA1 staff.

iii. The General Practice Specialty Training Programmes support GP training towards the MRCGP exam (60 trainees/year).

iv. New processes improve the experience of our MD students. These allowed increased enrolment (maintaining a 100% completion rate) from 23 to 49 MD students.

C. ***How we encourage the next generation of researchers.*** We prioritise the training of next-generation clinical and non-clinical scientists through intensive mentoring from the earliest opportunity. Our Medical Students engage with programmes designed to promote research-led teaching and case-based learning. These include laboratory-based taster days, extended placements, intercalation programmes, and initiatives endorsed by the Academy of Medical Sciences and the Wellcome Trust (e.g., INSPIRE). We also benefit from the **CU Research Opportunities Programme** (CUROP). This University-led initiative funds summer placements and provides a practical laboratory experience for motivated undergraduates from across the University. Through these programmes, we sponsored 248 students during this REF cycle. We also hosted 238 student placements through an active ERASMUS programme and provided additional short-term research secondments for 155 international students and fellows from other countries.

2.5. Creating opportunities for ECR

We embrace a culture of fellowship mentoring and encourage a community spirit that creates career opportunities for ECRs (**S2.3**). These include restrictions on teaching allocation that may impinge research productivity and access to dedicated resources and structures for BAME staff led by the Deputy Vice-Chancellor. In UOA1 ECRs have access to institutional programmes that provide courses on research management, scientific integrity, personal development and leadership (see REF5a). The **Cardiff Researcher Programme** provides tailored training opportunities for all university ECRs and includes schemes run *via* the **CU Research Staff Association** and **Cardiff Futures** (see REF5a). Many of our ECRs also engage with external organisations, societies (e.g., British Immunology Society) and charities (e.g., Versus Arthritis, Kidney Research UK). They benefitted from career programmes spearheaded by the Academy of Medical Science (e.g., Springboard), and the Welsh Crucible; an award-winning initiative (Times Higher Education Awards, 2013) designed to nurture the future research leaders of Wales (**S4**).

The SoM has a respected and long-standing track record of supporting the careers of ECRs. In a report provided by the MRC Training and Career Group (11/2012) our ECR policies and practices were highlighted as an example of good practice and were used to inform recommendations to universities on the employment of fellows. Building on these successes we enhanced peer review and interview preparations for all ECRs applying for fellowships or similar (e.g., MRC New Investigator Research Grants). We use a College of Experts comprising senior researchers (n=49 in SoM; 13 external) who hold either major awards or serve on grant-awarding panels (**S4.5**). Particular attention was given to schemes that support the early transition of post-doctoral researchers to fellowship programmes (e.g., Sir Henry Wellcome Post-Doctoral Fellowship, BBSRC Discovery Fellowship, MRC Skills Fellowship, Versus Arthritis Clinical Training Fellowship, HCRW Fellowships) (n=17; female:8; male:9). Recognising the wider career opportunities available to our ECRs, we encourage post-doctoral fellows to participate in extramural development programmes. These include teaching accreditations (e.g., Advance HE; Associate Fellows) and funding for training secondments (**S2.3**). We have invited external speakers to talk about their careers in higher education management, scientific journalism (e.g., editors from *Nature Immunology*, *Nature Reviews Immunology*), funding agencies (e.g., programme managers from MRC, Versus Arthritis), and industry (e.g., GSK, IMEC).

A. ***How we promote ECR development.*** UOA1 ECRs access institutional programmes that enhance skills and awareness in research management, scientific integrity and leadership.

i. *Early Career Fellowship Support*. The University runs a six-month programme twice a year offering workshops and peer review interactive training for ECRs with the potential to secure external funding (e.g., Future Leader Fellowship scheme). Activities include grant writing, peer review networks, and interview preparations.

ii. *Institutional Strategic Support Fund* (ISSF). UOA1 has benefitted significantly from our third cycle of Wellcome Trust ISSF funding (2016-2021; £7M). This initiative significantly invests in ECR training and funding (The SoM secured almost 60% of the allocated awards) (see REF5a).

iii. *Future Leaders in Cancer Research* (FLiCR). Established in 2016, this initiative invested £50,000 to support our most promising cancer researchers *via* dedicated CU bequests (*West*, *Zabkiewicz*).

iv. *The Hodge Centre for Neuropsychiatric Immunology*. Funding fellowships, concept development and the appointment of a Lecturer in Neuropsychiatric Immunology, the Centre supports cross-disciplinary projects designed to train scientists versed in neuroscience and immunology.

v. *Systems Immunity Research Institute*. Embedded faculty with expertise in bioinformatics, biostatistics and mathematical modelling support ECRs wishing to develop advanced computational skills in systems biology and precision medicine.

B. ***Portfolio of ECR awards.*** UOA1 researchers include 19 ECRs on senior, intermediate or introductory level fellowships. We supported the transition of a further 10 ECRs to internal academic appointments. These are summarised as follows:

i. *Fellowship awards*–including awards from the Wellcome Trust (Senior Fellowship, two Sir Henry Dale Fellowships, Sir Henry Wellcome Postdoctoral Fellowship and Springboard Award), MRC (Career Development Award, Clinician Scientist Fellowship, MRC Skills Fellowship), NIHR (two NIHR Doctoral Fellowships), Versus Arthritis (Career Development Fellowship, Clinical Training Fellowship), BBSRC (Discovery Fellowship), Kidney Research UK (two Career Development Fellowships), Prostate Cancer UK and HCRW.

ii. *Internal appointments*– we appointed nine ECRs to tenured academic (Female:3; Male:3; *Humphreys, McLaren, Raby, Watkins, West, Zabkiewicz*) or clinical academic (Female:1; Male:2; *Ahmed, Meran, Ingram*) positions during this assessment period.

iii. *Awards for early-stage academic staff*– includes to two MRC New Investigator Research Grants (*Stanton, Bonnet*) and a Wellcome Trust Springboard Award (*McLaren*).

2.6. How we sustain staff development in prioritised areas

Newly introduced initiatives support people in areas of strategic importance or research excellence. Recognising the demographic of our research base we prioritise investment in young investigators and early-stage academics (**S2.4**; **S2.5**). This is evidenced by the career progression of ECR (holding early or intermediate level fellowships) reported in our REF2014 submission. Of the 18 ECR included in our UOA1 return, 10 have since acquired senior fellowships, moved to full-time academic appointments (either in Cardiff or elsewhere– e.g., Bristol, Belfast, Newcastle, Swansea), or secured full time employment in industry or higher-level university administration. Thus, our research environment offers a vibrant and dynamic workplace to nurture the next generation of researchers. Moving forward we will adopt the following mechanisms to sustain and promote staff development:

A. Our centres of excellence, biomedical research units and institutions will provide development awards to encourage interdisciplinary research (e.g., studentships, small project grants), staff mobility and knowledge exchange.

B. Investments in computational infrastructure (e.g., ARCCA, Supercomputing Wales) and dedicated strategic appointments (administered by the SoM) will furnish our capabilities in systems medicine and digital health (**S3.2**). These enablers will provide UOA1 faculty with the platforms to respond to specific funding calls including doctoral training programmes (e.g., Wellcome Trust, Marie Curie).

C. Encourage closer engagement with our European and International support office to enhance researcher success in European and global initiatives. Since REF2014, the SoM saw a 164% increase in EU funding and includes UKRI/HEFCW GCRF and Newton awards (**S3.1**).

D. Use our new research facilities and infrastructures to drive community-building activities including roadshows, and workshops. This approach is reflected by the numbers attending organised annual symposia. For example, attendance at the annual Infection and Immunity meeting grew from 113 to 248 delegates over the last five years. Such activities have led to more formal research entities such as the Hodge Centre for Neuropsychiatric Immunology, CUICR and a virtual grouping with interests in optical imaging; **Vivat Scientia**.

E. Work with our Development and Alumni Relations team to prioritise philanthropic investments in people. Current examples include the Hodge Centre for Neuropsychiatric Immunology (£1M; supporting fellowships and PhD studentships), the Wales Heart Research Institute (£600K; supporting two new academic appointments), and funding dedicated to Cancer Immunology (£800K) and Arthritis (£100K; supporting PhD studentships).

F. University travel scholarships and bursaries will support students and post-doctoral fellows working in clinical medicine, e.g., the Cardiff Institute for Tissue Engineering and Repair Young Investigator Award, and bequest awards (ranging from £200-£5,000) including the Michael Banfill Scholarship, the William Morgan Thomas Fund, the Davey Fund and the Tom Owen Memorial fund. Other university-specific travel scholarships foster collaborations with strategic partner institutions– including formal university partnerships (e.g., KU Leuven) and CBLS-led or project-specific interactions (e.g., Monash, Boston University) (**S4.1**).

3. Income, infrastructure and facilities

3.1. Research income and enabling structures

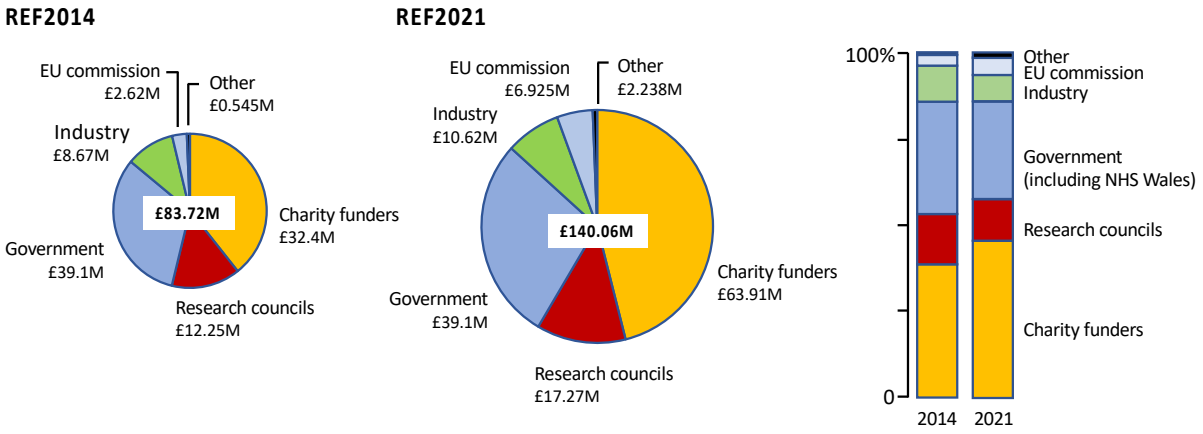
Our research income showcases a rich portfolio of awards from various sources. Staff benefit from technologies, infrastructures and facilities that catalyse discovery science, clinical translation and innovation, and experimental medicine. All UOA1 researchers have access to a dedicated administrative team in the SoM research office. Comprising project managers, grant coordinators and data analysts, this team works closely with applicants and the senior school management to develop bids, review performance and identify strategic priorities. This approach:

A. *Enhanced research income per FTE*– we prioritised support for grant preparation, mentoring and rigorous peer review utilising colleagues with experience of serving on external grant panels or successes with major funders (**S4**).

B. *Created a balanced portfolio of funding*– our research includes awards from research councils, UK charities, overseas development funds, NHS, and partnerships with industry.

C. *Fostered cogent research teams with the best possibility of success*– we have identified opportunities for new funding and worked with colleagues within the wider university and beyond to co-develop applications.

Fig-2. *Comparison of grant income attributed to UOA1 in REF2014 and REF2021*



During this REF cycle, we saw a 68% increase in research income (REF2014: £83.7M; REF2021: £140.1M) from research councils, industry, and overseas sources (see **Fig-2**). Our average research income now equates to £1.6M per FTE. These include 51 awards valued at over £1M from across the Unit. Our current grant portfolio shows funding commitments through to 2027 (totalling £8.4M in projected income). Here, the value of grants commenced in 2019 (before COVID-19) totals £51.8M and equates to 163 active awards.

New facilities and infrastructures enrich our environment and catalyse interdisciplinary research in neonatal sepsis, dementia, psychological disorders, autoimmunity, infectious diseases, and cancer. Successes include the Sêr Cymru Chair in Systems Medicine (£5.5M; *Ghazal*), four Wellcome Trust Investigator Awards (*Martin, Price, Sewell, Taylor*), three Wellcome Trust Collaboration Awards, and an ERC Advanced Grant (*O'Donnell*). We also hosted ten programme grants from the UKRI (*Morgan, Taylor*) or charity sector (e.g., CRUK, Versus Arthritis, British Heart Foundation; *Baird, Gallimore, Godkin, Jones, SA., O'Donnell, Parker*).

Investments in computational resources through the Systems Immunity Research Institute and Wales Gene Park enhanced the external perception of our research and increased grant capture. A £4.5M university investment in the Systems Immunity Research Institute generated an extra £56.7M in grant income, with 319 researchers in CBLS now interested in collaborative research involving immunology, infection or inflammation.

Initiatives including the Hodge Centre of Neuropsychiatric Immunology (£1M) and the HCRW **Brain Repair and Intracranial Neurotherapeutics Unit** (£2.76M), enhanced our research in neuroimmunology (**S1.5**). As part of a national MRC-led initiative (totalling £290M) into the causes of dementia, we are major participants in the Cardiff Dementia Research Institute (£23M; *Morgan, Taylor*). The Dementia Research Institute comprises a £3M laboratory refurbishment (winning a 2019 S-Lab award from the UK Science Park Association), providing a flexible working environment for laboratory and computational research.

UOA1 researchers in cancer and autoimmunity benefit from PET Imaging (PETIC; £16.5M), state-of-the-art MRI facilities (CUBRIC £44M), and proton beam technologies (Rutherford Cancer Centre) (*Ager, Barrett-Lee, Chester, Choy, Staffurth*) (**S1.4**). Established with a £16.5M award from the Welsh Government, PETIC provides routine clinical positron emission tomography for patients in Wales with various forms of cancers and brain disorders. PETIC links with the NHS oncology services in the Velindre Cancer Centre and offers advanced medical PET-CT imaging (£1.8M upgrade; 2017). Working with the Rutherford Cancer Centre, we use the latest IBA ProteusONE machine (£10M; Welsh Government). This unique resource will support our future oncology research and is the first high-energy proton beam therapy centre in the UK.

The sections below describe how our infrastructures and facilities support the priorities identified in **S1.2**.

3.2. How we have enhanced our computational capabilities

UOA1 researchers benefit from Cardiff's high-performance computing, specifically ARCCA and Supercomputing Wales (Welsh European Funding Office; £5.65M). Our new high-performance Hawk supercomputer (an HPE Apollo 9000 system; 2019) is one of the most powerful supercomputers in UK Higher Education. ARCCA provides a bespoke infrastructure for research of disease mechanisms and patients with complex diseases (e.g., virtual research computing, data archiving, and data visualisation). This resource allows detailed analysis of next-generation sequencing, lipidomic, metabolomic and proteomic datasets.

We are members of ELIXIR UK (comprising 15 other UK universities). This EU-led initiative manages, and safeguards data generated through the open science framework and unites Europe's leading life science organisations. Led by the Systems Immunity Research Institute, ELIXIR enables users in academia and industry to access services vital to their research. Here, we manage the LIPID MAPS gateway (an accredited £1.3M ELIXIR resource funded by the Wellcome Trust; *O'Donnell*) and curate the Human Gene Mutation Database (*Cooper*; **IMPACT CASE**) with Qiagen (**S4.6**). Working with colleagues in our UOA5 submission, we also contribute to the MRC **Cloud Infrastructure for Microbial Bioinformatics** (£7.6M) platform. This partnership with Warwick, Birmingham, Swansea, Bath and Leicester universities, and the

Quadram Institute provides free cloud-based computing, storage and analysis tools for academic microbiologists across the UK (e.g., UK-COG; COVID-19 Genomics UK Consortium).

UOA1 researchers contributed to the development of the Genomics for Precision Medicine Strategy (£6.3M). This Welsh Government initiative underpins our genomics research conducted *via* the Wales Gene Park (£6M; HCRW). Hosted by the SoM, the Wales Gene Park collaborates with the All-Wales Medical Genomics Service to conduct clinical studies of genetic disorders (e.g., MRC 100,000 Genomes Project in Wales, £1M). Working with ARCCA, the All-Wales Medical Genomics Service established a new computational facility (**WREN**) for clinical diagnosis in Wales. With a capacity to support future advances in sequencing technologies and changes in clinical need, WREN will facilitate new research involving the SoM and NHS Wales.

3.3. How our infrastructures and facilities catalyse clinical innovation

Delivering clinical innovations (**S1.2**) impacting patient diagnosis and treatment we are an Innovate UK Centre of Excellence for Precision Medicine and member of a related UKRI led Knowledge Transfer Network comprising Belfast, Cardiff, Glasgow, Leeds, Manchester and Oxford universities. Several new initiatives enhance the societal and economic reach of our UOA1 research:

A. The **Clinical Innovation Partnership** quadrupled early-stage funding for clinical translation (totalling >£10.4M). **Confidence in Concept** and **Proximity to Discovery** schemes (>£2M since 2014) and NIHR **Invention for Innovation awards** promote co-production between clinicians, healthcare professionals, researchers and the commercial sector. Awards supported the development of novel therapies (e.g., Immunocore), diagnostic tools (e.g., Mologic Ltd), medication monitoring systems (e.g., Diabetes Care Technology Ltd) and pre-clinical and early clinical evaluation studies (*Bowen, Eberl, Hughes, Weeks, Williams*). Examples of innovations arising from our research include:

i. TeloNostiX, a spin-out from CU, pioneered development of a Single-TElomere Length Analysis (STELA) assay for cancer patients. This technology has prognostic utility in various solid, and haematological malignancies. Two robust patent filings underpin this technology, and a high-throughput version of the test is in commercial development following inward investments from Innovate UK and CRUK (*Baird*).

ii. 3D-DIP-Chip is a genomic assay designed to screen the genetic safety profile of novel therapies (e.g., HDAC inhibitors). The technology was commercialised with Agilent Technologies and several pharmaceutical companies (e.g., GSK, Unilever, Astra Zeneca)adopted the platform in their drug development programmes (*Reed*).

B. The ACCELERATE initiative (Lead: Weeks; £8.4M Cardiff) was established in 2018 (S1.2). This initiative supports 34 projects involving collaborations with >70 commercial enterprises, four with CAVUHB, Velindre Cancer Centre and various schools in Cardiff University (e.g., Architecture, Dentistry, Engineering, Healthcare Sciences and Pharmacy).

C. In 2017, CU secured ownership of the **Cardiff Medicentre business incubator facility** on the University Hospital of Wales campus (£3M). To foster collaboration and co-production we established an advisory **Clinical Innovation Multidisciplinary team** to review project development. Since its inception, 11 companies hosted by the MediCentre grew to the point of relocation or acquisition. Combined acquisitions total >£30M and the centre is currently home to >20 biotech companies.

D. Translational virology research has benefitted from an embedded Cat-3 laboratory in the SoM, which allows the study of physiological models relevant to pathogen control, disease and immunity. This unit remains the only Cat-3 barrier facility in Wales and supports the **Public Health Wales** response to the COVID-19 pandemic (**S4.2**).

3.4. How we streamline translational and experimental research

Access to larger initiatives equivalent to NIHR support for clinical research (e.g., through NIHR Biomedical Research Centres) is more limited in Wales. UOA1 researchers have, however, secured infrastructure funds to enable experimental medicine research. These entities foster

collaborations between clinical specialities and our discovery scientists to generate societal impacts. Notable examples include:

A. Laboratory and clinical research into the causes of pathology and the basis of multimorbidity in chronic disease benefit from several entities. These include HCRW biomedical research units (>£16M), the Early Arthritis Experimental Treatment Centre (£0.8M) and the Centre for Biomechanics and Bioengineering (£2M; with colleagues in UOA3, UOA5, UOA12) funded by Versus Arthritis and the Wales Heart Research Institute. In cancer, investments in the Wales Cancer Research Centre and the Experimental Cancer Medicine Centre facilitated £28.2M in additional grant income and fostered collaborations with AstraZeneca, Bristol Myers Squibb, Novartis and Leo Pharma.

B. The CTR enhanced delivery and governance of clinical studies including evaluations of interventions, diagnostics and medical devices (**S3.5**). Awards generated through the CTR annually exceeds £13.5M. In the past three years, the CTR conducted 96 clinical studies. The average value of each award is £789K (54% of this income comes to CU).

C. Strengthening partnerships with NHS Wales by establishing a Joint Research Office with the CAVUHB. With an integrated team of staff overseeing arrangements for researchers' contractual status, research governance and ethics, funding and financial governance, this office streamlines procedures affecting clinical research (£0.75M; led by *Dayan*). Key infrastructure partnerships include the Advanced Therapy Treatment Centre (Innovate UK), shared clinical research facilities and portfolio studies. CU and the CAVUHB jointly host the first in Wales **Paediatric Clinical Research Facility** (2017). *Ghazal* holds an honorary contract with the NHS through this initiative to promote studies of neonatal sepsis. A 12-bed **clinical research facility** located adjacent to our cancer and immunology research laboratories supports trials in cancer, infectious diseases and immune-mediated conditions. These include therapies pioneered by UOA1 researchers (e.g., novel immunotherapies for cancer and autoimmune diseases such as type-1 diabetes and psoriasis, *Godkin, Dayan, Ingram*).

D. Our precision medicine research benefits from interdisciplinary investments in health informatics (e.g., NHS Digital), data repositories, biostatistics, and pharmacy. For example, the Wales Kidney Research Unit (*Uned Cymru I Ymchwil yr Arennau*) connects world-leading nephrology research to patients, practicing clinicians and NHS services (£2.45M; HCRW). The Wales Kidney Research Unit is hosted by the Systems Immunity Research Institute and supports the clinical evaluation of kidney disease and linked health informatics in the SAIL Database in Swansea (*Fraser, Meran, Philips*).

E. The **CU Biobank**. This purpose-built ISO9001:2015 accredited facility (opened; 2019) can archive 900,000 biological samples (£1.5M investment in build costs and equipment). Working with CAVUHB, the facility provides essential infrastructures for the linkage and coordination of human samples for research purposes. The repository currently hosts eight pre-existing biobanks (e.g., Wales Cancer Bank, Wales Kidney Research Tissue Bank).

F. Our translational research further benefits from joint and honorary appointments between NHS Wales, Public Health Wales and CU (**S4.3**).

3.5. Policies and practices underpinning research governance

CU and CAVUHB provide a single integrated academic and NHS review procedure for the ethical evaluation and approval of clinical and non-clinical research. Clinical studies adhere to strict rules and regulations that safeguard researchers and patients and ensures both research excellence and data integrity. These include adherence to national and international directives for clinical trials (2001/20/EC), the use of medical devices (93/42/EEC), frameworks for health and social care research, clinical trial ethics and the use of medicines in patients. All SoM research involving human samples is overseen by our Human Tissue Act Compliance team and conducted under a Hub Research Licence (No. 12422).

Staff in UOA1 adhere to a strict Research Integrity and Governance Code of Practice (see REF5a), which ensures all research is delivered safely, responsibly, and to expected standards (**S1.3**). Adhering to the principles outlined by DORA, our processes promote best practices in research

assessment and reproducibility. These include:

A. Development of standardised bioinformatic pipelines and data archiving for polyomic datasets (e.g., ELIXIR).

B. A more streamlined evaluation and monitoring of clinical research.

C. UOA1 researchers benefit from **Central Biotechnology Services**, providing an accredited (ISO9001 and 17025) facility for biomedical technologies. This includes training in advanced technology methods (e.g., next-generation sequencing, mass spectrometry, microscopy, flow cytometry, data visualization).

D. Opportunities for all staff to attend advanced training courses (e.g., Wellcome Genome Campus Advanced Courses, EMBO courses and workshops).

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

UOA1 researchers promote patient-centred care through clinical and non-clinical collaborations, impactful interactions with NHS colleagues, and industry. Extramural activities within the Unit enhanced the delivery of societal and economic benefits arising from our research. For example, the Dermatology Life Quality Index (DLQI) is internationally recognised as the gold standard criteria for the evaluation of dermatological conditions (licence revenues are £3.5M for this REF period) [**IMPACT CASE**].

Eight HCRW biomedical units jointly funded with Welsh Government support the clinical impact and reach of our research in infection, cancer, mental health and chronic diseases. The SoM leads five of these entities (Wales Cancer Research Centre, National Institute for Mental Health, Wales Centre for Primary and Emergency Care Research, Wales Kidney Research Unit, Brain Repair and Intracranial Neurotherapeutics Unit) and we play active roles in the others (Centre for Ageing and Dementia Research, Diabetes Research Unit Cymru, National Centre for Population Health and Wellbeing Research). These structures facilitate interactions with NHS Wales and foster closer working with healthcare professionals, patients and families.

Our discovery research displays significant potential to advance clinical medicine. In cancer immunology, our pioneering research of conventional T-cells opened the prospect of a 'universal' therapy for various cancer types (led by *Sewell*). Our environment benefits from close ties with NHS facilities and infrastructures, including our research of cutting-edge treatments e.g., proton beam technologies (*Staffurth, Barrett-Lee*), immunotherapies (*Gallimore, Godkin, Ladell, Sewell, Price, Rossjohn*) and profiling of rare (*Cooper, Dolwani, Sampson, Tee*) and infectious (*Eberl, Labeta, Stanton, Walsh*) diseases. Project Sepsis is an example of this synergy. Applying computational methods to the study of lipids, metabolism and functional genomics, Project Sepsis links with the NHS paediatric clinical facility and intensive care units to develop new interventions for sepsis (*Ghazal, Kotecha, McLaren, O'Donnell*). We continue to encourage NHS links *via* our new research entities in neuro-immunology, diagnostics and precision medicine.

4.1. Collaborations with Higher Education Institutions

A. **International.** CU has strategic partnerships with key international academic institutions (see REF5a). Our international collaborations further extend beyond these relationships, evidenced by co-authored publications, student exchanges, honorary appointments (e.g., *Morgan*; Spinoza Professorship, universities of Amsterdam and Utrecht, *O'Donnell*; University of the Republic of Montevideo, *Spiller*; University of Western Australia) and sustainability through shared renewable research grants and European consortia awards (£32.9M; equating to a 52% increase in funding since REF2014). Key exemplars include an **ERC Advanced Grant** (£2.29M; *O'Donnell*), fellowships through the Marie Sklodowska-Curie Actions schemes, various clinical consortia (e.g., £5.84M AML-related trials; *Adams*) and our partnership with Monash University. Additional examples include:

i. Membership of three Marie Curie Initial Training Networks. Led by Amsterdam (**EuTRiPD**), KU Leuven (**ArthritisHeal**; strategic university partner) and Barcelona (**DOCTIS Consortium**), these training programmes drive research into causes of immune-mediated diseases through broad-based collaborations with clinicians, academics and industrial partners.

ii. Researchers in UOA1 benefit from international partnerships with leading Chinese medical research institutions– Peking University (Honorary appointment; *Jiang*), Capital Medical University, Sun Yat-sen University and Yiling. This initiative supported a successful **MRC New Investigator Research Grant** (*Bonnet*).

iii. Our international collaborations extend beyond traditional boundaries of research-led partnerships and showcase projects designed to alleviate poverty and promote health in lower-income countries. Examples include **BARNARDS** and the **Phoenix Project** (two Times Higher Education Awards in 2017) with the University of Namibia. BARNARDS (Bill and Melinda Gates Foundation; £3.6M) assesses the negative impact of antibiotic resistance on neonatal morbidity and mortality in Bangladesh, Ethiopia, India, Nigeria, Abuja, Pakistan, Rwanda and South Africa (*Spiller, Toleman, Walsh*).

B. National. Partnerships with other UK universities include interdisciplinary programmes supported by the MRC (e.g., the Dementia Research Institute, *Morgan, Taylor*; MATURA, *Choy*), CRUK and EU sponsored stratified medicine programmes, Wellcome Trust Collaborative Awards (*Godkin, Humphreys, Morgan, Stanton*), the COVID-19 Immunology Consortium (Leads: *Gallimore, Humphreys*) and resources such as ELIXIR and CLIMB. Working with GW4 Alliance partners further enhanced the breadth of research delivered by UOA1. This initiative nurtures complementary research between our institutions and an initial investment of £2.8M in 87 collaborative GW4 communities generated £35.8M in research income (2019 data). Programmes relevant to our UOA1 submission include:

i. Wellcome Trust GW4-CAT. (**S2.4**).

ii. MRC/GW4-BioMed DTP. The programme funding 54 postgraduate students over three years (£3.3M MRC; £1.3M GW4) (**S2.4**).

iii. Shared facilities and infrastructures. These include the GW4 facility for high-resolution cryo-microscopy (Bristol) and shared functional imaging resources (e.g., multi-photon microscopy in Bristol; micro-PET/CT and MRI in Cardiff).

iv. The GW4 Crucible attracts 30 competitively selected future research leaders and provides opportunities to enhance career development.

4.2. Industry engagement

We engage with industrial partners involved in the development of clinical diagnostics, drugs and clinical devices (**S3.3**). These include:

A. Joint appointments and secondments with the pharmaceutical sector (e.g., GSK Immunology Network, *Triantafilou, K; Triantafilou, M*).

B. Training schemes (e.g., BBSRC Case awards, European Social Funds) (**S2.4**; **S4.1**).

C. Working partnerships through initiatives (e.g., ACCELERATE).

Industrial partnerships underpin research affecting the diagnosis, stratification and treatment of patients. These range from large pharmaceutical companies (e.g., Ferring Pharmaceuticals, Genentech, GSK, Janssen, MedImmune, Novartis, Pfizer, Qiagen, Roche, UCB) to smaller biotech organisations (e.g., Mestag Therapeutics, NovImmune SA, BioVitrum, Viropharma) and manufacturing CROs (e.g., Biovian, Finland, Lonza, UK). Our links include participations on industry-led advisory boards overseeing the development of new therapies targeting complement (e.g., GSK, Alexion Pharmaceuticals), cytokines (e.g., Chugai, EUSA Pharmaceuticals, Janssen, Roche, Sanofi-Regeneron), lipid mediators (e.g., Gilead Sciences) and immune signalling pathways (NovImmune SA, Pfizer) (*Choy, Jones, SA., Morgan, O'Donnell*). Our advisory involvements with the pharmaceutical sector informed the testing of biological drugs in COVID-19 (e.g., eculizumab, siltuximab, tocilizumab), and were significant in recommending eculizumab for patient care. We also worked with industry to test novel devices (Creo Medical) and preventative interventions designed to reduce COVID-19 transmission (Venture Life) using our Cat-3 containment facility (*Humphreys, O'Donnell, Stanton, Weeks*).

We work with industrial partners to advance technologies arising from our research (**S3.3**). Novel diagnostics for infectious diseases and cancers (*Baird, Bowen, Eberl, Kynaston, Labeta, Weeks*),

methodologies used in drug development programmes (*Reed*) and the curation of genetic mutations (*Cooper*) benefitted from collaborations with Agilent Technologies, Astra Zeneca, GSK, Mologic Ltd., Unilever and Qiagen.

4.3. Linking with CAT-C staff

The SoM hosts 124 CAT-C staff (female:53; male:71) and includes five Visiting Research Fellowships. These appointments provide access to library resources, research infrastructure and laboratory space for the completion of specific projects.

Those engaged in longer-term projects are appointed Honorary Research Associates (n=25), Honorary Research Fellows (n=21), Honorary Senior Research Fellows (n=21) or Honorary Distinguished Fellows (n=2). Appointees typically hold a three-year tenure and applications are reviewed and evaluated by a SoM committee (Female:4; Male:2). Individuals making substantive contributions to our research environment receive Honorary Visiting Professor (n=5), Honorary Distinguished Professor (n=2) or Honorary Professor (n=10) titles. For example, Professors Stephen Jolles (Consultant Immunologist, University Hospital of Wales) and Matthew Wise (Consultant Intensive Care Specialist) play leading roles in our COVID-19 research and clinical investigations of rare genetic disorders and infectious disease. Other examples of how our honorary staff engage with UOA1 researchers include:

A. Provision of training and mentoring for early-stage clinical academics. For example, collaborations between UOA1 staff and CAT-C appointments support the supervision and delivery of WCAT, GW4-CAT, and MD training schemes.

B. Clinical studies involving patient recruitment, clinical trial design, implementation and management, and sample collections from patients. These include co-authored publications, grant initiatives (e.g., UK-COG, 100,000 Genomes Project in Wales) and involvements in 80% of the impact case studies in our UOA1 submission.

C. Support for clinical facilities and infrastructures (e.g., HCRW resource units, the Experimental Cancer Medicine Centre), the administration of tissue and samples deposited in registered biobanks (e.g., Wales Cancer Bank), NHS diagnostic facilities (e.g., NHS All Wales Medical Genomics Service) and initiatives administered through our joint research and development office with CAVUHB (£0.75M investment).

D. Strengthening visible links between university colleagues and clinicians or health care professionals working within the community (e.g., HealthWise Wales).

E. Enhancing collaborative links with international university partners (e.g., joint supervision of PhD students).

F. Continued engagement of former University staff re-located to other institutions. These appointments ensure the completion of outstanding projects and continued supervision of ongoing students and staff.

4.4. Scientific recognitions

UOA1 staff participate in international advisory boards, academic societies, and have received recognition for their research. These enhanced staff profiles have improved our engagement with government, stakeholders and other decision-making entities. Examples include:

A. Professional service staff participation on the Athena Swan National Review Committee.

B. PhD students and ECRs received prestigious training fellowships or conference awards for their research (e.g., the British Society of Immunology, the International Cytokine and Interferon Society, British Society of Haematology, the UK CLL Forum, Keystone Symposia). Indeed, several now hold key roles in professional societies ranging from career advice, conference organisation, and PhD or ECR representation groups.

C. Senior roles in academic societies (e.g., British Society of Immunology [*Ager*; Chair of Forum, 2018, *Eberl*; Trustee], British Society for Gene and Therapy [*Parker*; Chair, Early Career Development and Collaboration Committee], International Cytokine & Interferon Society [*Jones, SA*; Development Committee; Meeting Committee], International Complement

Society [*Morgan*; Past President], UK Cell Adhesion Society [*Ager*; Past President]).

D. Clarivate Analytics identified one of our staff as among the world's most highly cited immunologists (*Rossjohn*). Publications by three of our researchers (*Humphreys, Moser, Sewell*) were in the top-10 most downloaded citations in *The Journal of Immunology* for 2018 and 2019.

E. Various honours and recognitions (e.g., Order of the British Empire [OBE, *Mason, Walsh, Weeks*; MBE, *Jiang*], Royal Society Wolfson Research Merit Awards [*O'Donnell, Walsh*], Fellow of the Royal Society of Biology [*Jones, SA, O'Donnell, Price*], Dorothy Hodgkin Lecture [Diabetes Research UK; *Wong*], Honorary Society Memberships [*Finlay*; former staff], National Clinical Bronze Award [*Adams*]).

F. Increased numbers of staff received fellowships from learned societies (e.g., Member of the Academia Europaea [*Morgan*; 2016, *O'Donnell*; 2020, *Piquet*; former staff 2017], Fellow of the Academy of Medical Science [*Ghazal*; 2015, *O'Donnell*; 2020, *Rossjohn*; 2017], Fellow of the Academy of Medical Educators [*Ingram*; 2014], Fellow of the Learned Society of Wales [*O'Donnell*; 2015, *Price, Rossjohn*, *Wilkinson;* former staff, all 2016, *Jones, SA, Mason, Moser, Wong, Weeks*; all 2019, *Sampson*; 2020], Fellow of the Royal College of Physicians [*Ingram*; 2017], Principle Fellow of Advance HE [*Williams*; 2019]).

4.5. Positions of influence

Staff work with Welsh Government to affect policy change or decision-making processes. These include senior stakeholder groups advising policy decisions. For example, CReST Cymru (*Chester*), and the Genomics for Precision Medicine Strategy (*Sampson*). During the COVID-19 pandemic, researchers contributed to national committees steering the societal response to the disease in Wales (*Sampson*; Welsh Scientific Advisory Committee for Welsh Government, *Humphreys*, *Stanton*; COVID-19 Scientific Advisors to Peter Halligan [CSO], *Stanton*; International Intelligence Committee). We also shape national policies on healthcare provision for people with terminal illnesses through our Marie Curie Palliative Care Centre (Lead: *Noble*; one of two centres in the UK). Others serve on the **Welsh Higher Education Brussels** board, which encourages Welsh interests in European initiatives and partnerships (*Jones SA., O'Donnell*). Relevant to our support for clinical medicine, we steered activities that enhance academic clinical research, including:

A. Protected sessions (up to 40% FTE) for NHS staff to develop collaborative research, e.g., through the South East Wales Academic Health Science Partnership fostering links between universities, funding bodies and industry.

B. Match-funding for research applications (e.g., £1.8M for PET-CT).

C. Recruitment to portfolio studies, local and multi-centre clinical trials, and biobanking (e.g., the Wales Cancer Bank).

D. Funding for patient & public involvement and engagement.

E. Technology transfer to NHS diagnostic laboratories and clinical services (e.g., translation of complement diagnostics to create a UK Centre for Complement assays).

In this REF period, we increased the number of researchers working with funding agencies and external stakeholders:

UK Government

UKRI (BBSRC; *Tonks*, Pool of Experts for Main Panels A-D, MRC; *Jones, SA*., [*Wilkinson*, retired]; Infection & Immunity Board, *O'Donnell*; Deputy Chair, Population & Systems Medicine Board; Deputy Chair, Non-Clinical Training & Career Development Panel, *Jones, SA*, COVID-19 Agile Panel), NIHR (*Chester*; Clinical Research Faculty Select Committee, *Choy*; Advanced Fellowship Panel), HCRW (*Jones, SA.,* Co-Chair, *Dayan*; Research for Patient & Public Benefit Panel, *Jones, SA.,* Deputy-Chair; All-Wales Prioritisation Panel).

Charities

British Heart Foundation (*Morgan*, Chair; Chairs and Programme Grant Committee), Cancer Research UK (*Adams, Barrett-Lee, Chester, Mason*; various clinical review panels, *Gallimore*; Science Committee, Vice-Chair; Immunology Expert Review Panel), Diabetes UK (*Wong*; Scientific Review Committee), Juvenile Diabetes Research Foundation (*Wong*, Chair; Scientific Review Committee), Kidney Research UK (*Bowen, Fraser* Co-Chair; Research Grants Committee), Versus Arthritis (*Jones, SA.,* Vice-Chair; Disease Sub-Committee). Wellcome Trust (*Humphreys*; Basic Science Interview Committee, *O'Donnell*; Biomedical Resource & Technology Development Committee, *Moser*; Henry Dale Fellowships, *Godkin*, *Humphreys*, *Moser*, *Sampson*; *Ad hoc* Investigator Award interview process).

International agencies

CNPq Brazil (*Wong*), French National Funding (HCERES; *Moser*), Irish Cancer Society (*Chester*; Clinician Research Leadership Award), *Gallimore*, Chair; Biomedical Funding Panel); Health Research Board Ireland (*Jones, SA.,* Chair; Investigator Led Projects, Chair; Trials Methodology Research Network Review Panel, Joint Select Funding Committee), Marie Curie Fellowships (*O'Donnell*), NIH (USA) (*Ghazal*; Scientific Advisory Board for NIH NIAID, *Wong*; emphasis panel review of Diabetes), Research Grants Council Hong Kong (*Wong*; Biology & Medicine Panel), Science Foundation Ireland (*Gallimore*).

Editorial Board Memberships

Chief Editors (*Moser*; Frontiers in Immunology, *Cooper*; Human Genetics, *Ingram*; British Journal of Dermatology), Emeritus Editorships (*Topley*; former staff, Peritoneal Dialysis International), Associate Editorships (*Clayton*; Exosomes, *Fegan*; British Journal of Haematology, *Gallimore*; Immunology, *Morgan*; Molecular Immunology, European Journal of Immunology, *Parker, Stanton, Wong*; Scientific Reports, *Wong*; Frontiers in Immunology; Current Molecular Medicine, *Jones, SA., O'Donnell*; Journal of Biological Chemistry; Function, *Jones, SA*; Signals-BMC, *O'Donnell*; Lipid Research, Function).

Clinical Advisory Groups

Joint Research Office (*Dayan*; Director, CU/CAVUHB), UK Clinical Review Panels (*Barrett-Lee*; NCRN/NCRI Breast Cancer Clinical Study Group, *Collins*; UK-CRN Non-Malignant Haematology Specialty Group, *Mason*; NCRN/NCRI Prostate Cancer Clinical Study Group), Senior stakeholder appointments (*Sampson*; International Scientific Advisory Board to the Tuberous Sclerosis Alliance (USA), Medical Advisor to the Tuberous Sclerosis Association, *Jones, SA*; Versus Arthritis, Senior Stakeholder Committee), European Organisation for Research & Treatment of Cancer (*Mason*; Chair, Independent Data Monitoring Committee).

National Advisory Groups

BSI and NCRI (*Ager*, *Gallimore*, Joint Committee; UK-wide strategy for cancer immunotherapy), Genomics England (*Sampson*; Scientific Committee), Health & Care Research Wales (*Dayan*, *Morgan*, *Sewell*, [*Topley*, former staff]; Senior Faculty, Health & Care Research Wales), UKRI/NIHR/AMS (*Morgan*; MRC Council, *O'Donnell* (Multimorbidity Steering Group, *Jones, SA*, *Fraser*; Multimorbidity scoping group), Versus Arthritis (*Jones, SA*; Centre Review Panel, Committee Restructuring Review Panel), Wellcome Trust (*Humphreys*; Immune System in Health and Disease Expert Review Group).

4.6. Open science and engagements

Embracing policies that promote Open Science (e.g., DORA; see REF5a) we manage open access repositories, infrastructures and facilities with direct benefits to researchers, NHS services (e.g., All Wales Medical Genetics Service) and patients. Notable examples include the Human Gene Mutation Database curating genetic information on 275,716 human polymorphisms and LIPID MAPS (**S3.2**). In 2020, LIPID MAPS was accessed over 1.5 million times and supported 69,357 international researchers. Through this platform, users obtain free access to a suite of databases, software tools, statistical methods, and educational resources for lipid research. Our Open Science initiatives also extend into our undergraduate programmes. We proudly publish **The British Student Doctor Journal** (ISSN:2514-3174; official journal of the Academy of Medical

Educators); an open access academic journal led by CU medical students, which publishes medical student-generated, peer-reviewed articles impacting UK clinical practice (Editorial Board: *Ingram*).

Research infrastructures and facilities support our commitment to engagement, involvement and participation. Lay faculty members are engaged in all our discovery and clinical programmes and have become an integral component of our research environment. Through new initiatives such as the Hodge Centre for Neuropsychiatric Immunology, we introduced activities that look to break boundaries between clinical specialities or research in defined diseases. In this regard, we deliver an integrated approach to public and patient involvements. For example, the Systems Immunity Lay Faculty (female:2; male:5; *Eberl*) consists of individuals passionate about science and health-related matters. The Faculty supports the communication and accessibility of all our research in cancer, infectious diseases, and complex immune-mediated or degenerative disorders. Established in 2015, faculty members help prepare grant proposals, impact statements and press releases, and input on discussions with stakeholders (e.g., Involving People Network, HCRW, NIHR) and other advocacy groups. We use innovative approaches to engagement that promote scientific understanding between patients, researchers, and clinical colleagues. For example, our **Sepsis Engagement Centre** (The Goldilocks Ward; Project Sepsis) offers an interactive training suite with exhibits and simulations showcasing cutting edge advances in the management of neonatal infection. We also deliver medical education programmes (e.g., the **Cytokine Signalling Forum** run by CESAS Medical [awarded Silver medal at the 2016 Digital Education awards], *Choy, Jones, SA*) to supplement continuing professional development for healthcare professionals (e.g., community practitioners, specialist nurses and pharmacists). We host a successful public lecture series and embrace initiatives that raise awareness of STEM subjects. Working with schools (Key Stage 3 & 4) we run a national, bilingual Life Science Challenge quiz (in Welsh and English) where schools participate in a head-to-head knockout competition (annually featuring 34 schools and over 150 children).

Research achievements are disseminated to the general public *via* charities (e.g., CRUK, Versus Arthritis, Kidney Research UK), participations at festivals (e.g., the National Eisteddfod, the Hay Festival, the Soapbox Science Festival, Green Man), pop-up events (e.g., Techniquest Science Museum) and interactive games (e.g., MacMan, Telomere Crisis developed with the University of South Wales). To raise awareness of antibiotic resistance, we transformed an empty retail unit in Wales's largest shopping centre into an interactive pop-up science shop (Superbugs; 2019 funded through our ISSF scheme, **S2.5**). Over 14 days, we welcomed 6,566 visitors and created 1,625 young antibiotic resistance champions in over 200 schools. Significant research achievements are advertised through the University website and newsletters such as ReMEDy (the SoM quarterly newsletter), which reaches over 12,000 readers including alumni and stakeholders. Colleagues in UOA1 regularly feature in local and national news reports. These include expert opinions for media outlets (e.g., BBC Wales, BBC Radio4, CNN) and interviews for news sections in scientific journals (e.g., *Science*, *Nature Biotechnology*).

4.7. Summary

Our research environment has changed beyond recognition since REF2014. Addressing health challenges affecting our society today, we present a sustainable and inclusive research environment equipped to harness discovery research for future clinical innovation and patient benefit. Achievements were delivered through increased investment in research excellence, including initiatives that bridge our core research strengths (e.g., immunology, neuroscience). This approach has increased our competitiveness for new funding and resources from government, industry, and charities. Thus, we are ideally placed to ensure the long-term sustainability of clinical medicine in Cardiff University and suitably equipped to deliver health research with direct benefits for society.