Institution: University of Leeds
Unit of Assessment: 2

1. Unit context and structure, research and impact strategy

Our research advances and applies methods to address major health and healthcare challenges. We develop and evaluate treatments, technologies and complex interventions using innovative mixed method, observational and trial designs. Our interdisciplinary collaborations harness expertise in trials, epidemiology, data sciences, behavioural and social sciences, health economics, and clinical disciplines. Extensive national and international collaborations, including low and middle-income countries, underpin our work.

The University of Leeds UoA2 submission includes 49.6 full-time equivalent staff in the School of Medicine within the Faculty of Medicine and Health (FMH). Our strengths within Public Health, Health Services and Primary Care research unite around three main themes:

Theme 1: Applied Health Research within the Leeds Institute of Health Sciences (LIHS);
Theme 2: Clinical Trials Research within the Leeds Institute of Clinical Trials Research (LICTR); and
Theme 3: Population Health Data Science within the Leeds Institute for Data Analytics (LIDA).

In practice, there is considerable cross-institute collaboration between these themes.

Achievements during the census period

This statement specifies how we have achieved goals set out in 2014:

- Establishing platforms and innovative methods for early phase clinical trials to accelerate the evaluation and delivery of cancer treatment;

- Promoting interdisciplinary development and evaluation of novel interventional technologies, biomarkers and other diagnostic tests;

- Exploiting large datasets from national disease registries, clinical audits and cohorts with state-of-the-art data analytics to advance the epidemiology of cancers and cancer care whilst expanding our cardiovascular disease portfolio;

- Leading both complex and efficient trials to evaluate complex interventions and advancing causal inference methods; and

- Delivering ambitious, policy-relevant research focused on population and health services priorities (e.g. older people and frailty, communicable disease control) across a range of settings (e.g. primary care, low and middle-income countries).

Headline achievements include:

- Delivery of high-impact research across the themes, with average annual research income rising from £7.8m in REF2014 to £10.3m during the present period, sustainably supported by a diverse range of funders.

- Major investments in establishing the £3.1m Wolfson Centre for Applied Health Research and LIDA, which hosts the £6.9m MRC Bioinformatics Centre and the £11m ESRC Consumer Data Research Centre.

- Major platform awards demonstrating substantial collaboration, such as a partnership bringing together the Faculties of Engineering, Biological Sciences, and Medicine and Health to accelerate the development of infection diagnostics tools to tackle antimicrobial resistance (£3.8m, MRC), the UK Bowel Cancer Intelligence Hub (£3.4m, CRUK), the Leeds In Vitro Diagnostics Co-operative (£1.3m, NIHR), the Yorkshire Cancer Research (YCR) Early Phase Clinical Trials Centre (£1.4m), the Leeds Surgical MedTech Cooperative (£1.4m, NIHR), the

Leeds CRUK Clinical Trials Unit (£2.1m, CRUK) and CONCORDE, the first early phase radiotherapy trials platform (£0.8m, CRUK & £0.8m, Astra Zeneca),

- A substantial portfolio of programme and large-scale trial awards, such as Community-led Responsive and Effective Urban Health Systems (ChoRUS, £7.9m, DFID), the Yorkshire Lung Screening Trial (£5.2m, YCR) and FLAIR for chronic lymphocyctic leukaemia (£3.4m, Abbvie).

- Partnerships in both the £9m NIHR Applied Research Collaboration (ARC) Yorkshire and Humber and the £4.8m NIHR Yorkshire and Humber Patient Safety Translational Research Centre, which bring together academics from different UoA2 themes as well as UoAs3&4.

- Strategic senior appointments comprising chairs in health economics (**Bojke**), primary care research (**Richards**), primary care oncology (**Neal**), and clinical trials research (**Stocken**). We have benefited from the University's £100m investment to recruit internationally competitive future academic leaders across core disciplines (*250 Great Minds*), appointing six within UoA2 (**Smith, Beeken, Ziegler, Allsop, Mulvey** & **Rousseau**).

- 1677 papers published over the census period by UoA2 staff, with 42% involving international collaborations (Figure 1), 25% in the top 10% of those cited worldwide, and 52% published in the top 10% of Scopus Sources.
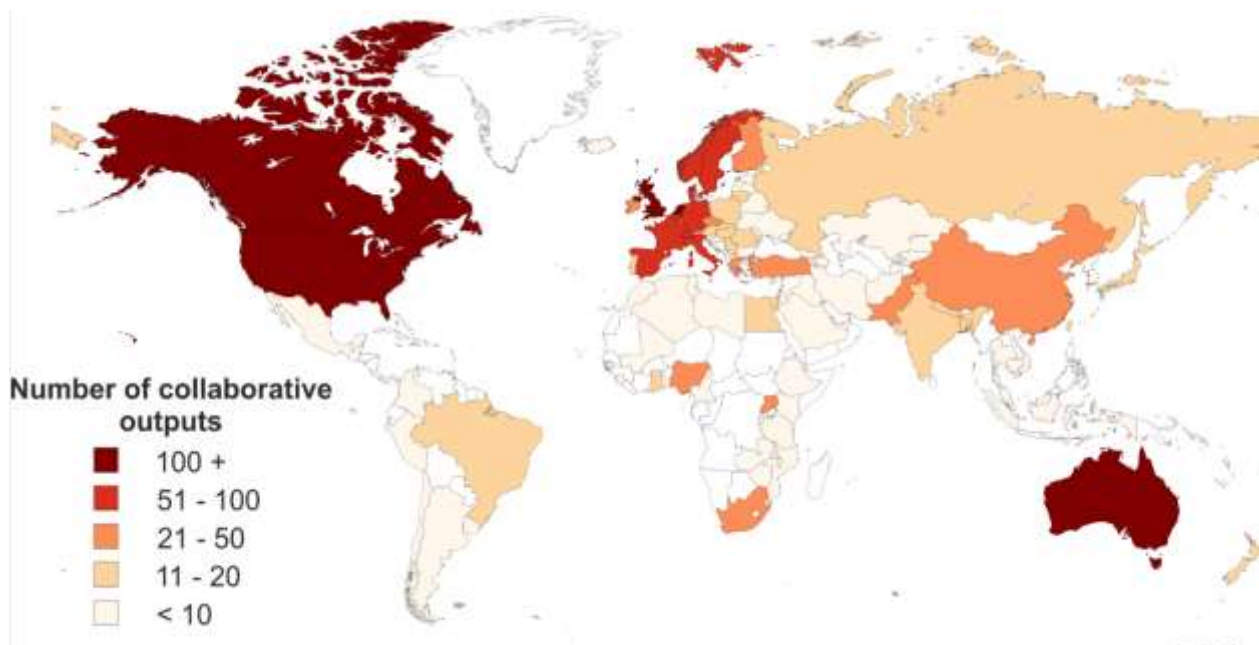

Figure 1. Collaborative outputs.

Research and impact strategy

Our overarching aim is *to deliver internationally leading, cutting edge and methodologically robust research that improves the quality, equity and efficiency of healthcare and population health*. Our problem-based research responds to national and international research user priorities in addressing:

- **Enduring challenges**, e.g. health inequalities, managing demand with finite resources;
- **Emerging challenges**, e.g. multi-morbidity and frailty, in global health; and
- **Emerging opportunities**, e.g. innovative complex trial designs, causal inference methods.

The scale and complexity of such challenges demands interdisciplinary partnerships within Leeds, such as those amongst researchers submitted in UoAs 1-5, 7, 11, 12, 14 and 19, and nationally and internationally. Our research is aligned with the School of Medicine strategy, focused on areas of international excellence and encompass the full translational pathway, including **global health**, **ageing**, **cancer** and **cardiovascular disease**.

We actively embed pathways to impact within our research, through strategic partnerships spanning patients, carers and the public, health and social care providers and commissioners, third sector and charitable bodies, policymakers, professional bodies, and industry. For example, the University co-founded the Leeds Academic Health Partnership (LAHP) in 2015, bringing together expertise from all the NHS organisations in Leeds, three of the city's universities, and Leeds City Council. The Partnership, one of the biggest of its kind in the UK, aims to accelerate innovation and improve health and wellbeing by engaging academic capabilities in education and research with the health and social care system across the city. We can demonstrate complementary approaches to impact through collaborative partnerships (Figure 2), including:

- Effective *end user involvement* and using appropriate *research designs* to ensure policy and practice relevant findings;
- Translating research into *national guidelines* and *care pathways*;
- Collecting and analysing data to provide *intelligence for improving policy and services*;
- *Training for service providers* in health, social care and voluntary sector organisations;
- Funding *knowledge mobilisation* initiatives and embedding *knowledge transfer* throughout all stages of research;
- Promoting understanding and use of research through *public events and the media*; and
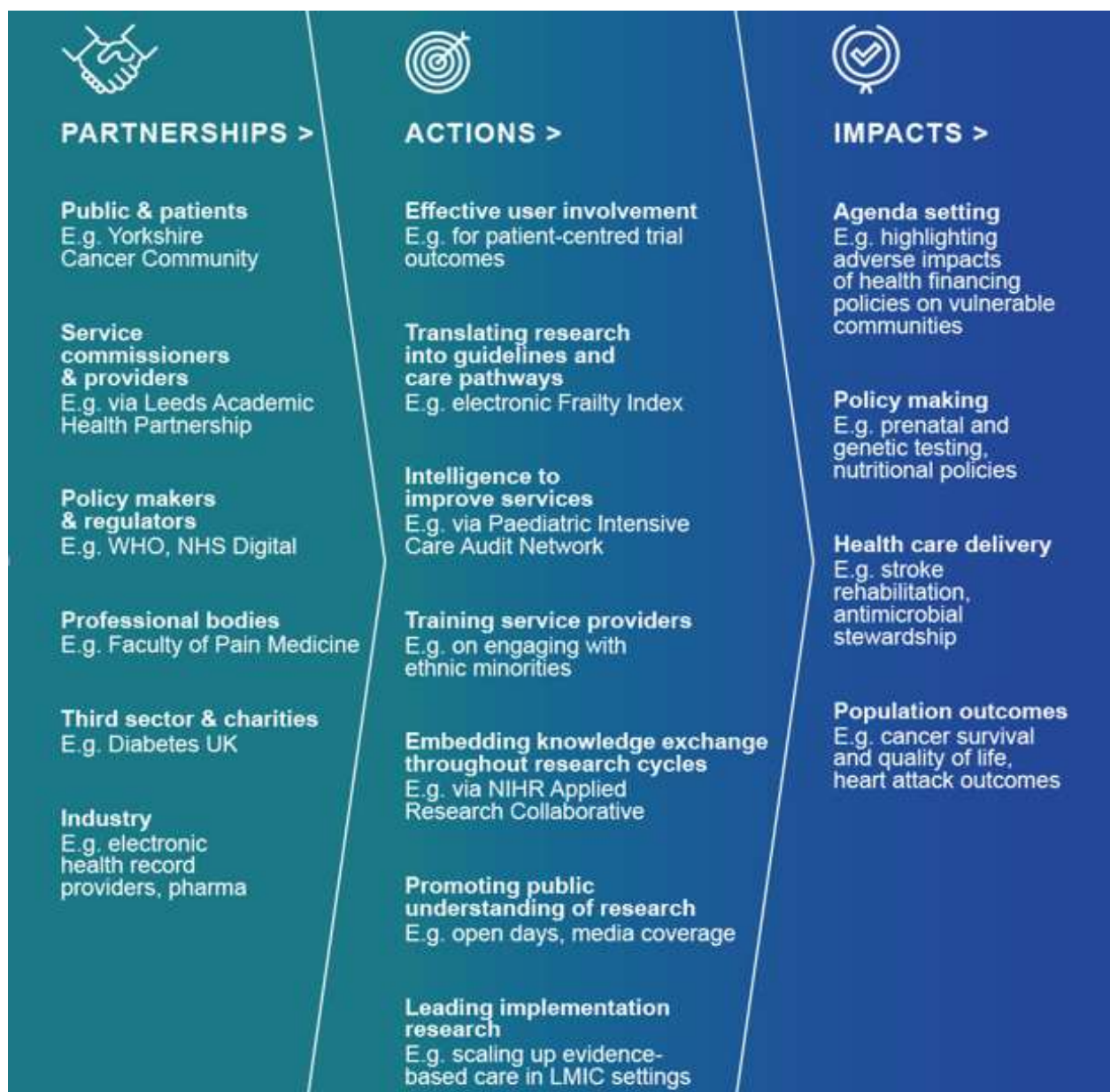- Leading *implementation research* to close gaps between evidence, policy and practice.

PARTNERSHIPS >

Public & patients
E.g. Yorkshire Cancer Community

Service commissioners & providers
E.g. via Leeds Academic Health Partnership

Policy makers & regulators
E.g. WHO, NHS Digital

Professional bodies
E.g. Faculty of Pain Medicine

Third sector & charities
E.g. Diabetes UK

Industry
E.g. electronic health record providers, pharma

ACTIONS >

Effective user involvement
E.g. for patient-centred trial outcomes

Translating research into guidelines and care pathways
E.g. electronic Frailty Index

Intelligence to improve services
E.g. via Paediatric Intensive Care Audit Network

Training service providers
E.g. on engaging with ethnic minorities

Embedding knowledge exchange throughout research cycles
E.g. via NIHR Applied Research Collaborative

Promoting public understanding of research
E.g. open days, media coverage

Leading implementation research
E.g. scaling up evidence-based care in LMIC settings

IMPACTS >

Agenda setting
E.g. highlighting adverse impacts of health financing policies on vulnerable communities

Policy making
E.g. prenatal and genetic testing, nutritional policies

Health care delivery
E.g. stroke rehabilitation, antimicrobial stewardship

Population outcomes
E.g. cancer survival and quality of life, heart attack outcomes

Figure 2. Approach to impact.

Achievements by research theme

Whilst our research is represented under three main themes (***Applied Health Research, Clinical Trials Research***, *and **Population Health Data Science***), our interdisciplinary approach typically cuts across these themes and demonstrates extensive collaboration across multiple UoAs.

> Notation: **returned staff**; *returned, retired or former staff with visiting status*; <u>staff returned in other UoAs</u>; and *non-returned early career researchers*

Theme 1: Applied Health Research

This theme focuses on understanding problems in healthcare and health, and evaluating interventions to improve outcomes. We evaluate interventions targeting individual, organisation and system levels of healthcare. Our research emphasises pragmatic, rigorous evaluation designs; innovative uses of routinely collected data; and policy, public and practitioner partnerships from design to dissemination – collectively ensuring 'real world' relevance. Our work is grouped around *Age-related Research, Global Health, Cancer and Palliative Care, Health Economics,* and *Health Services Research*.

Age-related Research (**Forster, Clegg, Godfrey, Hawkins, Richards, Teale**) addresses the challenges facing an ageing population by developing and evaluating models of care. Highlights include leadership of two of the world's largest ever stroke rehabilitation trials, which demonstrated that neither family-led rehabilitation in a low-resource setting nor a new system of longer-term care were superior to usual care (UOA2-618, UOA2-617). We developed the electronic Frailty Index (eFI) with The Phoenix Partnership, and Universities of Birmingham and Bradford. The eFI reliably identifies older people with frailty without the need for resource-intensive clinical assessment and enables evidence-based, proactive models of integrated care (UOA2-2413). It has been implemented in the *SystmOne* and *EMISWeb* primary care electronic health record systems, which together provide around 90% UK coverage (Impact case study UOA2-1).

Global Health (**Mirzoev, Ebenso, Ensor, King, Mir, Walley**) embeds research within national and global health programmes in response to changing disease patterns in low-resource settings, prioritising antimicrobial resistance and non-communicable diseases. Highlights include demonstrating the adverse impacts of health financing policies on vulnerable communities (UOA2-4309) and an intervention achieving sustained reductions in antibiotic prescribing in children (UOA2-266). Our evidence-based care package for <u>non-communicable diseases</u> (e.g. UOA2-267) has been adopted by and scaled up within national and provincial programmes in Pakistan, China, Nigeria, Eswatini, and Sierra Leone.

Cancer and Palliative Care. Our cancer research (**Neal, Beeken, Jones, Smith**) aims to prevent cancer and improve outcomes after diagnosis by promoting behaviour change, and addressing poor cancer outcomes through earlier diagnosis using clinical, biomarker and screening strategies. Achievements include demonstrating that increased times to diagnosis and treatment in symptomatic cancers are associated with poorer outcomes (UOA2-595) and that one of four evidence-based interventions can reduce the socioeconomic gradient in the uptake of colorectal cancer screening (UOA2-3615). Our palliative care research (**Bennett, Allsop, Mulvey, Ziegler**) aims to improve pain management in the community and promote earlier access to palliative care. We revealed the relatively late initiation and short duration of strong opioid treatment in patients with cancer before death, contrasting with epidemiological data pointing to earlier onset of pain (UOA2-2199). Our work has received national media coverage and been integrated into national and international guidelines and NHS pathways (Impact case study UOA2-2).

Health Economics (**Bojke,** *Hulme***, Longo, Meads, Mujica-Mota, Nikolova, Sagoo, Shinkins, Vargas-Palacios**) addresses cost-effectiveness, efficiency, equity, health outcomes and preferences in health care provision. Our methods span applied health econometrics, test evaluation using both trial-based and model-based economic evaluations, health economic

decision modelling, and evidence synthesis. Achievements include demonstrating that mechanical chest compression did not improve 30-day survival compared with manual compressions in out-of-hospital cardiac arrests (UOA2-2103), 'if-then' implementation plans reduced smoking initiation cost-effectively in adolescents (UOA2-2435), and intensive follow-up following resection for colorectal cancer was less cost-effective compared to no scheduled follow-up (UOA2-3208).

Health Services Research (**Hewison, Ahmed, Alderson, Bewick, Brennan, Bryant, Foy, West**) evaluates ways of improving healthcare delivery and outcomes, including healthcare systems, technologies, psychosocial interventions, and implementation. For example, we collaborated with UoA1 colleagues to synthesise a research framework for patient monitoring, spanning the full range of the biomarker pipeline from marker discovery to patient benefit (UOA2-58). We demonstrated how to recruit and retain adults with learning disability into a trial of supported self-management for diabetes by making reasonable adjustments to intervention and research processes (UOA2-762), changes now incorporated into the NHS RightCare Pathway and Diabetes UK advice for professionals. We worked with the National Screening Committee to improve patient-centred prenatal and genetic testing policies affecting antenatal care of over 3.5 million women in England and Wales during 2014-19 (Impact case study UOA2-3). In implementation science (with Lawton and Benn in UoA4), we demonstrated that a theory-based multifaceted intervention cost-effectively reduced high-risk prescribing in primary care (UOA2-2185); we subsequently collaborated with clinical commissioning groups (CCGs) across Yorkshire and Humber to address problematic opioid and antibiotic prescribing.

Theme 2: Clinical Trials Research

We design and execute internationally leading, innovative and robust multi-centre clinical trials and applied research into the effectiveness, equity, and value for money of healthcare interventions. LICTR is a top performing NIHR Evaluation, Trials and Studies Coordinating Centre Clinical Trials Unit and is UKCRC-registered and National Cancer Research Institute accredited. We provide multi-disciplinary academic leadership in clinical trials research, deliver early through to late-phase high-quality trials, and advance trial methodology. Over this REF census period, LICTR has grown with a portfolio across UoAs 1-4 totalling £171m of external income, and recruitment of 24,327 patients in 73 trials. LICTR spans three divisions: *Cancer; Complex Interventions;* and *Surgical, Diagnostic and Device Interventions*.

Cancer (**Brown J, Brown SR, Cairns, *Howard*,** with Cook (Gordon), Hillmen, Sebag-Montefiore & Seligmann in UoA1) includes portfolios in interventions (investigational medicinal products and radiotherapy) and in haematological cancers (multiple myeloma, chronic lymphocyctic leukaemia) and solid cancers (breast, colorectal, lung, urology, gastroesophageal, anal).

Early Phase trials work involves three programmes: (i) the Concept and Access Research Programme supports a comprehensive national network delivering early phase myeloma trials; (ii) the Yorkshire Cancer Research Early Phase Clinical Trials Centre, a Yorkshire-wide collaboration encompassing statisticians, methodologists, laboratory scientists and clinicians to deliver national early phase cancer trials; and (iii) CONCORDE, the first early phase platform worldwide to evaluate radiotherapy and drug combinations in patients with lung cancer, in a major collaboration between academia and industry. There is considerable leverage of industry partnership funding to improve the translational pipeline through access to and early phase evaluation of novel and repurposed cancer treatments. Late phase trials include well-established portfolios on haematological cancers and solid tumours. Highlights include a series of trials (Myeloma VII,IX,X,XI,XI+) incorporating multi-stage randomisations for initial therapy regimes and relapse treatment, which have influenced NICE and International Myeloma Working Group guidance and contributed to improved myeloma survival (e.g. UOA2-2323, UOA2-2325). Myeloma XI led to the licensing of lenalidomide as post-transplant maintenance therapy by both the US Food and Drug Administration and the European Medicines Agency in 2016.

Complex Interventions (**Farrin, Collinson, Cundill, Walwyn** with **multiple Theme 1&3 colleagues**, House in UoA3, and Cottrell, Guthrie, Bryant M in UoA4) designs and delivers both early-phase intervention development and definitive, large-scale, national trials.

We evaluate complex rehabilitation, self-management and behavioural interventions, as well as complex drug regimens, across various health and social care settings. Individual or group-level interventions involve people living with stroke, ageing and frailty, mental and physical co-morbidity, obesity and cancer, while implementation strategies mainly target organisations and professionals. **Richards** & **Farrin** established the [Leeds Unit for Complex Intervention Development](#) (LUCID) in 2019, a methodological research group to advance the development, optimisation and evaluation of complex healthcare interventions.

Highlights include the SHIFT trial, demonstrating that standardised and manualised family therapy yields no benefit over usual care in mental health services for young people following self-harm (UOA2-1690). In the largest, multicentre, stroke rehabilitation trial to combine timed administration of a masked investigational medicinal product (dopamine) with physical therapy sessions, we demonstrated no improvement in walking after stroke, and identified key lessons for future rehabilitation trials investigating drug effects on recovery (UOA2-1691).

Surgical Interventions, Diagnostics and Devices (**Stocken, Brown J, Brown S**, **Cairns, Rousseau**, *Sharples*, with Jayne, Subramanian, Scott, Coletta, Pandit, Greenwood J in UoA1, Nixon, Coleman, and Nelson in UoA3, and Valdastri in UoA12) was established in 2018 to integrate the expanding LICTR portfolios of trials encompassing colorectal and orthopaedic surgery, musculoskeletal disease, cardiovascular disease and diabetes, and skin and wounds research.

Our portfolio includes multi-arm, multi-stage trials. Amongst highlights, CEMARC-2 demonstrated that cardiovascular magnetic resonance reduced unnecessary angiography compared to NICE guideline-directed diagnostics in patients with suspected angina, without affecting major adverse cardiovascular events (UOA2-708). ROLAAR found the safety and quality of robotic surgery is comparable to laparoscopic rectal cancer resection undertaken by experienced surgeons (UOA2-2102). ROLARR clarified costs and the human factors for optimal implementation, informing the design and evaluation of more versatile, affordable robotic systems (Impact case study UOA2-4 with Jayne in UoA1). Based on substantial design and delivery experience, we developed a live, accessible [International Surgical Trials Toolkit](#).

Theme 3: Population Health Data Science

We develop, adapt and apply novel data scientific methods to better understand and exploit large and complex health data. We inform and improve data analytic practices, study design and policy using a mix of descriptive, predictive, and causal methods to evaluate determinants of population health, aetiology, prognosis, treatment effects, and healthcare system performance.

These activities benefit from the interdisciplinary environment of LIDA, a platform that brings together staff with interests in data science from all university faculties (see Infrastructure). We collaborate extensively with clinical and epidemiological colleagues in UoA1 and methodological researchers in UoAs 4, 11 & 14. Population Health Data Science addresses two substantive areas: *Exploitation of Large Health Datasets* and *Causal Inference Methodology*.

Exploitation of Large Health Datasets (**Gale**, *Barrett*, **Feltbower, Greenwood D, West**, *Morris*, *Parslow*). We make efficient use of large-scale observational and randomised trial data to deliver population-based studies, often involving linkage of electronic health records from primary and secondary care, to understand environmental, genetic and behavioural determinants of heath, and to examine the relationship between quality of healthcare and health outcomes. Our work in cardiovascular disease, cancer, and paediatrics and young adults relies on extensive cross-School collaborations and builds on national and international partnerships.

In cardiovascular disease, (**Gale**, **West** with Hall M in UoA1) we used the UK nationwide heart attack register, Myocardial Ischaemic National Audit Project (MINAP), to understand reasons for 10-year temporal improvements in clinical outcomes following heart attacks (UOA2-1044). We reported a potential lack of effectiveness of beta-blockers after heart attack in patients without heart failure, which set the stage for several international trials (UOA2-800). We demonstrated greater between-hospital variation in 30-day mortality for heart attacks in the UK than in Sweden, which was associated with higher variation in adherence to treatment guidelines

(UOA2-1043). Our research has influenced European Society of Cardiology Guidelines and led to international quality indicators for acute myocardial infarction.

Our cancer collaborations have evaluated both genetic and environmental factors underlying aetiology and prognosis (*Barrett*, **Greenwood D**, with Newton-Bishop in UoA1). We demonstrated that multiple genetic predictors of telomere length were strongly associated with melanoma risk, the first time this has been shown for any cancer (UOA2-1480). We found a dose-response relationship between fruit and vegetable intakes and reduced risks of cancer, cardiovascular disease, and all-cause mortality (UOA2-590), and showed that obesity is associated with poorer overall and breast cancer survival (UOA2-587).

Our research provides an empirical basis for the development and monitoring of cancer management policies, linking the results of clinical trials to policy formulation at the population level (*Morris*, with Hall G, & Carrigan in UoA1). We have quantified effects on outcomes for aspects of services not amenable to randomisation, e.g. delay in therapy, type of treatment centre. We revealed wide variation in post-colonoscopy colorectal cancer rates across NHS providers in England (UOA2-781), and demonstrated that higher hospital-level recruitment to clinical trials was associated with improved outcomes for all patients and not just those in the trials – used by the NIHR campaign, 'Clinical research is everyone's future,' to promote participation in clinical trials (UOA2-779).

Paediatric epidemiology (**Feltbower,** *Parslow* with Glaser in UoA1 & Stark in UoA3) encompasses co-leadership of the Paediatric Intensive Care Audit Network (see Collaborations) and using unique database linkages to identify the cumulative burden of long-term multimorbidity within the childhood, teenage and young adult cancer population. We undertook the first childhood and young adult cancer registry linkage to hospital episode statistics, quantifying the increased risks of cerebrovascular disease in a national cohort of long-term cancer survivors (UOA2-680). We led the development of the primary exposure measure for the largest cohort study of teenage and young adult cancer (BRIGHTLIGHT) and highlighted the positive impact of specialist care on quality of life and survival (UOA2-4299). Our research has brought about changes in service configurations within and beyond the UK, improving patient survival and satisfaction (Impact case study UOA3-3 with Stark).

Causal Inference Methodology (**Gilthorpe**, **Ellison** with Tennant in UoA3, de Kamps in UoA11, Norman & Heppenstall in UoA14) pursues interdisciplinary research across computing and geography that translates developments in data scientific theory to applied population health. We analyse large, complex, longitudinal, and non-experimental data for both prediction and causal explanation, highlighting important differences between these. Our problem-driven embrace of novel and emerging causal inference methods within observational research is changing the field of applied population health. We clarified causal interpretations of compositional data, for example, within nutrition research (UOA2-1337), highlighted the risks of selection bias in the analysis of childhood leukaemia (UOA2-2547), and revealed problems with conditioning on the outcome in longitudinal research (UOA2-1336). We led on producing guidance for the *DAGitty R* package for Directed Acyclic Graphs in observational research (UOA2-2545), and reviewed and made further recommendations on their application and reporting (UOA2-4323).

Plans for the next five years

We will tackle major health priorities aligned with the School of Medicine strategy through research spanning Themes 1-3 and other UoAs, especially in:

- **Global health**, leveraging the Global Challenges Research Fund to strengthen and extend interdisciplinary collaboration across the University.

- **Ageing**, consolidating Leeds as a major centre for age-related research, expanding our international role within stroke rehabilitation and recovery research, and leading major clinical trials.

- **Cancer**, developing and evaluating strategies across the spectrum of cancer prevention, screening, early detection, survivorship, and palliative care. We will strengthen our

international leadership in multiple myeloma and chronic lymphocytic leukaemia and develop a portfolio of world-leading clinical trials focused on new agent radiotherapy combinations and technological advances.

- **Cardiovascular disease**, using population-based data to identify opportunities to design and evaluate interventions in efficient large-scale trials.

We will continue to promote **interdisciplinary research** by leveraging the infrastructure and capacity of major investments, such as LIDA and the Wolfson Centre, and strengthening collaborations across institutes. For example, with Computing (Frangi in UoA11), we will develop *in silico* modelling for more efficient research pathways and demonstrate opportunities with the clinical trials community.

We will advance and apply our work in key methodological fields, especially:

- In **clinical trials**, by increasing use of routine data to enhance trials design, efficiency, conduct and analysis. We will exploit trials platforms, allowing multiple comparisons simultaneously and moving seamlessly from early through to late phase trials, with rich associated translational analyses allowing biomarker guided treatments and reverse translation in cancer.

- In **intervention design**, by developing statistical and mixed methods for the development, optimisation, and definitive evaluation of surgical, diagnostic, device and complex interventions.

- In **data sciences**, by building upon existing strengths in causal inference (and prediction) methodologies to enhance the impact of existing exploitation of large routine datasets amongst UoA2 and other research groups based in LIDA and the Wolfson Centre. This will also involve expanding these methodological capabilities into health-related AI research (with Computing), healthy living through research into Smart Cities (with Geography), and advancing quasi-experimental designs to evaluate models of care.

- In **health economics**, by maintaining and strengthening methods for our significant portfolio of economic evaluations, health technology assessments, evidence synthesis, applied econometrics and test evaluations.

We will further develop our thriving research environment through:

- Securing grants from major government, research council, charity and industry funders and target longer and larger awards to ensure sustainable **research income**.

- Leveraging policy-maker, professional, public and academic **partnerships** to maximise the relevance and reach of our research.

- Taking a strategic approach to **public and patient engagement**, by building sustainable partnerships with existing groups, increasing diversity, and developing novel methods of involvement (see Collaborations).

- Identifying and developing future **research leaders** by winning high quality doctoral, postdoctoral and senior training fellowships and mentoring our cohorts of earlier career researchers, University Academic Fellows, and clinical academic trainees (see People).

- Building on our Athena SWAN Charter Gold Award to promote a diverse, equitable and inclusive **research culture**.

2. People

Staffing strategy and staff development

Recruitment and retention. Our staffing strategy promotes long-term academic success and financial sustainability. We have augmented capacity in core methodological skills that underpin interdisciplinary research through strategic chair appointments in health economics (**Bojke**), primary care research (**Richards**), primary care oncology (**Neal**), and clinical trials research (**Stocken**), and internal promotions to chairs in psychological and social medicine (**Bryant**), geriatric medicine (**Clegg**), international health policy and systems (**Mirzoev**, 1st August 2020), cancer epidemiology (**Morris**), and cardiovascular medicine (**Gale**). We made seven internal appointments to associate professor (**Alderson, Brennan, Brown SR, Cairns, King, Meads, Mir**). In Clinical Trials Research, we plan two professorships through internal promotion and the appointment of an associate professor to further develop and sustain our team of research fellows, PhD students and trialists.

Research fellowships. Through the University's *250 Great Minds* scheme, we appointed six University Academic Fellows: **Ziegler, Smith, Beeken, Mulvey,** and **Allsop,** funded through the £4m Yorkshire Cancer Research (YCR) Fellowship Platform (led by Stewart in UoA1 with **Brown J**, *Meads*, *Hulme*, *Morris*); and **Rousseau**, leading mixed methods research on healthcare technology within Clinical Trials Research. Three have since been promoted to associate professor (**Ziegler, Smith, Beeken**).

Feltbower (with Glaser in UoA1) secured a £2.5m Candlelighters Trust award to appoint four Clinical Research Fellowships (*Amin, Friend, Hughes & Milner*) focusing on long-term health outcomes and treatment toxicity associated with childhood, teenage and young adult cancer.

In 2018, the University of Leeds became a partner in the Alan Turing Institute, the UK's national institute for data science and artificial intelligence, reflecting our investment in data science. The University provided a matched investment of £5m in securing 24 prestigious Turing Fellowships (**Gilthorpe**, *Morris*, including Tennant in UoA3 and Heppenstall in UoA14) to address a range of ambitious challenges facing science, society and the economy.

We encourage and support staff to apply for prestigious and competitive personal research fellowships to develop their independence and the vitality of their research groups. Successes comprise a Wellcome Trust Postdoctoral Fellowship (*Hall M*), two NIHR Advanced Fellowships (**Smith**, *Pini*), eight NIHR Doctoral Fellowships (*Corrigan, Downey, Drinkwater*, **Howard**, *Hughes, Paton, Smith, Wilkins*), an NIHR Knowledge Mobilisation Fellowship (*Ward*), five NIHR Clinical Trials and Research Methods Fellowships (**Alderson**, *Backhouse, Emmerson*, **Gale**, *Kelley*), an NIHR Pre-Doctoral Fellowship (*Everett*), an MRC Skills Development Fellowship (*Wilson*), a Cheney Fellowship (*Blazer*), and a Leverhulme Fellowship (*Tubeuf*). Clinical Trials Research has two UKRI Innovation/Rutherford Fund Fellowships aligned to MRC Industrial Strategy topics and connected to HDRUK.

Clinical academic training. The School of Medicine runs a thriving integrated clinical academic programme, providing training to NIHR Academic Clinical Fellows, Academic Clinical Lecturers and Clinician Scientists. The UoA2-relevant research strand, overseen by **Bennett** as Deputy Academic Training Programme Director, appointed seven Academic Clinical Fellows and two Clinical Lecturers spanning general practice, palliative medicine and care of the elderly (**Jones, Alderson** – now appointed associate professor).

We offer an in-depth postgraduate programme on Health Data Analytics (**Gilthorpe**, **Ellison**, with Hogg & de Kamps in UoA11 and Hall G in UoA1, £1m, HDRUK & NHS Digital) and an annual Alan Turing Institute-endorsed Summer School in Causal Inference, both of which receive excellent feedback. Similarly, for our Health Research programme (**Bewick**), over 90% of 34 respondents to the University's 2018-19 Postgraduate Taught Programme Survey agree the programme is intellectually stimulating, provides them with opportunities to apply what they learnt, and report high levels of satisfaction with the quality of the course. These programmes are open to all earlier career researchers and health service staff. For clinical academic trainees, senior academic staff regularly attend and run sessions at twice-yearly residential trainee

meetings, *Inspiring the Next Generation*. We have a guided pathway for promising medical academics, from intercalated BSc's through to Academic Foundation Year posts, which lead onto specialist academic training opportunities.

We recognise the need to grow capacity in shortage clinical academic specialities (e.g. general practice). We have secured NIHR Research Capability Funding from our CCGs (£0.4m since 2014) to fund protected time for early career primary care clinicians to develop fellowship bids and to pump-prime project bids. Successes include an NIHR In-Practice Fellowship (*Grice*) and an In-Practice Fellow progressing to an NIHR Doctoral Research Fellowship (*Drinkwater*). Our funded programmes also include capacity building, such as a CRUK CanTest doctoral fellowship (*Bradley*).

We frequently supervise and mentor medical and allied professionals beyond UoA2, e.g. NIHR Research Professorships (Catto, urology & Jayne, surgery), an NIHR/HEE Senior Clinical Lectureship (Siddle, podiatry), an NIHR Doctoral Research Fellowship (Kenny, dentistry).

Training and continuing professional development. All new academics are supported through the Organisational Development and Professional Learning (ODPL) unit, which offers courses on mentoring, attracting research income, applying for funding, partnership with industry, leadership, and commercialisation, and the University's *Next Generation Researcher* programme.

We prioritise the development of early career investigators through:

- Internal mentorship within a University scheme and external mentorship - including the Academy of Medical Sciences and Society for Social Medicine and Population Health schemes;
- Promotion advisors provide one-to-one guidance;
- NIHR@Leeds Early Career Research Network – including a key aim of facilitating women in clinical academic careers;
- School of Medicine Early Careers Group;
- Introduction of a new guarantee of 10 days' development activities for all early career researchers from 2019-20; and
- Academic Development Fund – awarding researchers up to £15k each to maintain career trajectory during or following extended leave for family reasons or illness. Since 2016, FMH has made seven awards to UoA2 staff returning from maternity leave.

The University's periodic Careers in Research Online Surveys generated a response rate of 26% (Russell Group: 27%) from the 937 postdoctoral staff with 'research' in their job description. Over 2013-17, the percentage of researchers finding formal staff reviews useful increased from 45% to 61% and awareness of Athena Swan doubled to 90%, whilst 90% would now recommend the University as an employer.

In response to a review of leadership behaviours across the University, ODPL developed a *Leadership Excellence Behaviours Framework* to foster an effective working environment. Twenty-one staff (16 women) in UoA2 have accessed an associated training programme launched in 2016, which targets personal, team and organisational-level leadership skills.

Academic development and progression. We hold structured annual academic review meetings with staff focusing on achievements, areas requiring CV development, collaborations, and applications for promotion and external awards. The discussion allows for self-reflection on performance and aligns 3-year plans for research, teaching and impact to School priorities. Joint meetings with NHS colleagues for clinical academics align service and academic objectives. Our annual 'Rewards & Recognition Scheme' provides discretionary payments for staff outstanding performance (UoA2: 42 awarded).

Training and supervision of PGR students

There were 165 (97.19FTE) Research Doctoral Degree awards during the assessment period. All PhD students have two to four co-supervisors, ensuring input from different research disciplines.

Procedures are in place to recruit high quality postgraduate researchers. Following written applications, a panel comprising the supervisory team and an independent member interviews all candidates using standardised questions. We encourage and assist potential PGRs to apply for external funding to support their studies. Our PhD external funding streams comprise NIHR (8), research councils (4), overseas governments (26), NHS (12), and charities (e.g. CRUK; 6). In addition, the ESRC-accredited White Rose Doctoral Training Partnership (a collaboration across the social sciences at the Universities of Leeds, Sheffield, York, Bradford, Sheffield Hallam, Hull, and Manchester Metropolitan) funded 5 PhDs and the University funded 77 PhDs (including Alumni and Endowed Scholarships). Twenty-one were undertaken by staff, indicating our institutional commitment to capacity building.

The School of Medicine has a strong culture for PGR support, augmenting the Doctoral College (see REF5a). PGRs participate in our Early Career Research group and special interest groups (e.g. a Qualitative Research Group), and have mutual support via a 'buddy system.' Staff regularly contribute to PhD DisCos (Discussions Communities) organised by PGRs themselves and which have covered a range of topics, such as research skills, ethical issues, and budgeting. A postgraduate committee, with PGR representation in membership, regularly reviews student experience and arrangements for PGR development. Each PGR has annual funding to support specific training and conference attendance. PGRs are encouraged to take up teaching opportunities for their career development and to apply for Associate Fellowship of the Higher Education Academy.

We integrate both clinical and scientific PGR students into our research activities, contributing to a lively and productive research environment. Institutes and research groupings in the School run excellent seminar series with international speakers, with PGRs often contributing to seminar organisation.

Sixteen out of 21 doctoral graduates responding to a survey had progressed to or within academic positions. The 2019 Postgraduate Research Experience Survey (116 responses from School of Medicine students) indicated high levels of satisfaction with supervisor skills and subject knowledge (93%), supervisor feedback (88%), development of research skills (91%), professional development (89%), and overall research degree experience (81%). The Faculty Graduate School ensures high quality financial, technical, infrastructural and academic support and is reviewed by an independent academic panel every five years. Our 2019 review highlighted strong engagement in research culture, facilitated remote working, and excellent interdisciplinary awareness of opportunities for cross-Faculty working.

Equality and diversity

Within the School of Medicine 42% of PGRs and 17% of staff do not identify as White British (comparable to 18% of the total population of Leeds). Fifty-nine percent of our academic and research staff identify as female. Out of 21 promotions to G8 Lecturer or above since 2014, 14 identified as female, three as BAME, and none as disabled. The School has taken significant steps in promoting equality, diversity and inclusion (ED&I) since 2014, maximising the potential of all staff to deliver excellent research. In 2020 we appointed the first Associate Dean for Equality, Diversity and Inclusion in the University (**Bryant**).

The School secured an Athena SWAN Charter Gold Award in 2019, building upon Bronze in 2013 and Silver in 2016. Nationally we are the first medical school to achieve a Gold Award. The School ED&I Committee was convened in 2016 to address broader equality issues and consider the impacts of intersectionality between gender and other protected characteristics. ED&I representatives have direct access to Institute and School Senior Management Teams, embedding equality at every level of School business.

Current priorities and action plans for staff and students centre on improving mental health and well-being, ensuring inclusion and equality for those identifying as LGBTQ+, improving opportunities and access for those with a disability, and identifying barriers to career progression associated with ethnicity and religion. The School is working in partnership with students to implement the BMA Charter to prevent and address racial harassment in medical schools.

The School has invested significantly in promoting equality. We have sponsored eight places since 2015 on career development programmes such as Aurora (Leadership Foundation for Higher Education), to support women with leadership aspirations in academia. We financially support the Leeds Female Leaders Network in partnership with the Leeds Teaching Hospitals NHS Trust (LTHT). The network has over 800 members across both organisations and evaluations demonstrate its career development value.

We were the first university nationally to initiate a reciprocal agreement with the local NHS to honour terms and conditions for all clinical staff on the Integrated Training Pathway. This protects clinical trainees' benefits, e.g. rights to maternity, paternity or adoption leave. It is now national and externally recognised good practice. Further initiatives include:

- Enhanced flexible working provision, including guaranteeing staff who reduce their hours that they can return to their original hours on request within five years;
- Extension of fixed-term contracts to the end of maternity leave to ensure access to redeployment and other support;
- Facilities to support women returning from maternity leave to continue breastfeeding;
- Raising staff and student awareness of how to identify and report unacceptable behaviour, including sexual and racial harassment. The School led on the University's new staff Code of Conduct and mandatory training addressing these issues;
- Career coaching for staff seeking promotion to improve representation of women at senior levels. During the REF2021 period there has been an equal number of female and male applications to professor and an equal success rate.

We are committed to research-informed ED&I activities. Research by social scientists in the School informed the 2017 NIHR Review of Training. While women were as likely as men to be awarded senior NIHR fellowships once they had applied, fewer females applied, and non-medical clinical academics (mostly female) were least likely to apply. This led to the convening of a national working group and commissioned multi-funder research (£216k) to address the lack of senior female clinical (medical and allied professions) academics across the UK.

Our ED&I strategy for the next five years focuses on three priorities:

1. Creating parity of career development for staff on fixed-term contracts and moves towards more sustainable careers for researchers. This includes enabling staff on open-ended, fixed funded contracts to supervise students and become grant investigators, and greater use of permanent contracts where appropriate, e.g. following University Academic Fellowships.

2. Understanding the impacts on careers of gender, race and disability. We work with the University and BAME networks on a programme of staff consultation. We ran focus groups with Black women to identify obstacles to career development. Mentorship was regarded as important and we have joined forces with other medical schools to pilot a cross-university intersectional mentoring scheme.

3. Increasing the proportion of female and BAME clinical academics in senior roles. We have appointed a Clinical Professor (Aijan in UoA1) to work with NHS partners and the NIHR Academy and champion this priority.

Since 2014, we have made major strides forward in promoting a more diverse, equitable and inclusive research environment at Leeds. Our strategic ED&I goals are embedded in the 2019 School Strategy and closely align with the University's Equality & Inclusion Framework and the Race Equality Framework.

3. Income, infrastructure and facilities

Income

Average annual research income rose from £7.8m in REF2014 to £10.3m over this current period, coming mainly from NIHR (£26.1m total over census period), UK Central Government/local health (£11.9m), charities (£16.3m), industry (£10.2m), BIS Research Councils (£4.9m), and EU government (£1.5m). Annual research income averaged £208k per submitted staff FTE. Major awards (over £1m) from NIHR include 10 PGfAR programmes, 11 HTA trials, five EME trials, four HS&DR studies, and four centre or other programme awards. Our cancer portfolio includes nine CRUK and five YCR awards.

Leadership of large programme and trial awards: personalised care planning in frailty (PROSPER; **Clegg, Teale, Foy,** *Hulme*, **West, Cundill, Farrin**, £2.8m, PGfAR); extended rehabilitation for frailty (HERO; **Clegg, Forster,** *Hulme*, **Cundill, Farrin**, £2m, HTA); communicable and non-communicable disease in low-income settings (**Walley**, **King**, £2m, DFID); the Yorkshire Lung Screening Trial (**Neal, Shinkins**, £5.2m, YCR); reducing sedentary behaviour after stroke (RECREATE; **Forster, Farrin,** £3m, PGfAR); health status and pain in advanced cancer (RESOLVE; **Bennett**, £2.3m, YCR); a portfolio of Global Challenge Research Fund grants (**Ensor, Mirzoev, King, Hicks, Ebenso, Mir, Walley,** totalling £1.9m, UKRI); GRACE risk score impact on non-ST elevation acute coronary syndrome outcomes (**Gale**, £1.1m, BHF); improving care transitions in heart failure (**Gale, Farrin, Alderson, Longo**, £2.3m, PGfAR); a UK Bowel Cancer Intelligence Hub (*Morris*, *Barrett*, £3.4m, CRUK); multidisciplinary team effects on bowel cancer outcomes (*Morris*, £1.5m, YCR); the Bowel Cancer Improvement Programme (*Morris* with Quirke in UoA1, **Alderson**, £2.2m, YCR).

Major partners on collaborative awards: community-responsive, effective urban health systems in low-resource settings (**Mirzoev, Ensor, King, Hicks**, £7.9m, DFID); the ARC Yorkshire and Humber (**Clegg, Forster, Foy, Farrin, Richards, West, Teale, Bojke,** £9m, NIHR); CanTest (**Neal**, £5m, CRUK); Policy Research Unit on Cancer Awareness, Screening and Early Diagnosis (**Neal**, £4.7m, NIHR); Aspirin for Cancer Prevention Collaboration (AsCaP; **Smith**, £5m, CRUK); Patient Safety Translational Research Centre (**Clegg, Bojke, Foy**, £3m, NIHR); infection diagnostics to reduce antibiotic misuse (**West, Bojke, Shinkins,** £3.1m, MRC); the Leeds In Vitro Diagnostics Co-operative (**Shinkins, Sagoo**; £1.3m, NIHR); the Global Research Group for Surgical Technologies (**Brown, Cundill, King, Ensor, Shinkins**, £2m, NIHR); CanGene CanVar (*Morris*, £5m, CRUK); the interplay between cancer and heart disease (**Gale**, £1.4m, BHF); personalised risk prediction and prevention of sudden cardiac death after myocardial infarction (**Gale**, £1.7m EU); PICANet (*Parslow*, **Feltbower**, £1.8m, HQIP); the Application of functional MRI (AFiRM, **Gilthorpe**, £2m, EME); Innovation for value added oral care (**Gilthorpe**, £5.5m, EU Horizon 2020).

Partners in large programme and trial awards: assisted reproductive treatment (**West**, £1.7m, EME); amitriptyline for irritable bowel syndrome (ATLANTIS; **Farrin, Alderson**, **Foy**, £1.8m, HTA); liaison psychiatry services and outcomes (**Hewison, West,** *Hulme*, £1.1.m, HS&DR); hip and knee arthroplasty follow-up (**Hewison, West**, £1.1m HS&DR); therapy for repeated self-harm (FRESH START; **Brennan, Bryant, Farrin**, £2.5m, PGfAR); self-harm treatment (SAFE; **Brennan**, **Farrin**, **Bojke**, £2m, HTA); exercise in prostate cancer (**Hewison, Farrin**, £2.5m, PGfAR); transitions of care (**Foy**, £2.3m, PGfAR); diabetes in severe mental illness (DIAMONDS; **Alderson**, £2.5m, PGfAR); comprehensive geriatric assessment at home (**Godfrey**, £2.3m, HS&DR); triage for delirium (**Godfrey**, £1.1.m, HTA); Contact tracing in care homes using digital technology (**Farrin, Bojke**, £1.5m, HS&DR); advanced colorectal cancer (ARIEL; **Meads,** *Howard*, £2m, EME); alleviating breathlessness in cancer (Better-B; **Brown S**, EU, £2.9m); the gut microbiome (DANTE Microbiome; **Cairns**, £2.5m, CRUK); metastatic melanoma (DANTE; **Meads**, £2.5m, HTA); colorectal cancer recurrence (EMT2; **Bojke**, £1.5m, YCR); chronic lymphocyctic leukaemia (FLAIR; *Howard*, Meads, £3.4m, Abbvie & STATIC; **Meads**, £2.9m, HTA); urothelial cancer (GUSTO, **Cairns**, *Howard*, £2.9m, EME); colorectal anastomotic leak prevention (**Brown J, Meads**, £1.9m, EME); knee arthroplasty (KARDS; **Stocken, Longo**, £1.8m, HTA); rheumatoid arthritis (MICA, **Stocken**, £1.2, MRC); diabetic foot

ulcers (CODIF2; **Longo**, **Brown S**, £1.7m HTA); laparoscopic versus open colorectal surgery (LACES 2, **Stocken, Meads, Brown J**, £1.8m, HTA); colorectal liver metastases (LAVA, **Brown J**, £1.7m, HTA); ulcerative colitis (MODULATE, **Farrin**, £1.5m, HTA); Myeloma XII (ACCoRD; **Cairns**, £1.4m, CRUK); Myeloma XIV (FITNEsS; £1.8m, **Cairns, Meads**, CRUK & £1.3 Takeda); Myeloma XV (RADAR; **Cairns**, £1.5m CRUK & £1.9m, Amgen); thyroid surgery (NIFTY; **Brown J**, £1m, EME); return to work after stroke (RETAKE; **Farrin**, £1.8m, HTA); return to work after trauma (RoWTATe; **Farrin**, £2.4m, PGfAR); irritable bowel syndrome (TRITON, **Farrin**, £2.1m, EME); psoriatic arthritis (TUDOR; **Brown S**, £2m, PGfAR); specialist care for teenage and young adult cancer (**Feltbower**, £2.2m, PGfAR).

Infrastructure and facilities

The School of Medicine has completed a £36m investment programme of refurbishment and reorganisation. Applied Health Research, Clinical Trials Research, and Population Health Data Science are all now co-located in high-quality accommodation within the same building, linked to LTHT.

LIDA brings together methodologists and applied researchers in data science to develop and exploit the latest technologies to advance human and societal health and wellbeing. Established in 2014, with major investments from the MRC, the ESRC and the University (including £4.6m over 2018-21 from UoL), LIDA has developed state-of-the-art physical and IT infrastructures to raise the bar in standards of data quality, access, protection and exploitation. We are currently increasing storage and computer-processing capabilities to provide state-of-the-art cloud computing and strengthen research capacity across the data sciences. LIDA houses 36 research centres, programmes and projects, enabling £61m research across the University, and engages a community of 280 people via research programmes, collaborations, and seminars. The groups include staff from the Schools of Medicine, Computing and Mathematics, the Faculties of Biological Sciences and Law, Health Data Research UK, the Consumer Data Research Centre, the Institute for Transport Studies, and the Centre for Immersive Technologies. Growing through support from local and national collaborators, LIDA is becoming a major powerhouse for research, civic engagement and business growth in the North of England and beyond. LIDA also houses nationally funded research and training programmes including Connected Health Cities, Centres of Excellence in Digital Pathology and Imaging, the EPSRC Centre for Doctoral Training in AI for Health, and our Alan Turing Institute Fellowships. The Connected Yorkshire database has already linked routinely collected data from education, health and social care for 1.4 m residents and shown the power of such data in improving health service delivery (e.g. the electronic Frailty Index).

We have a longstanding collaborative relationship with the Bradford Institute for Health Research (BIHR). The latest development in that relationship is the *Wolfson Centre*, a £3.1m facility launched in 2019 to bring together researchers from the Universities of Leeds and Bradford with clinicians from Bradford Teaching Hospitals NHS Foundation Trust (with £1m matched by UoL). It brings together a critical mass of applied health researchers (including **Clegg** & **Forster**) to explore holistic approaches to improving health outcomes and take advantage of a world class infrastructure. BIHR houses one of the world's most important longitudinal cohort studies, *Born in Bradford* - a unique resource for exploring how socioeconomic factors and ethnicity interact in determining child health and educational trajectories.

Leeds hosts two NIHR Medtech and In vitro diagnostics Co-operatives. The *NIHR Leeds In Vitro Diagnostics Co-operative* supports diagnostics developers in the design and validation of new diagnostic tests. It has leveraged over £52m non-commercial and over £10m commercial funding, provided feedback on or assisted with the development of over 34 *in vitro* diagnostic devices, connected with over 250 companies, and provided access to expertise in health economics (**Shinkins**, **Sagoo**), clinical trials, informatics and multi-disciplinary pathology. Work with **Neal** includes the establishment of a primary care 'TestBed' facilitating recruitment to studies of *in vitro* diagnostics, managed electronically and fully digitally integrated into the Leeds Care Record and the hospital laboratory. The *NIHR Surgical MedTech Co-operative* supports

the development of medical technologies in the fields of colorectal, vascular and hepatopancreaticobiliary surgery, drawing upon our expertise in clinical trials (**Brown J**) and health economics (**Shinkins**), as well as Engineering. The Co-operative provides a platform for early phase mechanistic trials of surgical and devices and developing methods for progression to definitive trials (**Stocken, Walwyn**).

The *Centre for Responsive Healthtech Innovation* is a partnership between the University and LTHT. It brings different disciplines together to develop new medical technologies that deliver better diagnosis and targeted treatments (**Gilthorpe**, **Stocken,** led by Frangi in UoA11 and Jayne in UoA1). We partner with medical technology companies looking for access to specialist expertise and researchers.

The central Research & Innovation Service (RIS) now housed within a new £42m commercialisation and innovation hub (NEXUS; REF5a), provides dedicated high-quality office and laboratory space to engage fully with commercial partners. Review and reorganisation of our support infrastructure has provided more effective financial, HR and contract advice, a more flexible approach to research management, and improved communication with funding bodies. Effective communication between the RIS and NHS partners supports management of Intellectual Property Rights, especially with public sector funding bodies. FMH provides central support for the University values-based ethics review policies and processes to assure these values, in compliance with the University's policy on ethics, the NHS framework for ethical research and legislative requirements. A Quality Assurance team supports clinical trials governance.

Following its prototypical development by LTHT and UoL in 2003, the *Leeds Care Record* has evolved into a joined-up digital care record that enables clinical and care staff to view real-time health and care information across different care providers and systems. It securely integrates important information about patients from general practices, hospitals, community healthcare, social services and mental health teams across Leeds. The Leeds Care Record currently comprises 4.3m patients, including 30.2m outpatient visits, 5.6m admissions with 199m blood tests, 9.7m radiology reports, 5.1m nursing observations and 14.3m coded diagnoses.

Advanced and secure *LIDA and LICTR computational platforms* provide specialist technical services and dedicated clinical trial-specific facilities for data handling and analyses, including large high-performance computing resources and data management coordination meeting regulatory requirements. Secure data storage has accredited certification to the international standard for information security management (ISO/IEC 27001:2013) and is NHS Data Security and Protection Toolkit compliant. This allows researchers secure access to sensitive data and enables external data owners to work with our data scientists.

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

Collaborations within the University

As shown in previous sections, UoA2 staff pursue interdisciplinary collaborations with colleagues in Computer Sciences, Earth and Environmental Sciences, Engineering, Food Sciences, Politics and International Studies, Geography, and Performing Arts, as well as extensive working across Clinical Medicine, Allied Health Professions, Dentistry, Nursing and Pharmacy, Psychology, Psychiatry and Neuroscience. As one illustration, our University-wide Global Health Theme brings together different disciplines to address six key challenges: antimicrobial resistance (**King**); global mental health (Hugh-Jones in UoA3); cancer care (**Allsop**); governance and financing to deliver pro-poor systems (Wallace Brown in UoA19); global health and migration (**Ensor**); low-cost surgical solutions (**Brown J**, Jayne in UoA1); and 'planetary health' - the impact of climate change on health (Berrang Ford in UoA7).

Regional collaborations

We have enduring NHS partnerships to deliver research, teaching and innovation, including with the West Yorkshire and Harrogate CCGs, LTHT, the Leeds and York Partnership NHS Foundation Trust, the Bradford Teaching Hospitals NHS Foundation Trust, and Leeds Community Healthcare NHS Trust. For example, our collaboration with the CCGs has resulted in over 300, typically 'research-naïve', general practices participating in joint research and quality improvement programmes (**Foy, Alderson**). Palliative care research is underpinned by a strong partnership with St Gemma's Hospice in Leeds, which became the world's first University Hospice in 2017, integrating research and education with patient care.

The Yorkshire and Humber Academic Health Science Network is an associate member of the LAHP. It was set up to create and harness a strong, purposeful partnership between patients, health services, industry, and academia. The Network assists in ensuring innovative products and services become part of routine clinical practice and in regional economic growth by supporting inward investment projects and industry for the health sector. **Clegg** is lead academic for its Healthy Ageing theme. The Leeds Centre for Personalised Medicine and Health was established through the LAHP to drive innovative risk sharing agreements and industry collaboration and to accelerate the evaluation and adoption of personalised treatments and technologies. Related projects include the Yorkshire Lung Screening Trial (**Neal, Shinkins**), led by Callister, Honorary Clinical Professor at UoL, and various industry partnerships (see below). The LAHP also enables cross-sectoral research; **Feltbower** is establishing an 'all ages' Leeds cancer cohort to evaluate the impact of care on health and educational outcomes using linked national databases (with Stark, UoA3).

Our collaborations in Yorkshire and the Humber include the NIHR Applied Research Collaboration (with BIHR, Sheffield, York), with UoL providing £0.6m matched funding. We lead two workstreams: exploring and refining innovative methods for the efficient evaluation of interventions to improve care for older people with frailty and in care homes (**Clegg, Forster, Farrin**); and embedding an 'implementation laboratory' to deliver efficient trials of audit and feedback methods and data-driven improvement within primary care in partnership with CCGs across Yorkshire and Humber (**Alderson, Foy, Walwyn, Farrin** with Benn in UoA4). In the NIHR Patient Safety Translation Research Centre, we focus on Workforce Engagement and Wellbeing in co-producing interventions to support staff in delivering safer healthcare (with Bradford & York; **Bojke, Foy**). Such regional collaborations are facilitated by the White Rose University Consortium – a strategic partnership between the Universities of Leeds, Sheffield and York. We are a partner in the Northern Health Science Alliance, which promotes the healthcare and life sciences industry in the North of England, and make significant UoA2-related contributions through our strengths in data analytics and medical technologies.

Leadership of national and international collaborations

Theme 1 - Applied Health Research. We build on an established track record of global health and systems research. We coordinated the Communicable Disease Health Service Delivery consortium (COMDIS-HSD; **Walley**) 2019. Our partnerships spanned Asia (China, Bangladesh, Nepal, Myanmar and Pakistan) and Africa (Ghana, Uganda, Ethiopia, Eswatini, and Zambia). Our portfolio focused on developing, evaluating and scaling up interventions for multi-drug resistant tuberculosis, malaria, HIV/AIDS, and antibiotic stewardship. We now coordinate the Community-led Responsive and Effective Urban Health Systems (ChoRUS; **Ensor**) with partners and projects across Ghana, Nigeria, Nepal, and Bangladesh, to develop and evaluate interventions to improve health system functionality in poor urban communities. We coordinate research on improving health systems responsiveness in Ghana and Vietnam (RESPONSE, **Mirzoev**), antimicrobial resistance in Nepal and Bangladesh (CE4AMR, **King**), social inclusion in 21 countries in Africa, Asia and North America (Partnerships for Equity and Inclusion; **Mir**), informed decision making about genetic cascade screening in Pakistan (**Ahmed**), and communicable and non-communicable disease control in Nigeria and Pakistan (EndHep, **Walley**). **Mirzoev, Ensor, King, Mir** are co-investigators on multiple collaborative grants, including studies addressing adolescent mental health in India and adolescent reproductive health in West Africa (Ghana, Nigeria, Senegal) led by our extensive global health networks.

Theme 2 - Clinical Trials Research. The NIHR Global Health Research Group - Surgical Technologies, established in Leeds in 2017, addresses unmet surgical needs in low and middle-income countries, and includes collaborations with Sierra Leone and India (co-led by **Brown J** & Jayne in UoA1, with **Cundill, King, Ensor, Shinkins**). We host one of six Royal College of Surgeons Surgical Trials Centres, leading international trials across the translational spectrum to evaluate both established and innovative surgical techniques and technologies, focusing on colorectal, orthopaedic and vascular surgery (**Stocken**). We established and host the UKCRC Registered CTU Network, comprising 53 academic clinical trials units across the UK (**Brown J**).

Theme 3 - Population Health Data Science. We lead the Paediatric Intensive Care Audit Network (PICANet) in partnership with Leicester and collaborators in Ireland, France, Latvia, Australia and New Zealand (**Feltbower,** *Parslow*). Now the definitive UK source of data for national audit and commissioning, PICANet has also enabled multi-centre trials, e.g. demonstrating that tight glycaemic control in paediatric intensive care offered no clinical or economic benefits over conventional management (UOA2-516). PICANet analyses have substantially informed commissioning, including a 5-year service plan for Scotland and a review of paediatric critical care in England. **Greenwood D** is developing methods applied to large-scale international consumer data to model trends in sustainable nutrition and global health, through directorship of the WHO Collaborating Centre in Nutrition Epidemiology (with Hardie in UoA1, Cade in UoA6, and external collaborations including Harvard, Imperial, Oslo and Queensland). **Gilthorpe** (and Tennant in UoA3) collaborate with colleagues in Boston and Nijmegen to aid with the translation, uptake, and understanding of contemporary causal inference methods, including Directed Acyclic Graphs and the *DAGitty* software.

Contributions to national and international collaborations

Theme 1 - Applied Health Research. **Ensor** collaborates with Knowledge for Development (K4D) to assist the Foreign, Commonwealth and Development Office and other UK government departments in responding to rapidly changing and complex development challenges, and with the WHO Eastern Mediterranean Office advising on capacity and systems. **Walley** works with country ministries of health and NGO partners in Africa and SE Asia on non-communicable diseases, infectious diseases (hepatitis, respiratory, TB and COVID-19) care, prevention and control. **Mir** established the Ethnicity Training Network to equip health, social care and voluntary service providers to engage with the UK's minority ethnic population.

Smith collaborates with the ASCAP consortium of aspirin investigators (QMUL, Newcastle, UCL, Harvard); **Neal** with the Policy Research Unit on cancer awareness, screening and diagnosis (with QMUL, KCL, UCL, Cambridge, Exeter, HYMS) and **Neal** & **Shinkins** with the CRUK CanTest Collaborative on diagnosing cancer in primary care (with Cambridge, UCL, Exeter,

Seattle, Houston, Melbourne, Aarhus and Utrecht). **Bennett** leads on cancer pain assessment in a European Association for Palliative care core collaborating centre (with Edinburgh, Milan and Aachen) and collaborates on the EU INADVANCE Programme (Valencia, Erasmus, Thessaloniki).

Clegg, Alderson, Farrin, Foy, Teale & West are developing a learning system to optimise anticholinergic prescribing for older people with Health Data Research UK North. **Forster** & **Farrin** collaborate with the International Stroke Recovery and Rehabilitation Roundtable Initiative (led by the Florey Institute).

Theme 2 - Clinical Trials Research. **Farrin, Walwyn**, **Foy** & **Alderson** co-founded the A&F MetaLab to advance the science and impact of audit and feedback with academic collaborators (Ottawa, Toronto, Quebec, Houston, Ann Arbor, Amsterdam) and UK national clinical audit programmes (MINAP, PICANet, National Comparative Audit of Blood Transfusion, National Diabetes Audit, and Trauma Audit and Research Network).

Farrin & **Brown J** collaborate with the MRC-NIHR Trial Methodology Research Partnership, **Walwyn** with KCL, Bristol and Aberdeen on experimental designs for complex intervention trials and LSHTM, Manchester and Essex on causal inference in complex intervention trials, **Brown J** with Birmingham and Sydney on patient reported outcomes in clinical trials, and **Stocken** with Liverpool, Oxford and Newcastle on developing Good Statistical Practice.

Theme 3 - Population Health Data Science. **Gale** collaborates with MINAP (Leicester, Public Health England), *Barrett* with the MAximising Therapeutic Utility in Rheumatoid Arthritis (MATURA) stratified medicine consortium, the Melanoma Genetics Consortium (GenoMEL) and the MELGEN training network, and **Feltbower** with the European Network of Teenagers and Young Adults with Cancer. **Gilthorpe** collaborated with the Alan Turing Institute DECOVID project, established as a rapid response to model Covid-19 in partnership with Manchester, UCL and Oxford. **Gilthorpe, Ellison** and Tennant are part of an international consortium on causal inference methodologies, linking the UK with Europe and US.

Industrial collaborations

Clinical Trials Research receives substantial industry funding for cancer trials, ranging from access to free pharmaceuticals to investigator-initiated trial grants and joint funding with charity or NIHR. **Brown S** & **Cairns** also work with Celgene on outcome measures for myeloma. **Stocken** is an invited member of the HealthTech Alliance, which works collaboratively with policy makers to ensure innovation reaches patients. Innovate UK Digital Health Technology Catalyst funded awards on machine learning based cancer risk prediction for primary care (with Pinpoint Cancer Limited; **Neal, Shinkins**, with West Yorkshire Cancer Alliance), a risk-stratification test for bladder cancer (with Randox; **Sagoo**), and predicting delayed graft function in renal transplants (with Biopassport; **Shinkins**). **Walley** & **Ensor** work with a consortium of consultancy organisations (HEART, led by Oxford Policy Management) to advise governments in low- and middle-income countries funded by DFID. We contributed health economics to NIHR I4I funded work introducing digital-based solutions to chronic disease management (**Meads**) a platform for the long-term management of men with prostate cancer (**Meads**), and an intra-abdominal platform for laparoscopic surgery (*Hulme* with Culmer in UoA12).

Patient and public involvement and engagement (PPIE)

Our strong arrangements are underpinned by our University's STAR framework: Social responsibility (e.g. sensitivity to diversity and inclusion); Trust (e.g. acting ethically and responsibly); Accountability (e.g. ensuring PPE collaborators can influence the research; and Relevance (e.g. acceptability of methods and topics to participants). Using the UK Standards for Public Involvement, we have identified strengths and areas for improvement.

- Secure meaningful and appropriate PPIE, increasingly represented across all phases of research, including investigator and authorship status. We have contributed to INVOLVE guidance on PPIE in clinical trials. PPIE has demonstrable impacts on our research, e.g.

PPIE was critical to ethics approval for 'opt-out' recruitment of general practices to randomised trials (UOA2-2185) and led to co-authored guidance on PPIE for implementation research. We work with groups with relevant lived experience, e.g. the Yorkshire Cancer Community, and plan to move from convening multiple PPE groups for individual projects towards more sustainable PPIE partnerships.

- Develop our capacity and infrastructure. The University's Public Engagement team runs training, support and community-focused events, e.g. the annual *Be Curious* open day that engages families in our research (now attracting over 1200 visitors a year and delivered online twice in 2020). A Wellcome Trust Engagement Fellow (*Muir*) ensures meaningful PPIE in our clinical trials. The University Engagement Excellence Scheme has awarded competitive fellowships to our staff to create a network of PPIE champions, including **Allsop** and *Muir* in UoA2.

- Develop and evaluate novel approaches to PPIE. For example, *Drinkwater's* NIHR DRF uses participatory research to strengthen the role of PPIE in general practice service improvement. *Drinkwater* and *Muir* secured an ESRC Impact Acceleration Award to explore novel approaches for dissemination working with the School of Performance and Cultural Industries. ESRC promotes **Mir's** work on participatory research as a model for ethical engagement. **Smith** received British Psychological Society funding to develop a behavioural science module for the Wellcome Trust's *'I'm a Scientist, Get Me Out of Here!'* – providing online access for children to behavioural researchers.

- Increase the diversity of people involved in our PPIE activities. We have begun to expand our existing PPIE networks, focusing on communities that typically do not engage with research, and building trust in researchers and research organisations, e.g. INVOLVE funded work with the York Travellers Trust. We will consolidate local links through networks such as *Healthwatch*, which purposely recruit diverse volunteers from hard to reach groups (e.g. homelessness, alcohol abuse).

Contribution to the research base, economy and society

We ensure that our research remains responsive to the priorities of key end-users and achieves impact by participating in national and international policy and advisory boards, funding committees, governance bodies and research networks.

International advisory boards and funding bodies, including: Health Systems Global (**Mirzoev**, Board of Directors); NIH, StrokeNet (**Forster**); Swedish Research Council (**Forster**); Swiss Development Cooperation (**Ensor**); WHO Collaborating Centre for Nutritional Epidemiology (**Greenwood D**, Director); Health Research Board of Ireland (**Hewison**, chairing several panels, & **Forster**); National Research Centre for Diet, Obesity and Diabetes, Ireland (**Gilthorpe**); Society for Reproductive and Infant Psychology (**Bryant**, Chair); European Geriatric Medicine Society (**Clegg**, Frailty SIG Co-chair); Canadian Frailty Network (**Clegg**); European Society of Cardiology NSTEMI registry (**Gale**, Chair); UN/World Bank Expert Group on Sustainable Development Goal 10 (**Mir**).

National research priority setting group membership, including: NIHR Trainees Coordinating Centre 10 year Strategic Review of Training (**Hewison**); NIHR HTA Elective and Emergency Specialist Care (**Meads**); NIHR Older People with Complex Health Needs (**Clegg**); NIHR Urgent Public Health Group (**Brown J**); NIHR HS&DR Support for Ethnic Minorities (**Mir**); NCRI Clinical and Translational Radiotherapy Research Working Group (**Brown SR**); National Myeloma Research Alliance (**Brown SR**).

National funding committee membership, including: NIHR HTA (**Brown J** – Chair, **Farrin**); NIHR Global Health Research Groups (**Hewison**); NIHR Global Health Policy and Systems Programme (**Mirzoev, Ensor**); NIHR PGfAR Strategy Advisory Group (**Hewison**); NIHR PGfAR subpanels (**Hewison** – Chair, **Forster, Foy, Meads**); UKRI Global Challenges Research Fund (**Mir**); NIHR In-Practice Fellowships (**Foy, Richards**); NIHR RfPB (**Neal, Smith**); NIHR HS&DR (**Alderson, Bojke, Forster, Mir, West**); NIHR Doctoral Research Fellowships (**Forster**); NIHR Clinical Trial Fellowships and DSE Panels (**Cairns**); Stroke Association (**Forster, Hewison,**

Meads); BHF (**Stocken**); Diabetes UK (**Stocken**); CRUK EMERP (**Brown SR**); CRUK Epidemiology Expert Review (**Gilthorpe**, subpanel chair); CRUK Prevention and Population Research (**Gilthorpe, Neal**); British Council Newton Fund (**Allsop, Mirzoev**); RCGP Scientific Foundation Board (**Neal**, chair); Dunhill Medical Trust Research (**Clegg**).

National research network and methodological groups, including: Health Data Research UK North (**Clegg**, Associate Director); NIHR ARC Ageing, Frailty, Dementia National Theme (**Clegg**, Joint Lead); NIHR Academy Methodology Incubator (**Hewison**); NIHR CTUs Standing Advisory Committee (**Hewison**); MRC/NIHR Trials Methodology Partnership (**Farrin**); NIHR HTA Elective and Emergency Specialist Care Methodology (**Meads**); Alan Turing Institute Causal Inference Interest Group (**Gilthorpe**, co-founder); Methodology Advisory Group, Healthcare Quality Improvement Partnership (**Feltbower, Foy**); NHS England expert reference group for Electronic Palliative Care Coordination Systems (**Allsop**).

National professional leadership, including: NICE guideline development groups for stroke rehabilitation, multimorbidity, delirium, and palliative care (**Forster, Clegg, Bennett**); NICE Indicator Advisory Group (**Gale**); NICE Technology Appraisal Committee (**Meads**); NICE Public Health Advisory Committee (**Bojke**); Scientific Advisory Committee on Nutrition (**Greenwood D**); National Screening Committee (NSC, **Bryant**); NSC Fetal Anomaly Screening Programme (**Hewison**, Deputy Chair of Advisory Group); Expert Scientific and Clinical Advisory Group, National Congenital Anomaly and Rare Disease Registration Service (**Hewison**); PHE Information and Education Group on national roll-out of non-invasive prenatal screening for Trisomy 13,18 & 21 (**Bryant**, Chair); NICE Implementation Strategy Group (**Foy**); National Institute for Clinical Outcomes Research (**Gale**, Co-Chair, Research Board); Faculty of Pain Medicine 'Framework for pain services in cancer and life threatening diseases' (**Bennett**, Lead); British Geriatrics Society (**Clegg**); Society for Academic Primary Care Executive (**Richards**); RCP Speciality Advisory Committee in Palliative Medicine (**Bennett**, academic lead); Advance HE's Athena SWAN charter (**Bryant**, panel chair); Nuffield Council on Bio-ethics working group on Non-Invasive Prenatal Testing (**Bryant**).

Peer review. Journal editorships include: *Journal of Developmental Origins of Health and Disease* (**Gilthorpe**, Statistical Editor); *Implementation Science* (**Foy**, Deputy Editor-in-Chief); *European Heart Journal Quality of Care and Clinical Outcomes* (**Gale**, Deputy Editor); *PAIN* (**Bennett**, Associate Editor); *Age and Ageing* (**Teale**, Associate Editor); and *BMC Family Practice* (**Richards**, Associate Editor). We contribute extensively to peer review, including through membership of 11 editorial boards.

Academic awards, honours and prizes include: NIHR Senior Investigators (**Forster** and **Brown J**); EHI Live Award for Healthcare IT Product Innovation, 2016 (**Clegg**); RCP Excellence in Patient Care Award, 2017 (**Clegg**); AHSN Innovation award, 2018 (**Alderson**); UoL Women of Achievement, 2016 (**Brown J**); the inaugural Doug Altman Scholarship, 2019 (*Bradley*).