University of Salford

Unit of Assessment: 3

1. Unit context and structure, research and impact strategy

Unit context and research structures

Salford's health research seeks to answer the question of '*How can we live well for longer?*' within the University's Research and Knowledge Exchange strategy and addresses this through the work of three interdisciplinary research centres: **Health Sciences Research Centre (HSRC)** and **Centre for Social and Health Research (CSHR)** in the School of Health and Society (SoHS), and the **Biomedical Sciences Research Centre (BRC)** in the School of Science, Engineering and Environment (SEE).

Research is delivered through eight research groups (Figure 1), defined through research leadership due to grant income and associated partnerships, and critical mass, and thus proven sustainability. Reflecting our approach of building multi-disciplinary teams and facilitating interdisciplinary work, two groups within CSHR are submitted to UoA20 and part of the Infectious Diseases group is submitted to UoA7. Long-standing research strengths represented in RAE/REF since 2001 have been developed significantly during this REF period, including human movement and rehabilitation, public health, cancer therapeutics and infectious diseases.

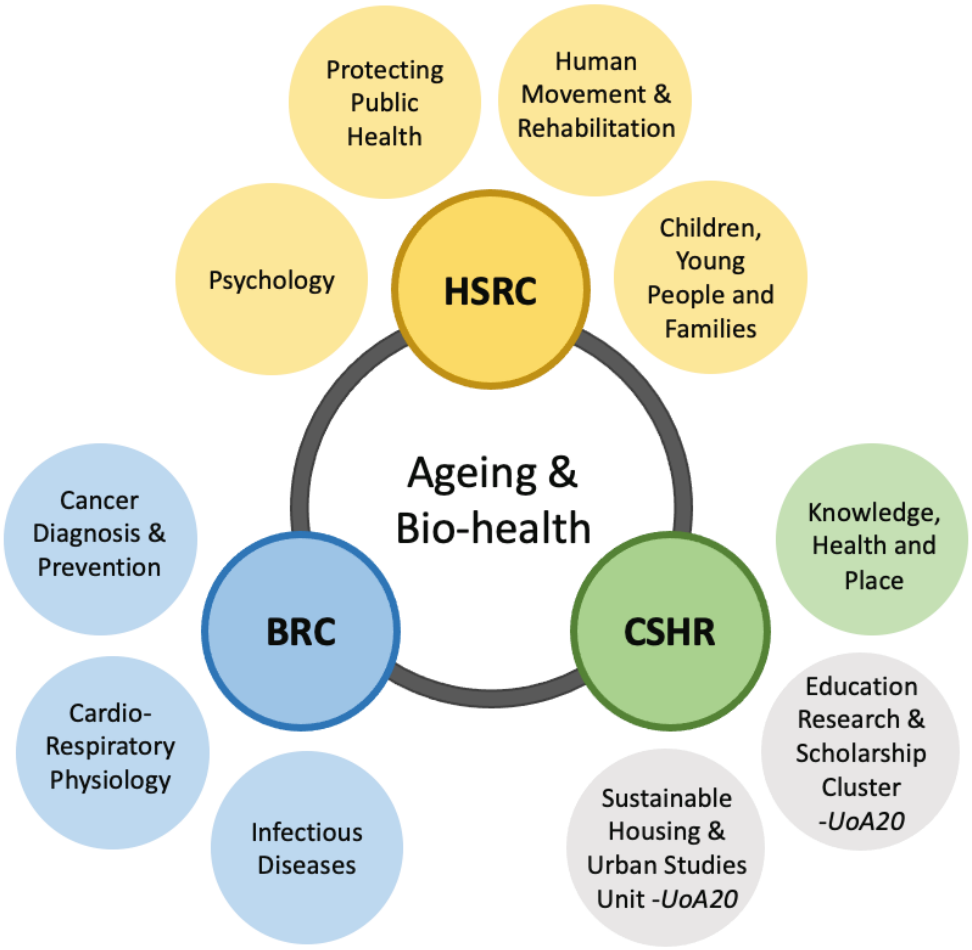

Figure 1. Research centre and group structure.

Major research achievements 2014 – 2020

Salford has demonstrated sustained research growth between each of its UoA3 RAE/REF submissions since 2001, with an acceleration in performance since 2014. Over the past seven years we have:

1. Significantly increased the scale and volume of our research activity

In REF2014, Salford submitted 42.1 FTE staff to UoA3 and 17.0 FTE biomedical scientists to UoA5 (Biology); a total of 59.1 FTE. Significant investment in new staff has resulted in a **35% increase in the size of our staff submission** to 79.7 FTE. This investment has been evenly split between research centres, with 13 new appointments in HSRC, 13 in BRC and 11 in CSHR.

In REF2014 our combined income reported to UoA3 and UoA5 was £7.5m. Supportive internal development, facilitating a culture of high performance, and strategic recruitment of staff with excellent track records has resulted in an **84% increase in income to £13.8m**. This impressive trend has been supported by both the Allied Health areas (HSRC and CSHR), who have **increased income by 71% from £5.9m to £10.1m** and the BRC, whose **income increased by 131%, from £1.6m to £3.7m**.

Benchmarking our income (HESA) further demonstrates our success against the national picture. Salford was **9th in the sector for total income reported to the 'Nursing and Allied Health' cost centre 2013-19**, moving from position 14 to 9 across the 6 years of available data. Our substantial increase in Research Council awards places us 6th in the sector for income from these funders and our focus on health technology innovation and industry collaboration is reflected by our 2nd place position both for income acquired from EPSRC and from industry sources. These factors represent the nature of health-related research at Salford, illustrating the value we place on generating new knowledge through technical innovation and aligning to the needs of patients, healthcare organisations and businesses.

In addition, it has been a priority to progress beyond project grants to hosting 'programme grants' over longer timeframes. Examples include a 5-year programme grant in child foot health and an 8-year EPSRC Centre for Doctoral Training (CDT).

2. Increased the number and quality of our research outputs

Submitted staff have published over **1100 articles with a Field-Weighted Citation Impact of 1.43** (SciVal). All staff follow the University's Open Access policy to ensure research outputs are disseminated accordingly. **Outputs from the three Centres have been downloaded over 1 million times** during this REF period, demonstrating that our research findings, datasets and methods draw considerable attention. We have improved dissemination by publishing widely in broad scope, open access journals and providing open-source software to accelerate translation of research into practice, with datasets available via Figshare, e.g. energy flow analysis of amputee walking (193 downloads) and rollator movement motion sensing data (167 downloads).

3. Grown our postgraduate community and strengthened the research training experience

In REF2014 we reported 98 PhD degree awards; 69 to UoA3 and 29 to UoA5. This has **risen by 106% to 202 PhD completions** in this REF cycle as our research staff base has increased in size and diversity of expertise.

Our flagship achievement is the EPSRC funded Centre for Doctoral Training in Prosthetics and Orthotics (EPSRC £5.5m). The CDT training is multidisciplinary by design and spans global inequalities in assistive technology, psychology of limb loss, responsible research and

innovation, the business of health care and health behaviour, alongside traditional training in engineering design and biomechanics.

4. Expanded the significance and reach of our impact

Our impact case studies presented in REF2014 were largely UK-focused. Now, through targeted funding and improved industry engagement, we can evidence impact on a global scale that is **changing health outcomes, policy and practice as well as facilitating economic growth**. Our research has informed breast imaging practices globally; provided the first update to clinical gait analysis methods in 40 years benefitting over 1000 clinical laboratories worldwide; improved healthcare training and provision in Uganda; set up new companies in the UK and China; and provided cost-effective research into gloves in arthritis, driving changes in NHS clinical practice (REF3).

5. Enhanced our alignment with regional, national and international agendas

We address the WHO and UN global agenda through research funded by **>£1m from three EPSRC Global Challenges Research Fund** projects and UKRI/Newton Fund. The EPSRC CDT delivers research training to specifically address the needs of the global P&O user community, 80% of whom are in developing countries. We have contributed to meeting national agendas on cardiovascular disease, diabetes and digital health and technology through participation in multiple and sequential **i4i and NIHR projects, totalling £2.1m**. Research focusing on **child health and health prevention is supported by more than £2m** in grants.

Regionally a key development has been the devolving of health and social care responsibilities to the Greater Manchester area in 2016, providing a new strong regional steer for collaboration. Manchester became the UK's second city to join the global 'Cities Changing Diabetes' programme and we invested £100k to support this. We have also invested £250k in the Manchester Institute for Health and Performance; a partnership with Manchester City Council and Manchester City Football Group.

Research Centre areas of focus, strategy and achievements

Consistent with plans set out in REF2014, **HSRC** and **CSHR** focused their investment in areas of proven strength to build critical mass and **BRC** invested in a clinically focused appointment to address their vision for undertaking more translational research. To facilitate this, several smaller research groups reported in REF2014 UoA3 were consolidated into larger research groups. Collaborative relationships have been converted into larger scale partnerships and practitioners, users and services have been embedded into research through Patient and Public Involvement and Engagement (PPIE) activities.

Research integrity is supported by the respective School Research and Enterprise Committee (SREC), a research oversight committee of academics, technicians and postgraduate researcher (PGR) representatives chaired by the Associate Dean for Research and Innovation (ADRI), and the School Ethics Approval Committee (SEAC), a School ethics oversight committee of Ethics Panel Chairs, and academic and student representation. All primary activity involving data collection requires approval from the School's Research Ethics Panel and clinically based trials are approved through the NHS REC committee process. Health staff undergo Good Clinical Practice training, and clinical trial registration and Prospero registration are completed depending on the research undertaken. This ensures informed consent, research governance and GDPR data handling are at the forefront of the research. UoA3 members sit both on University ethical panels (**Liu**, **Price**, **Thies**) and NHS research ethical committees (**Hammond**, **Nester**, **Tume**). Human Tissue (HTA) research oversight is managed via IRAS with compliance monitored in line with ethical consideration and includes regular audits (most recently July 2020). Research using Genetically Modified organisms is monitored, governed and audited by a GMO officer (**James**).

Health Sciences Research Centre (HSRC)

HSRC has always been outward facing, working with NHS and industry partners to develop and evaluate new treatments and innovative healthcare products and services. Expertise in healthcare technology has now been purposefully complemented with research on health behaviour, wellbeing, self-management and far greater involvement of patients and community groups (e.g. through PPIE, establishing a regional Care Home Community of Practice). Membership is deliberately diverse drawing staff expertise from nursing, engineering, physics, physiotherapy, psychology, public health social work and sport, working in an entirely integrated way to bring new approaches to contemporary health and social care challenges across all age groups.

HSRC is 53 staff (49.51 FTE) working across four groups:

1. Human Movement and Rehabilitation (HMR) (24 staff; 22.51 FTE).
2. Protecting the Public's Health: Prevention, Diagnosis and Treatment (PPH) (12 staff; 11.8 FTE).
3. Psychology (10 staff; 10.0 FTE).
4. Children, Young People and Families (CYP) (7 staff; 5.2 FTE).

Human Movement and Rehabilitation (HMR) is the most mature research group in the Centre and focuses on solving problems with movement and physical activity due to injury, disease, or ageing. Led by **Granat**, the group enhances understanding of how movement problems develop and impact lives and the design of technologies and therapies to assist movement. Patient/user input is integral to project design and evaluation, as is a focus on issues of cost and scalability of solutions. The research has led to novel technologies and fundamental changes to the practice of allied health professionals.

Reflecting the need for diverse views to solve complex health problems, the six Professors (**Granat**, **Hammond**, **Hogg**, **Jones**, **Kenney**, **Nester**) span occupational therapy, podiatry, mechanical engineering, sports science and biosciences. HMR has received continuous strategic investment and targeted its recruitment policies to support an **increase in FTE** returned from 17 (REF2014) to 25 (REF2021). Examples include permanent academic positions for rising stars in the pool of post-doctoral contract researchers, including **Parker** (Lecturer in digital health), **Prior** (Senior Research Fellow in digital health) and **Price** (Research Fellow, Footwear Biomechanics), all of whom are now Principal Investigators on grants and manage research staff. This builds on identical investments in permanent contracts for Research Fellows pre-2014 (**Hollands**, **Liu**, **Preece**, **Thies**), three of whom have progressed to Senior Research Fellow in this REF period.

A significant milestone was being awarded the highly competitive EPSRC CDT (7% success rate for new CDTs). This allows us to embed our multidisciplinary research culture in the development of future generations of doctoral graduates. The only externally funded Doctoral Centre associated with allied health professions (prosthetics, orthotics, podiatry, physiotherapy), this now supports a wide range of HMR members and is led by Salford (**Granat, Nester**) with Imperial College, Southampton and Strathclyde as partners. This £5.5m programme provides 58 four-year PhD studentships and the first cohort have backgrounds that span clinical podiatry, sports science, health service management (in Cambodia), through to mechatronics and mathematics. This is underpinned by 26 industry partners, which through advisory panel membership, positions the HMR group into the vanguard of agencies globally (e.g. World Health Organisation, GATE Initiative).

Reflecting the group's long-established expertise in movement problems and physical activity, the assessment of gait and movements of daily living is fundamental to HMR. The research is underpinned by six world-leading gait laboratories, plus several satellite laboratories distributed at partners across the UK (e.g. Scholl footcare, Clark's footwear). In a significant milestone for the sector, Baker and **Jones** pioneered the first major advancement in the field of clinical gait analysis in 40 years. Their wide-ranging novel methods and models reduced long standing measurement errors and improved data reliability, unlocking potential for cross laboratory collaborations across

the world. These innovations are available open source to the global gait research and clinical community of more than 1000 laboratories (REF3).

A critical mass of globally important prosthetic design research has been supported by multiple EPSRC and NIHR awards, Ministry of Defence funding and via collaboration with industry. **Granat** and **Kenney** were involved in three of only five EPSRC Global Challenges Funding awards in prosthetics, leading one project and partnering with Imperial and University of Southampton on two. **Kenney** (with **Head**, Howard-UoA12, Ackers-UoA20) leads the *Fit-for-purpose upper limb prosthetics* project (£1.4m) with partners in Uganda and Jordan, which is developing a locally manufacturable and maintainable design of an adjustable prosthetic socket and hand. EPSRC-funded work (**Kenney**) led to a design of an energy-recycling prosthetic ankle based on miniature hydraulics that is comparable to electrically powered designs but requires no battery. Baker and **Twiste** evidenced that amputee performance can be affected by a hitherto unexpected degree by intensive physical therapy. NIHR-funded work showed how upper limb prosthesis control could be improved, leading to i4i funding (£771k) (**Head**, **Kenney**). Seminal neural prostheses work received sequential NIHR funding awards producing an advanced functional electrical stimulation system to support arm rehabilitation following stroke, without the need for highly skilled and hence sparse and expensive staff. This led to a spin-out company and attracted investment of £2m (REF3).

NIHR funded research focused on improving upper limb prosthesis control and led to NIHR-Invention for Innovation funding in 2020 (**Head**, **Kenney**). **Kenney** has also shown that inertial sensors can be used to characterise user-prosthesis interaction in daily living and developed a miniature prosthetic ankle joint that is comparable to electrically powered designs in terms of performance but requires no battery. Baker and **Twiste** evidenced that amputee performance can be affected by a hitherto unexpected degree by intensive physical therapy.

By identifying factors influencing everyday upper limb prosthesis use (**Galpin**, **Granat**, **Head**, **Kenney**, **Thies**), research led to a major shift in the research community towards use of real-world data rather than laboratory studies. This builds on **Granat's** influential research on measurement of real-world free-living physical behaviour using body-worn sensors. His thigh-worn activPAL monitor has been used worldwide in more than 3,000 publications, innovating investigation of the relationships between physical behaviour and disease risk. This is pioneering the development of novel outcome measures for assistive devices, behavioural and public health interventions,and includes a Biobank study of over 100,000 participants (**Clarke-Cornwell**, **Granat**, **Preece**).

Jones leads osteoarthritis research and is a partner in the EPSRC OATech Network (led by Cardiff University) that combines over 100 academic, clinical and industry UK and International partners. **Jones** leads Salford in a well-established globally leading network of partners (e.g. Felson at Boston University and Hunt at UBC Canada), who undertake large trials on conservative treatments for knee arthritis. The work provided evidence to support use of low-cost interventions for relieving pain in knee osteoarthritis (insoles) and included the first randomised control trial of a novel foot-worn device leading to significant reductions in pain. The value of biofeedback devices to reduce pain in knee osteoarthritis is being supported by NIHR. **Preece's** NIHR Research for Patient Benefit (RfPB) grant developed the first biopsychosocial intervention for knee osteoarthritis, integrating new biomechanical concepts and digital heath solutions for physiotherapists.

Our rheumatological research impacts directly on practice. **Hammond** and **Prior** led the 4.5-year NIHR-funded RAFT randomised clinical trial evidencing that cognitive-behavioural therapy (CBT) is effective in reducing fatigue in rheumatoid arthritis. Training programmes have been rolling this out into clinical practice. The NIHR RfPB A-Gloves Trial evidenced that costlier arthritis gloves were no more effective than placebos, leading to changes in practice nationally and significant NHS savings. The 'Versus Arthritis' funded (WORK-IA) evidenced that job retention work rehabilitation provided by NHS occupational therapists may benefit employed people with arthritis. **Prior** has developed a digital platform on which PROMS and self-management tools are being made available to support people living with musculoskeletal conditions (REF3).

Nester's foot health research was described as 'world-leading' by the REF2014 assessment panel and has expanded since then, attracting £2.5m in funding and connecting academic, clinical and industry partners across the world. **Nester** led the Foot Health James Lind Alliance Priority Setting Partnership (2018) defining the research priorities in the UK. This impacted on strategic funding plans for the UK's largest foot health research charity (William Scholl Fund) and major charities (e.g. Diabetes UK). A strong focus on the national priority of diabetic ulcers and amputation prevention has developed. Investment of £100k supported a jointly funded NHS Post-doc Fellowship with North Manchester Diabetes Centre and participation in the global 'Cities Changing Diabetes' programme. **Nester**, **Parker** and **Prior's** three-year NIHR i4i funded project is developing novel sensors for continuous monitoring of foot ulcer risk in diabetes. **Parker** led work on digital methods of foot orthoses production evidencing that NHS supply chain processes have marginal impact on costs and health outcomes. Related orthoses research as part of the EU SMARTPIF project (**Nester, Preece**) designed a new insole that is now sold through spin-out Salfordinsole. **Parker** investigated orthotic materials to reduce shear stress under the diabetic foot and also leads the multi-faceted partnership with global footcare brand Scholl, now in its 12th year. This includes a three-year KTP (led by **Price**), two funded PhD studentships and contract research. A novel and now patented test rig (**Hashmi**, **Nester**) was developed with Scholl to characterise the events associated with foot blister formation and clinical trials showed over counter remedies to be equivalent to Podiatry management.

Building on over a decade of underpinning work, **Jones** and **Nester** led one of the largest studies of foot movements: the results challenged long established foot orthoses practices and led to a paradigm shift in under/postgraduate Podiatry and Orthotics education globally. A curriculum innovation grant via Erasmus+ is ensuring research outcomes impact HEIs across Europe. In addition, **Nester** and **Price** led a highly novel 5-year longitudinal biomechanical study (£750k) of foot development during the commencement of standing and walking in young babies. This challenging work included qualitative and survey studies with parents to understand foot health beliefs and footwear choices. **Price** now leads research with Clark's footwear on the development of feet in primary school age children. In other children's work, **Parker** leads the HTA funded OSTRICH Trial evaluating foot orthoses for children with symptomatic flat feet. **Nester**, **Price** and **Williams** completed over four years of research on the association between footwear and musculoskeletal pain at work. The research led to the establishment of a new company, external investment and the sale of >60,000 pairs of Salford-designed products (REF3). The project was rated in the top three of 600 projects for 'Best KTP Partnership' by Innovate UK in 2019.

Protecting the Public's Health (PPH) includes Public Health and Diagnostic Imaging research with a focus on prevention and early detection. Led by **Hogg**, the 12 staff span multiple professions (e.g. Occupational Therapists, Physiotherapists, Medical Practitioners, Engineers) with formal collaboration with >30 hospitals, industry and other universities across the globe. In 2016, Radiography at Salford was ranked the most prolific UK radiography department for publications and 3rd in the world (*Journal of Medical Imaging and Radiation Sciences, 47(1), 13-20*). In 2016, work on breast density estimation was awarded best journal paper in *Radiography*. Research on breast compression has driven changes in practice guidelines in the UK, Norway and Netherlands and uptake from the global radiography community has been rapid (REF3). During COVID-19, **Hogg** led an international team of over 50, including researchers from BRC (**Goodhead**, **James**), to create a web-based information and support system for radiographers imaging for COVID-19. This has now been adopted in 145 countries.

With £1.1m from multiple grants, **Cook** leads the UK in Foetal Alcohol Spectrum Disorder (FASD) research. MRC-funded research developed an intervention that could improve the lives of thousands of families affected by FASD. Reflecting the strategy of embedding users in our research, in NIHR-funded work, local volunteers were trained as alcohol health champions. Outcomes include life-changing conversations within communities and the volunteers have been shortlisted for various community awards and featured in other alcohol initiatives. Partnering with Salford City Council and Trafford Council, PPH are evaluating interventions to stop people smoking by using e-cigarettes. This work was cited in the Prevention Green Paper consultation document: '*Advancing our health: Prevention in the 2020s*.'

Psychology research has grown from four researchers in REF2014 to ten and focuses on disability, mental health, interaction with technology, climate change, social media and political radicalisation. This rapidly developing group has been fuelled by building on areas of strength, investment (£285k) in new labs and equipment and PhD student support. **Galpin**'s work in response to widespread concerns over the effects of social media and screen time on children's physical and mental wellbeing has been supported with dedicated lab space and access to state-of-the-art eye-trackers. His research led to new guidelines from the British Psychology Society (BPS) on 'Children, Adolescents, and Screen Use', presented to an All-Party Parliamentary Group. **Galpin** collaborates with **Kenney** (HMR), publishing some of the first work on visuomotor behaviours in users of prostheses. **Weinberg's** occupational wellbeing research founded a new section within the BPS and won the BPS Occupational Psychology Impact Award.

The Autism and Criminal Justice Hub focuses on awareness of autism across the criminal justice system. The hub lead, **Allely,** was supported by £57k of internal funding, is a member of the Neuropsychiatry Centre at Gothenburg University, Sweden and partners with the Director for the Center for Mass Violence Response Studies, Police Foundation, in the United States.

Children, Young People and Families (CYP) is a multi-agency research group focused on improving outcomes for children and their families. Led by **Long,** it conducts research that addresses real-world problems and increases knowledge and evidence related to the health and wellbeing of children and families. This impacts healthcare policy, clinical practice and service delivery.

Long collaborates nationally with NHS consultants in several areas: survivorship after childhood brain tumour and enhanced neonatal care; ameliorating parental experiences after sudden unexpected death of a child; and enhancing outcomes for children of prisoners. This resulted in evidence provided to drive the Children's Commissioner's demands for systemic changes. **Long's** PAT-POPS RfPB grant achieved the largest ever recruitment to a paediatric study in the NIHR CRN. Elsewhere, **Long** is using digital wearables to improve children's mental health outcomes, empowerment and advocacy; work that led to safeguarding policy changes at the British Medical Association and the World Medical Association. Emerging areas focus on improving mental health outcomes in children and young people, which is a key component of the NHS Long Term Plan (**Ayodeji**, **Foster**, **Ghio**, **McAndrew**, **Smith**).

Strategic investment for CYP included a new Reader (**Tume**) and appointments to strengthen collaborations with local partners, including A&E Consultant **Rowland's** (Northern Care Alliance) honorary Chair. **Tume** has led several high-impact, NIHR-funded studies improving effectiveness of treatments and outcomes in critically ill children, for example, on weaning invasive ventilation and preventing extubation failure (First ABC, £1.4m, NIHR HTA). In collaboration with researchers in HMR with muscle mass expertise (**Comfort**), **Tume** is investigating muscle mass loss and recovery during and after critical illness in children.

Biomedical Research Centre (BRC)

The Biomedical Research Centre (BRC) is a vibrant, collaborative unit of inter-disciplinary researchers impacting health and industry. Research ranges from identifying cancer stem cell metabolism processes and molecular biomarkers through to understanding the impact of zoonotic and pathogenic microbes on human and animal health. Research is supported by national and international collaborations focusing on new and improved disease treatments and partnerships with regional hospitals and commercial investment.

BRC has three research groups totalling 21 staff (19.6 FTE):

1. **Cancer Diagnosis and Prevention (CDP)** (11 staff; 10.6 FTE).
2. **Infectious Diseases (ID)** (11 staff; 11.0 FTE in total – 5.0 FTE in UoA3 and 6.0 FTE in UoA7).
3. **Cardio-Respiratory Physiology (CRP)** (4 staff; 4.0 FTE).

Cancer Diagnosis and Prevention (CDP) research ranges from cancer stem-cell metabolism (**Lisanti**, **Sotgia**) and cancer RNA biomarkers (**Mukhopadhyay**), cancer nanobiotechnology (**Krpetic**), to drug pharmacology (**Denbigh**), drug design and synthesis (**Hadfield**, **Pye**, **Wilkinson**), chemotherapy and drug repurposing (**Aziz**, **Krstic-Demonacos**, **Topham**).

In REF2014, a future aim was to focus on cancer therapeutics and drug design and BRC has recruited new Professorial leads to achieve this: **Lisanti's** and **Sotgia's** research is supported by the Foxpoint foundation (£755k over five awards) and Lunella Biotech, Inc – a spin-out pharma company they co-founded (four awards, £1.9m). Investment has included laboratory refurbishment and dedicated technical staff from which the wider CDP benefit. The team's foci are determining the role of cancer stem cell metabolism in carcinogenesis, discovering clinical targets and potential drugs. Key findings include improved understanding of the role of mitochondria in cancer tumour microenvironment and mitochondria as new therapeutic targets. Drug repurposing for cancer treatments has resulted in multiple patents on mitochondria-based therapeutics targeting cancer cells (US patent number 10512618; eight more patents are also filed). Clinical trials, in early-stage breast cancer patients, are ongoing with Pisa Hospital, Italy. Other BRC activity focused on anticancer treatments has been conducted through drug discovery spin-out ONCO-NX, established in 2011 (**Hadfield**). Cancer therapeutics company Incanthera acquired ONCO-NX upon listing on the stock exchange in February 2020, with **Hadfield** on the Incanthera advisory board.

Recruitment of **Mukhopadhyay** in 2016 led to a new strand of work in cancer RNA biomarkers. Currently, the group is focused on identification of extracellular RNA biomarkers towards non-invasive early diagnosis of lung and brain cancers. **Mukhopdadhyay's** research has attracted interest from diagnostic companies and is supported via collaboration with Affinity Biomarker labs, consolidated by an international industry collaboration between the University and a large private clinical centre in Vietnam (Vinmec International General Hospital).

Infectious Diseases (ID) focuses on bacterial and parasitic disease agents related to human and animal health. This group links human health with environmental and ecological factors in a 'One Health' approach and comprises 11 staff in total, with 6 researchers who focus on the characterisation and epidemiology of animal and plant pathogens submitted to UoA7. Major areas of research include understanding the ecology and evolution of nosocomial infections (**James**) and chronic parasitic and neglected tropical diseases (**Goodhead**, **Hide**, **Rogan**), including developing novel insights into the immune response (especially related to infectious disease co-morbidities with cancer and HIV/AIDS (**Goodhead**, **Hide**). Research also includes developing molecular diagnostics for epidemiology of infectious diseases, especially zoonotic infections (Echninococcosis and Taeniasis) in endemic areas across Asia, South America and Africa (**Rogan**). **Rogan** has established a commercial 'Cestode Diagnostics' service, officially recognised as a designated testing laboratory by the World Organisation for Animal Health. An iCASE studentship with the Falkland Islands Government looks at ongoing Echinococcosis eradication despite >30 years of intensive control programmes.

Further expertise exists in drug repurposing towards safer treatments for malaria (**Nirmalan**) and understanding the evolution and spread of Antimicrobial Resistance (**Goodhead**, **James**). Multi-disciplinary approaches to tackling Antimicrobial Resistance led to the Salford Antimicrobial Network, involving SoHS and SEE, which has resulted in development of impact (REF3) around enhancing antimicrobial stewardship in LMIC through rational use of antibiotics and improved infection control (**Goodhead**, **James**, Ackers-*UoA20*).

Cardio-Respiratory Physiology (CRP) has a focus on cardiac physiology from the cellular basis of heart disease and drug-induced cardiac toxicity (**Greensmith**); obesity as a risk-factor for Cardiovascular diseases (**Withers**); secretion biology in lung diseases (**Miklavc**) and fungal allergens in airway fibrosis (**Namvar**). One of the major foci of the group is to understand cardiac intracellular calcium signalling and its regulation in health and dysregulation in disease. To facilitate this work, **Greensmith** has developed a unique technique, including specialised

equipment and facilities, to dynamically measure intracellular oxidative stress, which can be applied to any area of cell-based research.

Centre for Social and Health Research (CSHR)

CSHR comprises three groups which bring together experts in criminology, digital information, mental health, midwifery, nursing, sociology, social policy and social work to address global social and health challenges. Challenges addressed across the Centre include ensuring fair welfare systems and services, addressing health and social inequalities, modernising health and social care, crime and justice and sustainability. The Centre aims to understand the delivery and receipt of interventions, practices and policies from the community perspective, increasingly using digital solutions.

Knowledge Health and Place (KHP) (12 staff; 11.6 FTE) is led by **Ormandy** and focuses on self-management, mental health and psychosocial care. A major strength is within the theme of digital health where the group has used social media interventions to improve health and social outcomes for kidney patients. **Ormandy** won two national awards (Innovation Champion for Use of Social Media 2015 and Big Chip Digital Awards 2018) and leads the *Greater Manchester Kidney Information Network* 'GMKIN'. Now expanded to cover Cheshire and Merseyside, the network supports over 700 patients, with further sites already identified for national roll-out in 2021. **McCarthy** and **Ormandy** created *Facemums,* the world's first professionally moderated, evidence-based social media environment to support pregnant women, with improved outcomes for mums-to-be and professionals (REF3).

Research into counselling practices has been advanced through **Widdowson**, who has published on the role of counselling and psychotherapy in the management of depression; **Roddy** who developed a competency framework for domestic violence counselling; and **Amos** who published a systematic review around counselling practice related to HIV testing. **Probyn** has identified self-care and psychosocial health needs by validating a diabetic assessment tool for adolescents. **Howarth** leads the Nursing special interest group within the National Social Prescribing Network and her research has highlighted the value of social prescribing for people with long-term conditions.

Future strategic aims for research and impact

We are committed to supporting our health-related research of international renown for further global benefit and impact with a particular emphasis on the design and use of technology in healthcare settings and by service users. In capital expenditure this will translate into:

- £1.5m investment in state-of-the-art radiography equipment to happen in 2021, supporting image sharing through PACS connectivity and improving the storage and accessibility of DICOM images. The system will also facilitate secondary data analysis, reducing data acquisition costs in many health fields.
- The North of England Robotics Innovation Centre (NERIC) to open at Salford in 2022/23 will have a dedicated health robotics lab supporting joint projects between SEE's Autonomous Systems and Robotics (ASAR) group and HMR.
- A new acoustics building (first phase of the Campus Masterplan, 2020-24) will support expansion of work on health-related audiology. Our Acoustics Research Group has 60+ years of research in acoustic measurement, building acoustics, environmental noise and psychoacoustics. The REF2014 UoA16 panel highlighted our *'particular strengths in acoustics'* with *'outstanding impact in acoustics for the built environment.'*
- A centre for prosthetics, orthotics and assistive technologies within our Innovation District as part of the Campus Masterplan. This will be a living lab, where multidisciplinary research and innovation interconnect with community and business partners.

We will invest in people through:

- New appointments aligning to areas of capital investment, e.g. Chair in Prosthetics and Orthotics (already agreed).
- Ensuring sustainability of our research groups by refreshing and growing our talent pool.
- Improving the diversity of our workforce to reflect wider society.

Impact priorities

We aim to intensify our impact activity across all 8 groups. This will expand existing projects in HMR, PPH, KHP and ID groups, and **Howarth's** work on wellbeing and gardening (REF3 for UoA7), while developing impact within Psychology (**Allely**), CRP (**Greensmith** through his iCASE industry PhD project) and CDP (**Mukhopadhyay**). Already we have 32 impact action plans in place where work is underway. Alongside this planning framework will be targeted internal strategic investment, both from the University's Research Impact Fund and from School sources, to provide the necessary support to see our research findings used for societal benefit. These will continue to be facilitated through individual and group impact action plans with support from the School Impact Coordinators in SoHS and SEE.

Alignment with external agendas and partnerships

We are committed to improving healthcare in LMICs. This will be expanded through greater partnerships with global networks in the assistive technology and related rehabilitation fields. The EPSRC CDT and assistive technology research strengths (HMR research group and BRC) are a strong platform for this. Staff will strengthen partnerships with UK leaders in this field, such as the £20m AT2030 (Assistive Technology 2030) strategy and Global Disability Innovation Hub at University College London and the new National Rehabilitation Centre (Loughborough). This will expand the existing links into the WHO Global Cooperation on Assistive Technologies (GATE) initiative and associated UN activities. We will submit for renewal of the EPSRC Centre for Doctoral Training in 2026-27 and thus maintain our high-quality training pipeline providing Doctoral graduates into the global health technology sector.

Digital health

This will be a key point of intersection between our research and the agenda embodied within the NHS Long Term Plan, specifically, greater personalisation of care, out of clinic care and reduced outpatient appointments. Wearable devices that monitor risk and produce personalised data to drive behavioural interventions will be advanced in several areas, specifically physical activity management and diabetic foot ulcer risk. Conservative approaches to the (self) management of rheumatoid and osteoarthritis via biofeedback, online needs profiling and outcome measurement, and use of physical therapies, will play a key role in helping to manage the inevitable service backlog due to COVID-19. The existing BRC-HSRC nexus will build collaborations between Bio-health, infectious diseases and clinical partners, using genomics and genome-driven precision medicine and tackling Antimicrobial Resistance, through improvements in antimicrobial stewardship bringing to bear expertise in data science, health analytics and data visualisation.

Engagement with end users

Training and resources will be expanded to make PPIE part of the fabric of all that we do. By way of example, we already work with national award-winning diabetes patient champions and the Chief Executive of the Muslim Heritage Centre on novel tools for engagement with these difficult-to-reach communities. Across a period of 18 months, Community of Practice across Care Homes has been developed through multi-faceted engagement activities and learnings from this will become standard practice.

Across the 3 Centres, digital themes within our research design, data collection, and dissemination will be expanded to become a feature of all our work. This reflects the changing needs and behaviours of users as digital content, e.g. social media and apps, influence and assist how we manage our health (especially post-COVID-19).

2. People

Staffing strategy

From 2014, major University investments have supported the recruitment of academic staff, research staff and PhD students in areas of existing strength. We have sought to recruit active researchers with promising track records and 95% of our new staff hold a PhD. We have funded 5-year research fellowships, awarded to Baker and **Jones**, which have led to new gait analysis methods and models (REF3) and used the external profile of our research to attract high calibre postdoctoral researchers, purposefully recruiting from this pool to move staff onto permanent academic positions. Examples include **Price** (KTP Associate to Research Fellow), **Parker** (Post-doc to Lecturer) and **Bramah** (PhD student to Lecturer).

A strategic priority for all three Centres was to strengthen collaborations with local clinical partners, notably via honorary and joint appointments. This has been realised through the appointment of **Rowland** (Northern Care Alliance NHS Group - NCA) to an Honorary Chair. The appointment of Dr Steve **Woby** (Managing Director of Research & Innovation for NCA) as Honorary Chair; together with our recent appointment, shared with the NCA, of Professor **Iles-Smith** further consolidates this collaboration. BRC has made a joint appointment (**Withers**) with the NCA to strengthen clinical collaborations. Another BRC member (**Mukhopadhyay**) is now appointed as the Genetics expert in the Gene Modification Safety Committee of the NCA.

Strategic investments have supported work around well-defined health priorities. The national crises around amputation rates and diabetic foot ulcers led to a jointly funded NHS Post-doc Fellowship (£100k) with North Manchester Diabetes Centre. A recent NIHR Doctoral Fellow was appointed to this post and has since progressed into an academic position. **Jones** was supported by HEIF funding (£260k) to create a sports medicine-focused post-doc post at the newly created Manchester Institute of Health and Performance.

We have submitted 17 Professors (21% of the submission), 30 Readers/Senior Lecturers (34%), 29 Lecturers (35%) and 8 permanent Research Fellows (9%). Overall, 57% of submitted staff are female and 12% are from a BAME background. Our Professorial roles are split across the three Centres, 7 in HSRC, 4 in CSHR and 6 in BRC to ensure each area benefits from senior leadership expertise for development of Centre and group strategy and effective mentoring of junior staff. Promotion opportunities during the REF period have ensured staff are supported to progress in their careers at Salford, with 16 staff promoted internally using research criteria: 4 Professors, 7 Readers, 3 Senior Lecturers and 4 Senior Research Fellows. Of these, 13 are female (81%). In addition, three staff (**Goodhead**, **Hogg** and **Rogan**) have been promoted to ADRI roles.

Staff support and development

Formal career development processes

Between 2014 and 2019 research workload was assessed locally through the research group leads and heads of directorates (resource centres). From 2019, research-active academics could access support through completing a three-year research plan after consulting with research group colleagues. This informs decisions about research workload, training and development needs and eligibility for submission to REF. Research workloads are set in line with the outcome from the assessment of the three-year plan, with a minimum of 20 workload units for staff with 'significant responsibility for research' as described in our REF2021 Code of Practice. There is no upper limit of research workload allocation and nine staff receive 100% research workload. Adjustments to workload are made to account for health, caring and other personal circumstances. three-year plans now feed into the annual Career Conversations staff have with line managers, which allows for feedback and advice on the individual's research trajectory, setting of research objectives and measurement of achievement.

Mechanisms to support a vibrant research culture

Staff benefit from support opportunities within Research Centres where there is a specific emphasis on 'creating and sustaining a research culture', with forums, research seminar series and research training that help socialise and assist Early Career Researchers (ECRs) and more experienced researchers to achieve research outcomes. Within the regular seminar series, open to all staff and PGRs, we have hosted international academics, such as Professor David Felson, Boston University, Professor Michael Hunt, University of British Columbia, Vancouver, Professor Kate Webster, La Trobe University, Australia and Professor Peter Bruggemann, German Sport University, Cologne, Germany. Part-time and joint appointments between the University and external organisations are also used to bring a wider external perspective to the research activities, for example, **McCarthy's** secondment to Health Education England.

The University has organised an Inaugural Professorial Lecture Series, at which seven staff have presented details of their research programmes and achievements. Each Research Centre organises all-staff meetings on a regular basis (e.g. quarterly) to bring researchers together to share research developments and in both Schools, regular Professoriate and research leadership management meetings support research decision-making at School level. In SoHS School newsletters ensure information about research activities are disseminated more widely to keep staff informed and in SEE a weekly all-School open research meeting allows the ADRI to share details of upcoming funding opportunities and discuss research matters.

Supporting high quality grant applications, outputs and impact activities

Complementing the University-wide researcher training and development (SECRET) programme, through SEE and SoHS, staff receive more tailored guidance for bidding, publication quality and impact activities. Each School has established an internal peer review process, which provides mentorship and constructive feedback to grant applicants to help develop rigorous proposals for successful external funding. 'Grant labs' facilitate the preparation of bids in the early stages and study leave can be requested to provide additional time for application development, e.g. **James** received a 2-month sabbatical to develop her successful BBSRC bid. In SEE, major applications benefit from dedicated support from a Research Development Manager. To support staff to produce high quality research outputs, Schools run an internal peer review process that provides feedback to authors on their publications using the criteria of originality, significance and rigour.

Development of research impact is a strategic priority and supported in multiple ways. Internal funding from the University's Research Impact Fund has been available through 2 funding calls per year and provided £68k for development of impact activities for 29 UoA3 staff. Annual impact action plans were introduced in 2018 to support researchers to develop their impact in a strategic manner to maximise the benefits of the research for wider society. School Impact Coordinators (one each in SoHS and SEE), who are academic colleagues experienced in impact development and are provided with a workload, assist colleagues with development of impact. This includes regular meetings with impact plan holders to monitor objectives and discuss future activity. Additional research workload has been provided to support the development of REF3 case studies.

Since 2014, the University has provided £267k from central internal financial support to pump-prime research or help with conference attendance and research visits. Individual discretionary accounts are actively encouraged and accrue funds from consultancy and 25% of the overhead recovered from any award. Professors and large grant holders are asked to spend their funds on supporting other staff, for pump priming, research equipment and help with dissemination and impact.

Early career researcher support

Twenty-one new staff have received the VC's Scholarship with financial pump-priming and additional research workload allocation. As described earlier we seek to retain ECRs into permanent positions where possible and develop flexible plans for those transitioning roles e.g. from ECR and research assistant/fellow to full academic posts. Staff who wish to transition into

research can receive support through working towards a PhD on an in-service basis. Benefits include fee waivers, workload allocation and provision of an experienced and qualified supervisor. Assisting staff to achieve a PhD has been important for many UoA3 disciplines. For example, in 2008 only one member of radiography held a PhD and now 12 do (65% of the total staff). To provide a supportive community environment, in SoHS the ECR group (established six years) meets six times/year and the University ECR conference is well attended and offers leadership opportunities.

Support and career development for research technicians
As a signatory to the Technician Commitment, support is also key for staff who are an important spoke in the wheel of research. **Bendall** was a technician when he commenced a PhD at Salford and subsequently progressed to a lecturer position. He won the British Psychological Society and Association of Technical Staff in Psychology's Technical Support in Psychological Research Award in 2015. Sam Royle is currently Psychology's technician and is fully involved in research. He won the same award for research (2015) and teaching (2018). He was also 'highly commended' in the Papin Prizes for 'outreach' in 2017 and 'newcomer' in 2019 (Papin Prizes recognise the importance of technicians in higher education and awarded at the Higher Education Technicians Summit). The BRC (and SEE) is also supported by an excellent team of 15 full-time and 4 part-time technical staff (male:female = 1:2), four of whom have been supported to undertake a PhD.

Ensuring an excellent postgraduate research experience

Pathways and funding mechanisms
Since 2014, 202 PhD degrees have been awarded with 52% being female and 45% from a BAME background. To accommodate a range of professional backgrounds including international academic staff (7 enrolled between 2017-19), international students and students joining from practice settings, our routes to PhD include traditional, split-site, distance learning, published works, full-time, part-time and accelerated professional doctorates. The accelerated route was introduced to address the lack of clinical staff without PhDs and is populated by a greater number of women, providing them with a supportive networking environment with flexible delivery. PGRs can access specific modules on any undergraduate or postgraduate course and, to support part-time and distance students, masterclasses and intense training sessions take place on Saturdays and can be accessed remotely.

We intend to adopt good practices from our EPSRC CDT to benefit our wider PGR community. The four-year PhD programme comprises a year of Master's level taught study followed by 3 years of traditional PhD research. The student experience includes clinical/industry placements, projects linked to industry, supervision from a second university (either Imperial, Southampton or Strathclyde) and is supported by a dedicated budget of £16,700 per CDT student. Students benefit from a range of activities that create a clear sense of cohort cohesion between the CDT students, including a student-led CDT student society and linked PhD projects.

Fifteen internally funded PhD studentships were awarded based on '*Pathway to Excellence*' and '*Graduate Teaching Scheme*' models along with a '*Doctoral Training Alliance'* scheme. Particular successes from these cohorts include McGrath, now working as a Scientist in the Prosthetic industry leader, Blatchford; Greuel, now working at Alder Hey Children's Hospital as a Research Physiotherapist; Walters, employed by Defence Medical Rehabilitation Centre as a Research Scientist; and Joynson, a Senior Postdoctoral Research Associate at the Earlham Institute, Norwich.

PGR development experience and involvement in School research activities
To ensure an excellent supervisory experience and build capacity, lead supervisory roles are taken by those who have previously advised/supervised PGRs to completion, with less experienced supervisors undertaking co-supervision often with external clinical advisors. Supervisor training is mandatory for staff and must be regularly refreshed.

Each School's PGR Director oversees support for the student community, monitoring progress through defined progression points in the PhD journey and identifying and resolving issues at an early stage through the supervisory team and ADRI. Progression is formally monitored at SREC and these committees include PGR representatives to provide a student voice in research decision-making. Students have monthly formal meetings with their supervisory team, ensuring there is a common understanding of expectations and that an excellent supervisor-supervisee relationship develops. To help with communication, work quality and student experience, PGRs are often co-located with their supervisors within their Research Groups. Many wish to assist with teaching and also have opportunities to work with visitors from UK and overseas universities, e.g. from the University of Twente, Delft University of Technology, University of Bath, Sao Carlos University Brazil, University of British Columbia Canada and Shanghai Jiao Tong University, China. Several of our PGRs have spent time in Canada and the USA, supported by Santander scholarship programmes.

PhD students are encouraged to work alongside ECRs and more experienced academic staff to co-organise research seminars, developing their skills while supporting the research culture. PGRs are supported to attend external research seminars and conferences with national and international audiences and benefit from an individual annual stipend towards their development, e.g. for conference attendance, which can be supplemented by the institution-wide PGR conference fund, supervisor discretionary funds and external grants.

The research training provided at Salford ensures PhD graduates can succeed, whether their choice is an academic, industry, government or clinical career. Post-qualification destinations of our PhD graduates since 2014 have included:

- ***Academia**:* Angmorterh, Acting Head of Department, University of Health & Allied Sciences, Ghana; David, Lecturer at University of Sharjah, UAE; Mraity, Professor at the University of Kufa, Iraq.
- ***Clinical**:* Alharbi, King Fahd Medical City, Saudi Arabia; Alrayani, Saudi Arabian Military Forces.
- ***Industry**:* Panwar, Randomlight Ltd.; Rajab, Hematogenix.
- ***Government**:* Prior, Senior Research Associate, Equality and Human Rights Commission.

Our students have been recognised in their disciplines for the quality of their research. Selected PhD student prizes include:

- Alqurashi, Best Presentation. International conference on Next Generation Sequencing in Biology, Rome, 2019.
- Anderson, 'Young Investigator Award' at the 13th Biennial 'Footwear Biomechanics Symposium', Australia 2019.
- Chadwell, Sun and Pace finalists in STEM for Britain (House of Commons) 2016 and 2020, Best Student Presentation, Myoelectric Controls symposium, Canada 2018 and runner-up in IMechE Healthcare Engineering Awards 2019.
- Tarabulsi, Best Presentation, International Conference on Medical Parasitology and Microbiology, Barcelona 2019.

Equality, diversity and inclusion (EDI)

Consistent with doing research with those who have a disability or other health challenges, we value diversity in personal and professional identities, promote an ethos of complementarity and offer equality of opportunity. We embed EDI into our research culture in line with the University's policy of an action-based strategy. In alignment to our REF2021 code of practice, during the production of REF2 we conducted an equality impact assessment and determined that 53% of outputs are attributed to women, compared to REF1a, which is 60% female, and that 7% of outputs are attributed to staff from a BAME background compared with a proportion of 9% in REF1a. We recognise that these discrepancies reflect our lower proportion of female and BAME staff at higher grades and are committed to addressing this in the next cycle.

EDI strategy is informed by work with the University's Inclusion & Diversity Manager, so that local policy and actions are linked to institutional policy and practice. We hold two bronze Athena SWAN awards made to the Schools that contain BRC and HSRC. Staff are supported on an individual basis by their line manager where they can report difficulties due to health, caring and/or equality of opportunity as related to protected characteristics. This has been used to make reasonable adjustments for staff whether this be financial support for return to work after maternity targeted to the needs of the individual and their activities, relocation, or adjustments to workload to increase research time. All internal funding opportunities are made available openly whether these are at School or Centre level and decisions are made by suitably diverse panels. Staff on appointment panels have completed unconscious bias and active bystander training and panel composition is overseen by HR professionals to comply with EDI policy.

The EPSRC CDT is an exemplar of our EDI strengths. It has a specific staff member designated as EDI champion and a £15k budget to support EDI developments. EDI data on PGR applications, interviews and studentship offers are monitored by a management board. There are active conversations about valuing PGR applications from those with non-traditional academic journeys e.g. a refugee who accessed A-level and foundation degrees through colleges at their own cost, prior to considering PhD study. Data on supervisor characteristics is collected alongside academic data to monitor and respond to trends that indicate bias. PGR students and all supervisors are provided with EDI training and EDI is a standing item on the management agenda.

PPIE is now firmly established in all our major projects in HSRC and CSHR as an essential step in a high-quality research process. **Prior** acts as PPIE in many major projects and because of this she was selected for the NHS North West R&D Wonder Women Series. Our PPIE practices include training for all members of the public who participate and clear roles for a PPIE panel in the design and delivery of research projects, as well as the research itself. All PPIE engagement is costed at nationally agreed rates and often includes PPIE process evaluation (where funding allows). Separately, a Care Home focused Community of Practice was developed over 18 months (**Hollands**) through multi-faceted engagement activities and supported experiential learning for the research centre. Other recognition of our EDI culture include comments from a NIHR Programme Grant under review (**Nester** £2.5m programme grant) that our proposal showed '*widespread incorporation of the patient voice and experience*', was an '*exemplar illustrating how to be inclusive*' and that *'The collaboration between the research team, academics, stakeholders, organisations, charities, patients and public is inspirational'*.

3. Income, infrastructure and facilities

Growth in research income

The combined REF2014 income for UoA3 and UoA5 stood at £7.5m with no consistent growth over the period. In contrast, our income for this REF period is £13.8m and has **increased year on year, from just over £1m in 2013/14 to £3.1m in 2019/20**. Our income from Research Councils is 10% of total income and has **increased by 119%** from £652k in REF2014 to £1.43m, and income from UK charities, which forms 21% of total income has **increased by 212%** from £948k to just under £3m. We received most funding from UK central government/industry, totalling £5.64m (41% of the total), alongside £2.48m (18%) of income from non-EU sources (predominantly charitable foundations) and £1.25m (9%) from European sources.

Our income relates to 343 projects active during the census period and 58 of these continue into the next REF period. Our diverse staffing strategy focused on key health challenges means that we are competitive when applying to a wide range of funding bodies. For example, in HMR we have gained funding from clinically focused funders, such as MRC and NIHR as well as EPSRC and WHO. As our body of experienced PIs has grown, we have implemented a grant-writing mentoring process, targeting ECRs. For experienced researchers, grant acquisition is a key component of their annual objectives, as is moving away from smaller grants to larger and longer-term funding and recovering a higher proportion of the costs (fEC). Examples of larger Research Council funded projects are:

- EPSRC £5.5m (£2.8m to Salford) 2019-27 – Centre for Doctoral Training in Prosthetics and Orthotics, alongside our partners at Imperial College, Southampton and Strathclyde (**Granat**, **McAdam**, **Nester**)
- EPSRC £1.8m (£200k to Salford) 2015-19 – Adaptive Assistive Rehabilitative Technology: Beyond the Clinic (AART-BC) (**Kenney**)
- EPSRC £1.4m (£421k to Salford) 2018-22 – EPSRC/NIHR Global Challenges Fit-for-purpose prosthetics project (**Head**, **Kenney**)
- EPSRC £909k (£53k to Salford) 2018-22 – A Step Change in LMIC Prosthetics Provision through Computer Aided Design, Actimetry and Database Technologies (**Granat**, **Kenney**)
- MRC & Versus Arthritis £1.4m, with a further £2.2m in 2019 (£111k to Salford) 2014-24 – National Centre of Excellence for Musculoskeletal Health and Work (**Hammond**, **Prior**)
- MRC £148k (£127k to Salford) 2019-20 – Developing and testing a parenting intervention and manual for children with foetal alcohol spectrum disorder (FASD) (**Cook**).

To support the impact of our work, via clinical guidelines, novel technologies and translation into practice, we have targeted applied clinical funders, including NIHR and local government awards:

- NIHR HTA £1.56m (£198k to Salford) 2019-22 – Foot orthoses to children with symptomatic flat feet (**Parker**)
- NIHR PHR £905k (£252k to Salford) 2018-21 – A three-arm cluster randomised controlled trial to test the effectiveness and cost-effectiveness of the SMArT Work & Life intervention for reducing daily sitting time in office workers (**Clarke-Cornwell**, **Granat**)
- NIHR PHR £774k (£429k to Salford) 2017-22 – Communities in Charge of Alcohol (CICA) Programme: Evaluation of an alcohol health champions programme in Greater Manchester (**Coffey**, **Cook**)
- NIHR i4i £569k (£332k to Salford) 2013-17 – A practical, yet flexible functional electrical stimulation system for upper limb functional rehabilitation (**Kenney**)
- NIHR RfPB £316k (£30k to Salford) 2017-20 – Refining and testing the diagnostic accuracy of an assessment tool to predict admission and discharge of children who attend an emergency department (**Long**)
- NIHR RfPB £160k (£120k to Salford) 2018-20 – The feasibility of using Biofeedback to reduce Pain in people with Knee Osteoarthritis (BEPKO) (**Jones**, **Preece**, **Williams**)
- Health Education North West £250k 2014-18 – Social media peer support networks for women during pregnancy (**Ormandy**)
- Greater Manchester Health and Social Care Partnership £145k (£130k to Salford) 2019-21 – The first UK project that aims to estimate prevalence of foetal alcohol spectrum disorder (**Cook**).

We secured nine Innovate UK KTP partnerships and nine Industrial Case Studentships. As noted in Section 2, our strategy of recruiting from the talent pool working on externally funded projects has been fruitful. For example, a previous KTP associate (**Price**) is now an ECR on a permanent contract with two KTP awards, with impact included in REF3. Selected projects are:

- KTP WearerTech Ltd. £221k 2017-19 – Footwear in occupations that involve prolonged standing (**Nester**, **Price**)
- KTP Dynamic Health Systems £103k 2014-18 – Evaluation of VitruCare™: usage health outcomes and productivity enhancement to enable rapid deployment at scale (**Ormandy**)
- ICASE Falklands Islands Government £94k 2018-22 – Transmission and control of Echinococcosis and other Taeniid infections in the Falkland Islands (**Rogan**)
- ICASE Shandong BetR Medical Technology Co. Ltd £65k 2019-23 – Further innovations to the functional electrical stimulation system (**Kenney**).

Work funded by UK charities has further established our profile and outreach in areas related to arthritis and podiatric care:

- William Scholl Podiatric Development Funds, £1.5m (£755k for Salford), 2016-21. SMALL Steps – Five-year research programme on the development of babies' feet and health behaviours of parents and children (**Nester**, **Price**, **Williams**)
- Versus Arthritis, WORKWELL trial, £651k (£360k for Salford) 2018-21 – Evaluating job retention and work rehabilitation (REF3) (**Hammond**).

We have acquired over **£2.5m** of funding from the Healthy Life Foundation (**Lisanti, Sotgia**) and The Foxpoint Foundation (Canada) for an industrial research contract with Lunella Biotech, Inc. (Canada) (**Lisanti**), and, also from industry, **Jones** has been funded by BAE Systems into understanding gender influences on injury risk when carrying heavy loads.

Research infrastructure and facilities

Biomedical research facilities

Research infrastructure for BRC is shared between the different research groups and across Centres. The **£3.2m Bodmer laboratory** and **£1.6m, 600m^2 Translational Medicine (TM) lab** opened in 2015 and are part of a large-capacity teaching and research facility. This environment can be used flexibly for research spanning pharmaceutical science, human physiology, infectious diseases research, clinical and molecular genetics, medical biochemistry and clinical immunology. Research students are trained to use modern, leading-edge laboratory equipment that will typically be found in hospitals, industry and research institutes. **Salford Genomics Facility** was established in 2015, receiving **£525k to establish DNA sequencing and bioinformatics** capabilities, which now underpins research by **Goodhead**, **James** and **Rogan** and is also used by CDP, CRP and molecular ecologists within the Ecosystems and Environment Research Centre in SEE. Salford's first **cardiac physiology lab** was established by **Greensmith** in 2014. Through external grants of £200k (including Royal Society, British Heart Foundation), the lab provides equipment, such as a cardiac cellular physiology rig and Confocal Microscope with a custom-built perfusion system and cell stimulation apparatus**.** This set up is one of few capable of confocal and conventional (rig) photometry with patch clamping to allow direct measurement of all components of excitation-contraction coupling in isolated heart cells.

In line with the strategy of increasing capacity for inter-disciplinary research, BRC invested £40k in a unique instrument for nanoscale characterisation: a CPS Disk Centrifuge DC2400 UHR. Through this and the strategic positioning of a nanobiotechnologist (**Krpetic**), the unit is now poised to grow further towards a fully equipped **nano-technology laboratory**. A significant portion of the industry funding for CDP research (**Lisanti and Sotgia**) has been used to purchase new equipment to create a **drug discovery laboratory**, reinforcing the overall infrastructure.

Gait labs

We have a strong heritage in gait laboratory work from fundamental methodological approaches (Baker, **Jones**) to more applied clinical studies (**Hollands**, **Jones**, **Preece**, **Thies**). Since 2014, and to embed research into clinical practice and consolidate partnerships, **three new gait laboratories have been established bringing the total available to six**. The first is within the NIHR Clinical Research Facility in Central Manchester and supports the world-leading 'Research in OsteoArthritis Manchester' team (**Jones**). The second (measuring 60m by 15m) is in the Manchester Institute of Health and Performance where Salford provides the Research oversight for the sports medicine facility (**Herrington**, **Jones**) and is key to delivering the Enhanced Rehabilitation Programme for individuals injured in the 2017 Manchester Arena terrorist attack. These facilities are used to support a range of human movement research, including elite sport (**Comfort**, **Herrington**, **Jones**) and as test centres for new Prosthetic/Orthotic products and services (London Orthotic Consultancy, Blatchfords, Ossur) and globally leading motion analysis companies Qualisys and Vicon. Finally, the University has dedicated and equipped **the world's first movement lab designed specifically to measure crawling and early walking in young children, supported by a five-year award (£754k)**. In addition to these facilities, equipment for data collection is regularly moved to our industry partner sites, including Scholl footcare and the network of primary schools that support Clark's footwear.

Psychology labs
In 2018 the University invested **£285k to build five new Psychology labs** equipped with neuroimaging and stimulation of brain activity assessment equipment, state-of-the-art eye-trackers and virtual reality headsets. Our state-of-the-art **Counselling and Psychotherapy Centre** has been used to research a model of counselling practice and a competency framework. Developed through research with survivors of domestic violence this resulted in a specialist counselling service now integrated with agencies across Greater Manchester (City Council, Mental Health Service, Mind and local IAPT services). Client progress is monitored through a range of outcome measures which will be compared with usual treatments for domestic violence survivors to influence future policy and practice (**Roddy**, **Widdowson**). The Centre is part of a research consortium including York St. John University, Abertay University and Newman University collecting data across the four institutions to examine the outcomes of humanistic therapy.

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

A strategic approach to industry and clinical collaborations

One of our strategic aims post-REF2014 was to convert collaborations into longer-term partnerships and embed clinical partners and service users into our research. We took opportunities to drive innovation through new partnerships with SMEs in traditionally technology-averse areas, such as footwear, walking aids and leg ulcer management. This strategy was well aligned with the University's vision 'to pioneer exceptional industry partnerships' and its implementation has been shaped in part by the devolution of health and social care responsibilities to the Greater Manchester region.

Consolidating and extending existing partnerships
Numerous examples illustrate success in deepening our relationships with industry, charities and hospitals. At the start of the REF period Baker and **Jones** had well-established and high impact collaborations with world-leading motion analysis companies Qualysis and Vicon, who together cover 80% of the global market (REF3). These collaborations were evolved via a five-year Fellowship supported by the University and company funding (Vicon £50k, Qualysis £44k) and Salford is now the test site for Qualysis products. A well-established collaboration with sector-leading footcare brand Scholl was drawn into a partnership model (**Parker**) to provide co-ordination of multiple cross cutting research, education and consultancy activities. This is underpinned by a sabbatical year for **Hashmi**, two PhD studentships and a KTP. **Ormandy** and colleagues built on well-established relationships with UK kidney charities and Salford Royal Foundation NHS Trust to co-design an online resource for kidney patients (REF3) via funding from Kidney Care UK, British Renal Society, Kidney Patients Association and others. **Prior** consolidated established collaborations with clinicians and patients to establish an online self-management platform (mskhub.com) using internal funding (REF3). The partnership with UK prosthetics leader Blatchford, which dated back to the early 1990s, has been consolidated via EPSRC and NIHR funding and in-kind support for the CDT. In the area of radiography research, the targeted use of honorary contracts enabled a network of collaborators from multiple NHS trusts to deliver a multi-centre trial showing the key role played by breast compression in mammography.

New partnerships driving innovative technologies
Innovate UK Knowledge Transfer Partnerships (KTP) have been an important vehicle for developing new partnerships. A collaboration with Toffeln Footwear (**Nester**, **Price**) led to a new company, WearerTech Ltd., producing footwear designed by Salford (sold 60,000 pairs) and was rated in the top 3 out of >600 projects for 'Best KTP Partnership' (REF3). A KTP with the global Clark's children's footwear brand is capitalising on their network of schools to collect large volumes of data on children's feet and connecting this with footwear design. A similarly innovative collaboration with NRS Healthcare (**Thies**) led to one of the first KTPs in the walking aids sector to design evidence-based walking aids. Funding from the EU SME schemes (£390k to Salford) supported OTIVIO AS (Norway) in their innovation of negative pressure devices for leg ulcer management. Lastly, a collaboration with Volpara in New Zealand led to novel breast imaging software (REF3).

Partnerships shaped by the devolution of health and social care responsibilities to Greater Manchester

A new collaboration with the Manchester Institute for Health and Performance, included work with survivors of the Manchester Arena terrorist attack (£330k, WeLoveManchester, CCG). We are a partner in the 'Cities Changing Diabetes' programme, initiated by Novo Nordisk, which brought together 20 cities from across the world to address the diabetes epidemic. We have engaged with Greater Manchester Health and Social Care Partnership to lead the Teaching Care Homes (TCH) initiative focusing on improving quality of care in care homes. This includes a Salford-initiated collaboration with Schlegel Research Institute for Ageing/Care Homes, Canada and produced a 'Community of Practice' highly valued by Care Home management, staff and residents. This is now a national model for care transformation involving international collaborations. We also developed the first evidence-based guidelines on walking aid use. The collaboration with Northern Care Alliance has been supported by Honorary Professorships, joint Professorial appointments and joint research working, spanning all 3 Research Centres. Many staff are active members of pan-Manchester research clusters, specifically in the 'Inflammation and Repair', 'Cardiovascular' and 'Neuroscience' domains. **Nester** is contributing to strategic planning for the Northern Care Alliance 'Institute for Trauma' and re-established a Greater Manchester AHP research hub (via CAHPR).

Supporting public engagement with health and bioscience research

Salford's close working with broadcast media companies is used to reach a wide audience, bringing health and biomedical research findings to the public's attention. Media appearances include **Bramah** and **Preece** (featured in a BBC 'Get Fit' programme), **Goodhead**, **James** and **Withers** (BBC, ITV, Channel 4, National science festivals at Manchester and Cheltenham, Bluedot Festival), **Hogg** (BBC Radio Manchester), **Jones** (BBC North West) and **Thies** (BBC radio news Manchester). At Manchester Science Festival (MSF) in 2018, the BRC organised MicroBiHome; a mixed-media installation inspired by the microbiome that brought together artists, scientists, technicians and communicators to bring microbiology to the public. Our prosthetics work featured in *'You have been upgraded'*, a collaboration with a theatre company described by Visit Manchester as a 'futuristic, science-inspired mash up of The Graham Norton Show meets Top of the Pops'. **Nester** and **Price** have produced videos and podcasts to support their child foot health research, 'Great Foundations' and commissioned an award-winning children's author to pen a science book about feet.

Academic collaborations changing the global health arena

Global health and healthy ageing are key foci, exemplified by innovative collaborations between social scientists, clinicians, engineers and bioscientists. A collaboration between social scientists (Ackers) and bioscientists (**James**, **Goodhead**) addressing antimicrobial resistance led to reduced deaths from sepsis, reduced patient hospital stays and created an evidence-based model for improved anti-microbial stewardship (REF3). **Hide** established a successful collaboration in China around the host-immunity surrounding chronic Toxoplasmosis with implications to human multimorbidity and mental health. **Goodhead**, **Hide** and **James** have developed research Memorandums of Understanding with the Universities of Makerere, Gulu and Mountains of the Moon, Fort Portal (REF3), addressing parasitology, DNA sequencing and analysis, and mentoring research staff in international funding schemes (UKRI, charitable funders). **Goodhead** has a visiting lectureship (since 2018) with Gulu University and has led training sessions in DNA sequencing and analysis for Gulu researchers, mentoring research staff in international funding schemes (UKRI, charitable funders). **Nirmalan** is developing novel drugs for malaria treatment, including novel intellectual property, through collaborations in Nigeria to identify novel molecules from natural compounds, and India, for optimisation of dehydroemetine for repositioned use in malaria.

Baker, (funded by US Agency for International Development) collaborated with partners at Isfahan University (Iran) on work which contributed to the WHO/ISPO Standards for prosthetics and orthotics. **Kenney** and **Nester** contributed to the WHO Great Consultation event in 2019. Funded

collaborations in this domain now include UCL, Imperial College, University of Southampton, University of Jordan, Makerere University (Uganda) and the Cambodia School of Prosthetics and Orthotics. The collaboration with the latter was consolidated via the award of a PhD studentship (£140k) for the lead clinician to study for a PhD through the CDT. **Kenney** and **Granat** lead Salford's contribution to the global Exceed Research Network, an international disability research consortium involving universities, NGOs and private sector organisations from Australia, Europe, SE Asia, UK and USA.

Granat is a pioneer in real-world monitoring of physical behaviours. Building on his work with BioBank he developed a collaboration with Harvard, UCL, University of Sydney and others. This aims to bring together existing and future observational studies of thigh-worn accelerometry via a new digital platform: The Prospective Physical Activity, Sitting, and Sleep consortium (ProPASS). Collaborations with researchers in osteoarthritis have been further developed over the period. These include University of Manchester ROAM research group, Boston University (USA), University of Bern, University of Zurich, University of Toronto and University of British Columbia and have led to key publications in the field (JAMA 2020 Altmetric >100) (**Jones**). **Nester** leads Salford participation in the global 'Cities Changing Diabetes' programme, a network of 20 cites focusing on policy to manage risk of diabetes.

Contributions to the sustainability of the research base

All staff contribute to supporting the activities of their respective disciplines via journal editorships, membership of Research Council and funding body panels, leadership of special interest groups, and governance of learned societies. Salford staff have led and chaired international conferences and symposia, contributed to policy development and public engagement events.

Leadership positions within international societies
Staff consistently demonstrate a global presence in their field: **Granat** is a founding member and current president of the International Society for the Measurement of Physical Behaviour (ISMPB). Their annual conference attracts >300 delegates and launched the *Journal for the Measurement of Physical Behaviours*. **Granat** was instrumental in the formation of ProPASS (see above). **Tume** is the past nursing president of the European Society of Paediatric and Neonatal Intensive Care (ESPNIC). **James** is chair of the impact and influence committee for the Microbiology Society (from January 2020) leading on publishing strategies and the role of digital technologies in academic communication. **Prior** has received a Royal College of Occupational Therapists Merit Award for Outstanding Contribution to the Occupational Therapy Profession in 2017. **Hammond** was awarded a Fellowship of the British Health Professionals in Rheumatology/British Society of Rheumatology in 2014 for outstanding contributions to Rheumatology.

Selected international conference keynotes and invited papers
Hammond (Casson Memorial Lecturer, Royal College of Occupational Therapy 2014, British Society of Rheumatology Droitwich Lecture), **Nester** (*World Congress of Biomechanics* 2014, *4th Congress of the International Foot and Ankle Biomechanics*, Annual conference of Society of Chiropodists and Podiatrists, 2017 and 2018), **Krstic-Demonacos** (*23rd World Congress on Advances in Oncology* and *International Symposium on Molecular Medicine*, Greece, 2015-2018; University of Antwerp, 2017), **Granat** (*International Conference on Ambulatory Monitoring of Physical Activity and Movement* 2017 and 2019), **Jones** (*Scandinavian Conference in Prosthetics and Orthotics* and *ESMAC* 2018), **Comfort** (*NSCA*, Washington 2019), **Herrington** (*International Ankle Symposium*, Amsterdam 2019), **Hollands** (*Robot Assisted Rehabilitation National Symposium*, Czech Republic, 2019).

Selected Chairing of international conferences
Hide (*International Conference on Parasitology*, Philadelphia, USA, 2015; *Chinese Protozoology Society Biodiversity Conference*, Guangzhou, China, 2017; *International Conference of Parasitology*, South Korea, 2018), **Thies** (*XV International Symposium on 3D Analysis of Human Movement*, 2018), **Hollands** (*International Society for Posture & Gait Research*, 2019), **Howarth**

(*2nd International Social Prescribing Research conference*, 2019) and **Kenney** (Europe's upper limb prosthetics conference, *TIPS*, 2019.

Selected Journal Editorships

Staff have roles as editors in over 39 journals; four individuals (**Coffey**, **Comfort**, **Herrington**, **Tume**) are editors-in-chief for: *International Journal of Workplace Health Management, Journal of Strength and Conditioning*, *Physiotherapy in Sport* and *Nursing in Critical Care* respectively and seven contribute to editorial boards, e.g. *Parasitology* and *Radiography*. Members also served on editorial boards for *Frontiers Open Access* aligning technological developments in health (**Jones**, **Prior**). All groups within the submission contribute to peer reviewing for journals and/or professional practice publications.

Peer reviewing for funding bodies

UoA3 staff are represented on numerous funding and strategy panels: British Health Professionals in Rheumatology Scientific Committee (**Hammond**, **Prior**); Starworks Advisory Committee (**Head**); College of Radiographers - CORIPS grant panel member **(Hogg)**; Inspire Foundation – chair (**Kenney**); Versus Arthritis Musculoskeletal Disorders Research Advisory Group (**Jones**); NIHR Clinical Lecturer/Senior Clinical Lectureship Scheme Review Panel (former deputy chair of NIHR topic Identification panel); NIHR Fellowship panel (**Nester**); William Scholl Foundation (**Nester**); NIHR HTA Funding panel (**Tume**); National Wound Care Strategy (**Webb**).

Nester is also the lead for the Greater Manchester Hub of the Council for Allied Health Professions Research giving a focal point to GM based AHP research initiatives. **Kenney** has been on the panel for EPSRC as well as UKRI/COVID-19 panels.