

Institution: Imperial College
Unit of Assessment: 02 Public Health, Health Services and Primary Care
<p>1. Unit context and structure, research and impact strategy</p> <p>1a. Unit Context and Structure</p> <p>Research in UoA2 at Imperial College London predominantly takes place within the School of Public Health (SPH), established in 2010. SPH is located within the Faculty of Medicine (FoM), forming one of eight departments. Our aim is to achieve better health in the population through strengthening the public health science base, training the next generation of public health leaders, and influencing health policies and programmes locally, nationally and internationally. Our success in REF2014 has catalysed significant growth through strategic investment in people, growing our FTE from 54.6 in REF2014 to 79.5 in REF2021, with research income of £282m since 2014 (£506k per FTE/yr). Targeted strategic fundraising has secured £57m to support establishment of new endowed Chairs (Mohn Chair in Population Child Health, Toledano, and the Battcock Chair in Community Health and Policy, Kelly [UoA14]) and to build a new home for public health research on our White City Campus. Within the REF period, two major research groups transferred to SPH: the Environmental Research Group (15.3 FTE returned in UoA14), led by Kelly, from King's College London (KCL), and The George Institute for Global Health UK, led by MacMahon and Norton, from the University of Oxford. Our move to the heart of the new White City campus, adjacent to Hammersmith Hospital, will enhance our interdisciplinary research mission through co-location with fundamental health researchers, engineers, and physical scientists.</p> <p>SPH houses three broad research groups - infectious disease epidemiology, chronic disease epidemiology and clinical trials and evaluation (including primary care and public health). It incorporates two MRC Centres (Global Infectious Disease Analysis, and Environment and Health, both exceptionally renewed for a third term), three National Institute of Health Research (NIHR) Health Protection Research Units (HPRUs: Chemical and Radiation Threats and Hazards, Environmental Exposures and Health, Modelling and Health Economics) jointly with Public Health England (PHE), our UKCRC-accredited Imperial Clinical Trials Unit (ICTU), Environmental Research Group, The George Institute for Global Health UK, Dr Foster Intelligence Unit, UK Small Area Health Statistics Unit (SAHSU), NIHR School for Public Health Research at Imperial, NIHR Applied Research Collaboration (ARC) Northwest London, UK Medical Bioinformatics Partnership programme (UK MED-BIO), Mohn Centre for Children's Health and Wellbeing and Abdul Latif Jameel Institute for Disease and Disease Emergency Analytics (J-IDEA).</p> <p>People are our greatest asset and extensive procedures are in place to ensure equality and diversity in the recruitment and support of staff and research students, and in staff retention and promotion (Section 2). We aim to foster a vibrant and inclusive research culture where a diverse range of opinions are encouraged. We support individuals for internal promotions based on a transparent and equitable process, and recruit externally, to maintain research excellence in an environment where people feel appreciated and valued. Gender is 39% female compared to 33% in REF2014. Black and Minority Ethnic (BME) group representation has increased (19% vs 5% in REF2014). Thirty-eight academic staff have been recruited (34% female) and a further 32 promoted (14 female) including 11 to professor.</p> <p>We foster a sustainable environment based on recruitment of talented early career researchers (ECRs) and junior fellows and a growing research student base. During the REF period we appointed 21 ECRs and trained 127 PhD students. We have well-developed succession plans in place for senior staff and a growing supply of highly qualified and skilled staff eligible for appointment to senior roles.</p> <p>A key element of our mission is to enable the rapid translation of our research into public health policy. To support local policy adoption, we work within the Imperial College Academic Health Science Centre (AHSC), formally re-designated in 2020 and nested within the Academic Health</p>

Unit-level environment template (REF5b)

Sciences Network (AHSN). Our NIHR HPRUs with PHE support national decision-making; and internationally our range of global academic and public health partnerships include hosting three World Health Organisation (WHO) Collaborating Centres. We actively promote public involvement in our research through our Patient Experience Research Centre (PERC, Director, Ward) and our NIHR ARC (Director, Majeed).

In late 2019, through philanthropic funding, we established J-IDEA, bringing together researchers across the three UoA themes to improve the response to emerging disease threats. Our cross-disciplinary approach has been evident in the prominent role that researchers across SPH have played in supporting the UK and worldwide response to the COVID-19 pandemic. Examples include:

- Establishment of the REal-Time Assessment of Community Transmission (**REACT**) study of SARS-CoV-2 infection in the community - a partnership between Imperial College London and Ipsos MORI involving researchers across all three UoA themes and laboratory and clinical investigators in UoA1 (Barclay, Cooke, Darzi).
- Development of statistical methods to support tracking of the disease in the UK, Europe and New York State (at the request of Governor Cuomo) undertaken as a partnership between SPH and the Department of Mathematics.
- Research supporting hospital capacity and the economic response in collaboration with the Business School.

Through PERC, community involvement was garnered throughout our COVID-19 response including the “*Let’s Talk About COVID-19*” public engagement campaign to bring the public and researchers together to share stories, insights and experiences of the pandemic (section 4d).

1b. Research Strategy

Our research falls under three broad areas, through which we undertake inter-disciplinary research with high translational impact. All groupings have a strong focus in training the next generation of researchers with established Masters and PhD training programmes and development opportunities for ECRs (*italicised below*).

A. Infectious Disease Epidemiology

Number of highly cited outputs: 24 outputs over 100 citations, 8 outputs over 250 citations, 5 outputs over 500 citations, 2 outputs over 750 citations, 1 output with over 1000 citations.

Key Centres: MRC Centre in Global Infectious Disease Analysis (MRC GIDA), NIHR HPRU in Modelling and Economics (in partnership with London School of Hygiene and Tropical Medicine [LSHTM] and PHE), Bill and Melinda Gates Foundation (BMFG)-Gavi funded Vaccine Impact Modelling Consortium, WHO Collaborating Centre for Infectious Disease Modelling, WHO Collaborating Institute on Polio Data Analysis and Modelling, J-IDEA

Research volume since 2014 (pro rata): £108m

Web of Science Highly-Cited Researchers (2014-2020): Bhatt, Ferguson, Jombart

Number of ECRs: 8 – *Blake, Gaythorpe, Jauneikaite, Lees, Nayagam, Sicuri, Turner, Winskill*

Our strategy - “*to provide an international resource and centre of excellence for research for the epidemiological and modelling of infectious diseases*” - is aligned with the goals of MRC GIDA. Research spans ten disease areas (Zoonoses and Animal Diseases; HIV, STIs and Hepatitis; Malaria; Tuberculosis; Influenza; Arboviruses; Neglected Tropical Diseases (NTDs); Enteric Infections; Bacterial Pathogens; Fungal Pathogens) within five inter-disciplinary cross-cutting themes (Outbreak Analysis and Modelling, Global Health Analytics, Vaccines, Antimicrobial Resistance, and Methods and Tools). We work across multiple disease areas and cross-cutting themes, resulting in a highly collaborative internal research environment and a coherent and highly visible external profile.

Major funders include MRC and other research councils (BBSRC and NERC), BMGF, US National Institutes for Health (NIH), NIHR and Wellcome Trust. The translational impact of our research is strengthened through our formal collaborative partnerships with the WHO, PHE, the Global Fund and Gavi (the Vaccine Alliance).

Key research achievements since 2014 include:

- Real-time analysis and modelling support for the COVID-19 pandemic (Lancet Infect Dis 2020; Nature 2020; Science 2020 [2]) (see impact case study MED2-04).
- Support for the global response to outbreaks, including the West Africa and Democratic Republic of the Congo Ebola outbreaks, the Zika pandemic in Latin America and MERS (NEJM 2014; Lancet 2014; Science 2016).
- Expanded global health portfolio providing underpinning research to inform global strategies (via WHO, the Global Fund, Gavi) and new interventions for HIV, Hepatitis, TB, malaria (see impact case study, MED2-01) and NTDs (Lancet 2014, 2015, 2019).
- Research on immunisation strategies to minimise vaccine-derived poliovirus emergence directly supporting the Global Polio Eradication Initiative (NEJM 2018; Science 2014, 2018, 2020).
- Development of analytical tools to exploit genetic data and gain fundamental insight into disease transmission and bacterial pathogen evolution (PLoS Biol 2016; Cell 2020).

Progress against the aims set out in the REF2014 submission:

- Strengthened research collaborations with national agencies including PHE in the UK through the NIHR HPRU in Modelling and Health Economics, partnership with the Public Health Foundation of India and Ministry of Health and Family Welfare and with China CDC. Established new collaborations involving national public health agencies in Malawi and Colombia.
- Enhanced capacity in integrated genetic and epidemiological analysis through the appointment of Croucher (Senior Lecturer) and Faria (Reader) alongside existing staff (Volz). Established a health economics group led by Hauck. Advanced biostatistics strengthened by the appointment of two new lecturers (Baguelin, Cori).
- Launched new MRes course to form a 1+3 PhD programme and trained over 60 students including eight from low- and middle-income countries (LMICs).

Over the next 5 years, we will:

- Continue to lead future pandemic planning and outbreak response (learning from experience with COVID-19).
- Align and integrate approaches for global health planning across diseases to support rational resource allocation, develop metrics for progress monitoring and programme evaluation, and guide strategic planning at global, regional, national and local levels.
- Leverage research on vaccines across College to enhance use of modelling to inform product development, clinical trial design and implementation.
- Build formal pipeline to rapidly translate methodological research (phylogenetic inference, genomic analysis, machine learning) into openly accessible software and enhance software engineering capacity to support user-friendly tools for public health decision-making.
- Support capacity building in quantitative epidemiology in LMICs through local partnerships and training of the next generation of local scientists.

B. Chronic Disease Epidemiology

Number of highly cited outputs: 43 outputs over 100 citations, 18 outputs over 250 citations, 6 outputs over 500 citations, 5 outputs over 750 citations, 3 outputs over 1000 citations.

Key Centres: MRC Centre for Environment and Health, The George Institute for Global Health UK, NIHR HPRUs in Chemical and Radiation Threats and Hazards, and in Environmental Exposures and Health, SAHSU, UK MED-BIO (bioinformatics), NIHR Global Health Research Unit, NCD Risk Factor Collaboration (NCD-RisC), Mohn Centre for Children's Health and Wellbeing.

Web of Science Highly-Cited Researchers (2014-2020): Elliott, Ezzati, Jarvelin, Prokopenko, Riboli, Vineis, Woodward

Research volume since 2014 (pro rata): £93.3m

Number of ECRs: 8 – Ahmadi Abhari, Chan D, Kaforou, Lill, Lucas, Muller, Vuckovic, Zuber

We undertake leading cross-disciplinary research to advance understanding of the distribution, causes and effects of the major chronic diseases and thereby influence policy for improving health. We hold major funding from MRC, NIHR, Wellcome Trust, Department of Health and Social Care (DHSC), European Union, and NIH. Key areas include: aetiological studies, notably on cardiovascular disease (and its risk factors), type-2 diabetes and cancers; application of genomics and other 'omic technologies to understanding disease causation and pathogenesis; environmental epidemiology; analysis of international trends in chronic disease and risk factors; and methods development. We established and lead NCD-RisC, the world's largest collection of population-representative health data, working closely with WHO (Ezzati) and lead the World Cancer Research Fund International Continuous Update Project (*Chan D, Tsilidis*). We lead major cohort studies including REACT (DHSC-funded), the 500,000 person EPIC study (Riboli), the international COSMOS study (mobile phones and health), MRC-funded Airwave Health Monitoring Study (police cohort) and SCAMP (adolescents), the multi-country INTERSALT and INTERMAP studies (NIH), Northern Finland Birth Cohorts 1966 and 1986, LOLIPOP and the South Asian Biobank (£5m Wellcome Trust and NIHR Global Health Research Unit [£9.2m, Director, Chambers]).

Key research achievements since 2014 include discovery of:

- Novel genetic variants and epigenetic signatures associated with multiple traits and diseases (Nature 2014, 2017, 2020; Nature Genetics 2014, 2015 [2], 2017, 2018, 2019; Cell 2018, 2020 [2]; Science 2019; JAMA 2018).
- Population genomic variation in Africa, Australia and New Guinea, transcriptomic signatures of infection and mutational signatures of smoking (NEJM 2014; JAMA 2016; Nature 2015, 2016; Science 2016, 2017; Cell 2019).
- Efficacy of blood pressure lowering by cardiovascular disease risk and in type-2 diabetes, thrombolytic therapy in acute stroke and evaluation of risk scores for coronary artery disease and kidney failure (JAMA 2016, 2020; Lancet 2014, NEJM 2014, 2016).
- Trends in adiposity and diabetes worldwide, diabetes-related complications and mortality (Lancet 2014, 2016 [2], 2017, 2018; NEJM 2014; JAMA 2014).
- Inequalities in accessibility to cities and effects of socioeconomic status, risk factor reduction, temperature and air and noise pollution on mortality (Nat Climate Change 2014; Lancet 2014, 2017; NEJM 2019; Nature 2018 and see impact case study, MED2-05).

Our progress against the aims set out in the REF2014 submission:

- Further consolidated our leading position in environment and health research through re-funding of the MRC Centre for Environment and Health (Director, Elliott) and the NIHR HPRU in Environmental Exposures and Health (formerly HPRU in Environmental Threats and Hazards, Director Kelly [UoA14]) and the move of the HPRU in Chemical and Radiation Threats and Hazards (Director, Elliott) to Imperial.
- Developed and expanded our portfolio of cohorts to include the REACT programme (see impact case study, MED2-04) and the South Asia Biobank.
- Expanded our successful PhD programme, bringing together training in the MRC Centre and the two HPRUs into one jointly run programme. Established a successful new Masters programme in Health Data Analytics and Machine Learning, now in its third year (42 students).

Over the next 5 years, we will:

- Further develop our strengths in environment and health building on the MRC Centre and two associated HPRUs.
- Integrate further with The George Institute for Global Health UK, including development of new programmes in multimorbidity and women's health.
- Strengthen our collaboration with the Dementia Research Institute at Imperial (Director, Matthews [UoA4]), where we lead a programme on molecular epidemiology and causal inference (Elliott, Dehghan, Zuber).
- Extend and follow-up our cohorts including through remote and face-to-face contact, and data linkage.

Unit-level environment template (REF5b)

- Further develop and extend our training programme at both Masters and doctoral levels and continue to provide a high-quality training environment to the next generation of researchers and research leaders.

C. Clinical Trials and Evaluation

Number of highly cited outputs: 25 outputs with over 100 citations, 15 outputs over 250 citations, 7 outputs over 500 citations, 5 outputs over 750 citations, 3 outputs over 1000 citations including 1 with over 2000 citations and 1 with over 3000 citations.

Key Centres: ICTU, Dr Foster Intelligence Unit, WHO Centre for Public Health Education and Training, NIHR ARC Northwest London, NIHR School for Public Health Research at Imperial

Web of Science Highly-Cited Researchers (2014-2020): Neal, Poulter, Ray

Research volume since 2014 (pro rata): £80.3m

Number of ECRs: 5 – *Al-Lamee, Laverty, Pinder, Vallejo-Vaz, Vamos*

We aim to be at the forefront of evaluation of the benefits and risks of treatments/interventions, through clinical trials, pharmaco-epidemiology and evaluation of health service performance. Our research, working with partners in **UoA1**, reflects the strong history of clinical trial involvement across a broad base. Example applications include cardiovascular and metabolic disease (*Al-Lamee, Greenhalgh [UoA1], Neal, Peters, Poulter, Ray, Rodgers*), HIV & Infection (*Fidler [UoA1], Weber [UoA1]*), ageing (*Kivipelto*), endocrinology (*Dhillon [UoA1]*) and emergency medicine (*Finfer, Gordon [UoA1]*). The theme also includes the NIHR ARC NW London (Director, *Majeed*), the UKCRC accredited Imperial Clinical Trials Unit (ICTU, Directors, *Poulter and Ray*); the WHO Collaborating Centre for Public Health Education and Training (Director, *Rawaf*) and the Dr Foster Centre for Health Intelligence Research (Director, *Aylin*).

Key research achievements since 2014 include:

- Lead roles in the design and analysis of major trials in cardiovascular and metabolic disease (*Lancet 2018; NEJM 2016[2], 2017[5], 2019[2]; JAMA 2014, 2015, 2018*).
- Identified genetic associations of variants related to CETP inhibitors, ATP citrate lyase and lipoprotein levels, and designed trials of inclisiran, targeting PCSK9 messenger RNA to lower LDL cholesterol (*NEJM 2017, 2019, 2020[2]; JAMA 2017; see impact case study, MED2-006*)
- Developed major new areas for trials including ageing (*Lancet 2015*), emergency medicine and critical care (*NEJM 2016, 2018, 2019, 2020; JAMA 2016, 2020*), nephrology (*JAMA 2017*).
- Undertook evaluations of real-world data including Clinical Practice Research Datalink (CPRD) and NHS administrative data for a diverse range of conditions including antibiotic management (*BMJ 2016, 2019; Lancet 2014, 2016*), obstetric management (*BMJ 2015*), diabetes (*Diabetes Care 2015*) and health service performance (see impact case study, *MED2-02*).
- Systematic reviews of access to treatment for end-stage kidney disease, blood pressure lowering on cardiovascular disease risk and evaluation of infection outcomes in Intensive Care Units (*JAMA 2020; Lancet 2015[2], 2016[2]*).

Our progress against the aims set out in the 2014 submission:

- Further developed ICTU as a centre of excellence for trials: re-accredited with UKCRC in 2017, *Ray* appointed as Deputy Director and *Cornelius* as Head of Statistics strengthening links with industry and building methodological strength, upgrading clinical data systems (*OpenClinica, REDCap*).
- Completed a cluster randomised trial of salt substitute and stroke in rural China, with publication due in 2021 (*Neal, Elliott*).
- Consolidated and expanded our capability in health service performance monitoring/evaluation through the Dr Foster Intelligence Unit, the Whole Systems Integrated Care (WSIC) database and the Discover-NOW data repository (*Health Data Research UK Hub*).

Over the next 5 years, we will:

Unit-level environment template (REF5b)

- Develop capacity for digital trials using resources such as the iCARE digital platform in Imperial College Healthcare NHS Trust (ICHT), WSIC and Discover-NOW
- Undertake cohort studies through primary care (e.g., CHARIOT:PRO) and novel trials of lifestyle interventions in dementia.
- Build on the strategic recruitment of The George Institute for Global Health UK and their expertise in trials design and implementation in a global context.
- Strengthen links including evaluation of public health initiatives in the local population around our new White City campus, especially through the NIHR Applied Research Collaborative (ARC).
- Expand our capability for monitoring of health service performance through the analysis of large integrated patient datasets that include data from primary care, community services, social care, mental health and hospital care.

1c. Approach to Supporting Interdisciplinary Research

Interdisciplinary research is central to our strategy in UoA2, the FoM and the College, with a focus on convergent science, physical (e.g. at White City) and virtual co-location through College Institutes, Centres and Networks (see Ref5a). Interdisciplinarity is reflected through our broad internal and external collaborations. Staff draw on expertise in clinical research with numerous collaborations with staff in FoM (UoA1, UoA4), for example, ICTU works closely with researchers across FoM to support trial development, design and analysis.

We actively participate in cross-Faculty interdisciplinary research through Imperial's Networks of Excellence (Air Quality, Antimicrobial Research Collaborative, Malaria, Vaccine Research), the Data Science Institute, the Grantham Institute for Climate Change and the Environment and the Cancer Research UK Imperial Centre). Externally we collaborate extensively in inter-disciplinary projects and networks in the UK and globally (**Section 4**). Our work on health system evaluation and public health involves widespread collaboration with other departments, including Endocrinology (Johnston), Surgery (Darzi, Mayer [UoA1]) and the Business School (Sassi [UoA17]). Work on dementia involves collaborations with the UK Dementia Research Institute (Matthews, Sharp [UoA4]), Dyson School of Design Engineering (Haddadi, [UoA12]) and the Department of Computing (Russo [UoA11]).

The inter-disciplinary nature of our research is reflected in our training. We recruit individuals from a broad range of disciplines including biological sciences, medicine, computational sciences (mathematics, statistics, computer science, physics) and social science (economics). We support transfer between disciplines through short courses on relevant topics and collaborative work within and between teams through regular internal work-in-progress seminars given by research students and postdoctoral staff.

1d. Approach to Achieving Impact

Our research is driven by the desire to have meaningful and sustained impact in improving public health (see impact case studies). We achieve a high level of translational impact through deep and sustained partnerships with industry and public health agencies locally, nationally and globally. In the UK, our translational impact is supported through our collaboration with PHE via our three joint NIHR HPRUs, as well as through the MRC Centre for Environment and Health and SAHSU. Internationally, staff engage extensively with global health partners. We host three WHO Collaborating Centres – the Centre for Infectious Disease Modelling (Ferguson), the Institute on Polio Data Analysis and Modelling (Grassly), and the Centre for Public Health Education and Training (Rawaf), NCD-RisC (Ezzati) in close collaboration with WHO, and the UNAIDS Reference Group on Estimates, Modelling and Projections. These provide regular two-way interactions that help shape the research and enable translation of research outputs into tangible policy impacts. We partner with the pharmaceutical industry and not-for-profit product development initiatives, allowing us to directly support the development pipeline for new tools, diagnostics, therapeutics and vaccines (**Section 4**). Our impact case studies arose through these long-term sustained

partnerships: our COVID-19 Modelling work in the UK and the REACT study were enabled by our formal collaboration with PHE via our NIHR HPRUs alongside positions held by academic staff on government advisory committees; our malaria case study arose through one of our WHO Centres; our health effects of noise case study through SAHSU and the MRC Centre for Environment and Health; our health service performance case study through our expertise in analysing large NHS datasets, and the inclisiran case study through collaboration with industry (The Medicines Company).

To ensure researchers are fully engaged in translation of their work, we hold regular workshops with industry and public health partners to understand their research and policy needs. These are targeted at all levels including research students and ECRs who are encouraged to engage directly with the organisations and present their results. Consequently, we have a high level of engagement with stakeholders, and encourage additional opportunities for student and postdoctoral placements. Recent examples include a PhD student seconded to WHO, another to a start-up genetics company and a postdoc to GO-Science.

1e. Enabling an Open Research Environment

Since REF2014 we have striven to create an environment in which research is readily and rapidly shared with the wider scientific community and the public. This is reflected in our outputs, with all but one REF output OA compliant. However, we aim to go above and beyond the REF OA policy requirements to ensure that our data are accessible to all, our research methods are reproducible, and our outputs are widely disseminated beyond the traditional academic publishing model.

Much of our research draws on data from national and multinational cohort studies. Our approach to data storage to enable sharing is outlined in **Section 3.c**. For example, the INTERMAP China Study (Chan Q, Elliott) data collection protocol was published in Wellcome Open Research and the analysis code is available on GitHub. The Airwave Health Monitoring Study (Elliott) data have been shared with >30 research groups worldwide via the Dementias Platform UK data portal. Data on the Indian Chronic Disease Network (Jha) have been shared with the international network of chronic kidney disease cohorts. NCD-RisC (Ezzati) computer code, output and input data where legally possible, are made available in a harmonised format on an open access basis with country estimates used extensively by other researchers. Clinical data from the UK Neonatal Research Database (Modi) are available through the HDR UK Alliance Gateway.

We have invested heavily in making model code accessible and usable by external groups through establishing an internal software development team (**Section 3**), allowing independent validation of our research methods and code (**Section 4.g**), and have explored innovative ways to allow tools and results to be accessed by a broader audience. We host a website for sharing analyses of bacterial genetic data (<https://poppunk.net/>, Croucher, Lees), a data visualisation tool to share global estimates of the public health impact of vaccination generated by the Vaccine Impact Modelling Consortium (Gaythorpe, Ferguson, Grassly, Hallett, Ghani <https://www.vaccineimpact.org/dataviz/>), and a website to host district-level estimates of HIV incidence and prevalence and antiretroviral therapy uptake to support local planning (<https://www.hivdata.org.za/>). NCD-Risc (Ezzati) hosts an online visualization tool (<https://www.ncdrisc.org/data-visualisations.html>) accessed from 228 countries/territories since launch in 2016. We have used dashboards to share results during the COVID-19 pandemic which can be updated daily or weekly to complement traditional scientific publications. Examples include <https://mrc-ide.github.io/global-lmic-reports/> (Walker, Ghani) and <https://imperialcollegelondon.github.io/covid19local/#details> (Bhatt, Ferguson, Flaxman [UoA10], Gandy [UoA10]).

User-friendly interfaces to models help support science translation and public health planning. Examples include: two tools for HIV planning “Shiny90” (<https://shiny90.unaids.org/>) and “Naomi” (<https://naomi.unaids.org/>) with UNAIDS (Eaton), the “Mint” tool (<https://mint.dide.ic.ac.uk/>) to support malaria planning with WHO (Churcher) and the www.covidsim.org software in

collaboration with WHO to support country healthcare planning and vaccine introductions (*Winskill, Walker, Ghani*).

1f. Maintaining Research Integrity

Researchers in the UoA take advantage of FoM and College procedures. Imperial is a signatory of the UK Concordat to Support Research Integrity. We have adopted the Universal Ethical Code for Scientists and uphold its three principles. Researchers are supported by the Joint Research Office (JRO) and the Research Governance and Integrity Team (RGIT). The JRO facilitates the management of research grants, contracts and EU projects while RGIT ensures researchers meet their responsibilities in research governance to fulfil the legal, ethical and scientific obligations of the healthcare research process. This includes general data protection regulations (GDPR) via the data protection team and human research ethics via Imperial College Research Ethics Committee (ICREC) which reviews health-related research involving human participants and/or their data where not covered by Health Research Authority Research Ethics Service. We have also established the Science, Engineering and Technology Research Ethics Committee (SETREC) to review non-health related research involving human participants and/or their data and high-risk educational research undertaken by College staff or students.

College provides guidance and training to staff and students across a wide range of areas linked to research integrity, including mandatory plagiarism awareness training for doctoral students. Plagiarism software is used for all PhD theses and Masters' Dissertations.

2. People

2a. Staffing Strategy

Our highest priority is our staff. We strive to attract and retain world-leading and rising-star academics, to develop leaders in their fields, and support our professional staff to fulfil their potential. We foster an intellectually challenging and invigorating environment in which collaborative science is centrepiece, as evidenced by the high degree of research collaboration between staff. We place a strong emphasis on supporting and mentoring junior investigators by providing training and professional development opportunities. At all levels staff are supported through career development pathways, providing opportunity for advancement both within academia and externally. Our holistic programme ensures that development activities fill skills gaps and equip staff for organisational change so they can be agile and responsive to new ways of working, as evidenced by the way staff adapted to working remotely during the COVID-19 pandemic.

To facilitate public health translation, we make strategic joint appointments with key stakeholders (e.g., White, joint appointment with the PHE Modelling and Economic Unit). Staff and students also undertake secondments to public health partners (e.g. Hargreaves to the Department for Education as deputy science adviser, Greaves previously clinical advisor to the Chief Medical Officer, now Director of Science, Evidence and Analytics at the National Institute for Health and Care Excellence (NICE) and Deputy Director of Public Health Science to Joint Biosecurity Centre (JBC), PhD student Thompson and research associate Hamlet to WHO, Blangiardo and PhD student Green to JBC). We have identified and acted upon strategic opportunities; for example, recruitment of the Environmental Research Group from KCL to strengthen our environmental epidemiology expertise and The George Institute for Global Health UK from Oxford to augment translation to policy and our global clinical trials expertise. We have many international joint appointments that build on established and new research collaborations (**Section 4**). Since REF 2014 we have expanded our connections with LMICs to support the development of research globally (**Section 4**).

2b. Staffing and Recruitment Policy

We have invested heavily in attracting new academic staff with a combination of open and strategic recruitment targeting areas of identified need. We have recruited 38 academic staff (13 professors, 3 readers, 15 senior lecturers and 7 lecturers, 34% female), representing an investment in salary costs alone of over £20m during this REF period and contributing to our 45% FTE increase in submitted staff. Our gender ratio across UoA2 is 39% female and BME representation has increased (19%). We continue to identify opportunities to improve this (**Section 2f**).

We have successfully expanded the number of ECRs, thereby supporting the transition from postdoctoral work to independence. The Imperial College Research Fellowships (ICRFs; formerly Imperial Junior Research Fellowship) support the brightest and best early career researchers from across the world. We have appointed 10 ICRFs since REF2014 (including *Jauneikaite*, *Lees*, *Winskill*). We have also increased our cadre of exceptional ECRs holding prestigious competitive fellowships including Wellcome Trust Sir Henry Wellcome (*Pons-Salort*, *Kaforou*) and Sir Henry Dale (Croucher, *Pons-Salort*), MRC (*Verity*, Walker), The Royal Society (Okell), and MRC FLP (Robinson [UoA14]).

Many of those that completed fellowships have subsequently secured senior appointments. For example, Lamberton (ICRF 2012 cohort) is Reader at the University of Glasgow, Oude Griep (ICRF 2014 cohort) is Senior Research Associate at the MRC Epidemiology Unit in the University of Cambridge, whilst Mostowy (ICRF 2015 cohort) leads a lab at the Jagiellonian University in Kraków, Poland. Others moved into non-academic environments; for example, Slater (ICRF 2016 cohort) to the international NGO PATH whilst Lehne (ICRF 2015 cohort) is Data Science Lead for John Lewis. Several external fellowship holders have also been promoted to academic appointments (Croucher, Okell, Walker).

2c. Research Student Training

The research student body in UoA2 has expanded since REF 2014 with a total of 124 research students enrolling between 2014 and 2020 (with annual numbers ~ 100 enrolled students) and 91% submission within 4 years of enrolment across this period. We have worked hard to ensure a diverse student population with 59%/41% female/male ratio and 5.1% Black, 7.2% Chinese, 13.0% Asian, 13.4% mixed and 61.4% white students. Students are supported through doctoral training accounts (DTAs) from the MRC, BBSRC, NERC and EPSRC, through funding provided directly to the two MRC Centres, the three HPRUs, via a 4-year Wellcome Trust PhD programme and the Wellcome Clinical PhD programme, through the J-IDEA PhD programme and via the NIHR-funded ARC. Additional 17 studentships have been awarded from the Imperial College President's PhD programme.

We run a rigorous recruitment process and are heavily over-subscribed with ~10-15 applications per place. Applications are independently scored by several academics and rankings made prior to interview, ensuring a rigorous and unbiased selection process. We have increased efforts to improve diversity in student recruitment. This year, FoM staged a PG recruitment webinar called "Think Imperial!", with the aim to widen participation rates and the diversity of PG applicants. The event had ~440 students registered, representing 172 institutions (65% non-Russell group). We also trialled "anonymised" applications at the short-listing stage in which gender and other identifiers are removed. To better reflect the global nature of our research, we ring-fenced specific funded places for students from LMICs; during this REF period we enrolled students from across the global south including Asia, Africa and Latin America. Additionally, we successfully supported students from LMICs through Commonwealth studentships.

Students joining the research programme embark on either a 3- or 4-year programme. Students undertake a first week orientation providing an overview of key training elements and milestones and develop a research training plan during the first 6 weeks - incorporating a review of skills needed for the research and for future employment. This includes generic (transferable), project-specific and discipline-specific skills training. Sources of training include graduate school activities (including a compulsory online plagiarism awareness course, a minimum of four professional skills courses, a residential skills and development course or two additional professional skills courses,

and one of the international summer schools or two further additional professional skills courses), departmental training such as research seminars and courses, and from other sources (internal or external courses, Masters modules, the Centre for Academic English). A monitoring plan includes an independent assessor panel (one internal and one external to the department or College) providing feedback on progress at three points (three months, 12-18 months and 18-24 months).

Training for PhD supervisors is through the College's Continuing Professional Development programme, involving mandatory training and encouragement to take further development courses including "Best practice in supervision" workshops and an online course supporting the mental health and wellbeing of doctoral students.

Research students take part in an annual SPH PhD day in which they present their research in conference style, providing an opportunity to interact with their peers and to build connections as a cohort. A postdoc-student mentoring scheme enables established postdoctoral researchers to provide support to students at admission, helping them to integrate into the wider activities of the department. The PhD students organise regular social events as a cohort (financially supported), ranging from regular coffee-chats or pizza lunches to external social activities.

Clinical Academic Training: We are returning five clinical ECRs. To support them and others, Imperial AHSC set up a Clinical Academic Training Office (CATO) in 2015, with a dedicated team reporting directly to the Imperial FoM Dean and AHSC NHS Chief Executives. CATO takes responsibility for the entire academic training path for Health Education England and NIHR-funded fellows (foundation doctors, Academic Clinical Fellows (ACFs), Clinical Lecturers). CATO also supports all clinicians undertaking PhDs and runs a novel 2-year Post-Doctoral Fellowship to support doctors after PhDs before applying for intermediate fellowships. For our growing non-medical clinical academic programme, they have established fellowship opportunities for pre-doctoral and post-doctoral clinicians (one-year secondments to develop their research interests and capabilities and apply for further funding) and a range of other support activities specifically for non-medics. In 2018 Imperial established the Healthcare Professionals Academic Group (HPAG) creating a "home" for Imperial non-medical clinical academics and patient-centred research.

2d. Supporting Junior Researchers

Within UoA2, we have 21 REF-defined ECRs. Dedicated support for ECRs and post-doctoral researchers is provided at College level via the Postdoc and Fellows Development Centre (PFDC) who coordinate an extensive portfolio of support activities including 10 development days written into their contracts, career advice, support with applications for fellowships (CV, mock interviews) and one-to-one support. In partnership with the PFDC, we supported a 2-day residential workshop targeted at supporting the transition to independence. The PFDC also run a bespoke programme of support for our independent research fellows and clinicians actively pursuing academic careers at Imperial.

This programme is supplemented by specific activities within SPH, including an established mentoring programme for postdoctoral staff, regular participatory workshops to support CV development, grant-writing and promotion applications, and biennial career days involving external speakers (including former staff) from industry, government departments, research funders and international health agencies such as WHO. Technical training and support is also provided, including seminar series (many organised and led by ECRs) and training workshops to fill specific skills gaps (including statistical methods, data presentation and programming).

Representation within the departments is enabled through postdoctoral representatives, who help shape policies around PhD supervision and inductions and are represented on management committees. Each department has an academic "post-doc champion" who ensures that postdocs and fellows' needs are being met.

Imperial has implemented fully the Concordat to Support the Career Development of Researchers and has been awarded the European HR Excellence in Research Badge since 2012 (see REF 5a). Imperial is committed to and mapped our actions against the 40 principles of the European Charter and Code. Each year, every member of College staff is required to undertake a Personal Review and Development Plan, a two-way discussion between staff member and manager aimed at recognising achievement, providing constructive feedback, and assisting with career development. Staff benefit from the College's flexible working policy.

2e. Staff Development

Policies for leave are outlined in **Section 2.f** and for facilitating exchanges in **Section 1.d**.

Retention of staff is key. We have implemented a suite of activities to recognise and reward our staff. We run annual promotions rounds where we consider all eligible staff as well as inviting open expressions of interest from staff themselves. Clear promotion guidelines are made available to all eligible staff with reminders sent on a regular basis. Promotion documentation explicitly considers administration, pastoral, outreach, mentoring and diversity activities, as well as caring responsibilities or parental leave. Quality of research is emphasised over quantity and teaching contribution is emphasised, especially at lower grades, while research, mentoring and international reputation are encompassed at higher grades. Interview panel members undertake unconscious bias training and panels include academic representation, an Athena representative and a College Consul who serve to ensure fair process across College. We run an annual pay relativity exercise to objectively review each member of staff's salary in line with benchmark information or the relevant Pay Progression Framework to ensure parity between colleagues undertaking similar roles. FoM has been working with colleagues in Manchester (Professor Lennon) and Oxford (Professor McShane) to **develop a clear career path** for all those undertaking research roles within a Team Science context, including technologists, coordinators and managers. This will encompass all staff, including fixed-term and part-time contracts. We aim to develop a framework for career progression with implementation in 2021/2.

2f. Supporting Equality and Diversity

Imperial College is committed to supporting all staff to achieve their best. Recognising, as a sector, that there are issues to overcome in equality and diversity, we have made substantial changes to support our staff. At College level, we have established an **executive Equality, Diversity and Inclusion (EDI) Strategy Group** headed by the Provost, appointed Imperial's first Assistant Provost (EDI) and established an EDI Forum with a broad and representative membership. These new bodies work closely together to promote the integration of the values of EDI that are envisaged in the strategy document.

The FoM Culture Initiatives Management Group (CIMG) was formed in 2019, reports directly to the Dean and is Chaired by the Vice Dean Institutional Affairs (Lloyd, [UoA1]). This Group aims to create an inclusive culture and environment and is involved in shaping strategies, policies and processes, as well as generating resources and improved signposting for students and staff at all levels and career stages. We have also convened a Black Lives Matter working group, reporting in to the CIMG, to specifically focus on issues of racial inequalities for students and staff. Recognising the importance of this work, in late 2019 we appointed our inaugural Project Director of the CIMG (Essilfie-Quaye).

Since REF2014 we have improved our gender balance (39% female) and increased the ethnic diversity (19% BME) of our staff. We have also increased the visibility of women at the top level, with 5 out of 11 women on the SPH board and a female Director of the School. However, we are cognisant that further improvement is required across the academic sector and have therefore instigated a programme of work to address issues that have been identified as barriers to progress. This is overseen by our Equal Opportunities Committee (EOC, Co-Chairs Bottle, Fecht [UoA14]), who work closely with broader initiatives in FoM (through a Faculty Culture Initiatives Management Group chaired by Vice Dean for Institutional Affairs, Lloyd [UoA1]) and across the College to plan

and coordinate EDI activities including Athena SWAN, the Race Equality Charter, and Staff Survey Action Planning.

The EOC meets regularly to monitor and act upon data on research student admissions and outcomes, academic recruitment, promotion, training, and uptake of flexible working and career breaks. Entry into research student programmes is gender-balanced but there remains a level of under-representation of some BME groups; this is reflective of the undergraduate representation of the institutions from which we have historically recruited. To redress this, we are working across the Faculty to explore options for increasing applications and admissions from previously under-represented institutions (e.g., outside the Russell group) and to support students at an earlier stage in their career (e.g., by enabling support for under-represented undergraduate students to undertake summer research projects). To increase diversity of our academic staff appointments, we instigate formal search committees using a panel for senior appointments and advertise extensively internally and externally for advertised lecturer and senior lecturer positions. All recruitment panels are mixed gender and panel staff are required to take regular EDI training. We have identified internal promotion as an opportunity to increase the diversity of our staff and we ensure that all staff are aware of the annual procedures for promotion and are actively encouraged and supported by senior staff. Furthermore, all staff are considered without application to make sure that no-one is missed. We also support broader career development activities, including specific support at the postdoctoral level (via the PFDC) and for junior academic staff (through the Learning and Development Centre and the annual personal review and development programme which is monitored by the EOC), highlighting the range of career pathways available to illustrate that there is no “one size fits all”. Support is available for all staff in applying for research funding, with “shadow” panels now instigated for MRC applications to provide early feedback, for the two Boards piloted, success rates have improved on average, 10%.

College staff may take paid study leave of up to three days each year and apply for flexibility in their work schedule to facilitate attendance, to sit examinations, revision and the preparation of coursework. Staff can take an interest-free loan to help with costs of part-time study. We are proud to have been listed in this year’s Top Ten Employers for Working Families and to have won The Cityparents Best for all stages of Fatherhood Award (2017). Through the working practice changes imposed by COVID-19 we supported staff and students working from home by ensuring they had the necessary equipment needed to work, including attending to relevant health and safety needs, and by instituting regular remote departmental meetings and social opportunities.

Practical support is provided for new parents with caring responsibilities, including College-wide new parents workshops, “keep in touch” days, childcare vouchers and monitoring of satisfaction with flexible working options through an annual parental voices survey. Staff are encouraged to apply for the Elsie Widdowson Fellowship award provided by College to enable returning academic staff to be relieved of teaching or administrative duties to fully concentrate on research for up to 12 months. Practical support to cover caring costs when staff attend conferences or undertake training is provided through a College-wide scheme. Social activities support this wider ethos; we have successfully established annual away days for staff and families, ensure meetings are scheduled within the working day and are flexible to different working patterns and consider the cultural appropriateness of social activities.

Additional measures to support staff with, for example, illness, disability and return from long term absence include “Staying Healthy at Work” plans, access to 24hour confidential care line and mental health first aiders (51 within FoM across all campuses). Each department has a disability officer as the first point of contact for staff and students and there is financial support for adjustments to support those with a disability.

The EOC support activities to ensure a culture of respect and inclusivity. All staff participate in courses to raise awareness including unconscious bias and active bystander training. Senior staff are encouraged to undertake 360-degree appraisals to identify and address EDI issues. We run an annual showcase to celebrate research success, excellent teaching outputs and public engagement activities across the School. Our annual Athena SWAN lectures given by prominent

leaders in academia, health and related disciplines are well attended by staff. We also run a lunchtime discussion group to address and debate issues around inclusivity. Alongside the College's accreditations (Athena Swan, Race Equality Charter, Time to Change, Disability Confident, AccessAble, Stonewall) and networks (Able@Imperial (disability), Imperial 600 (LGBTQ+), Imperial as One [BME]), we engage with the British Medical Association racial harassment charter for medical schools and target advertising through agencies such as "Black British in STEM". We also engage with the FoM 2eMPOWER Project – making STEM accessible for students with specific learning difficulties throughout their education.

All academic staff are included in the REF submission. Independent research staff were identified as per the College's REF code of practice. All staff were asked to nominate 10 outputs, and these were scored by a panel composed of senior academic staff. A computer-based algorithm (agnostic to individual characteristics) was then used to select the outputs based on the assigned scores whilst ensuring each person returned at least one and no more than five outputs. The selected outputs were further reviewed to ensure that outputs with multiple UoA2 authors were assigned to the most appropriate author. Thirty-nine percent of outputs were assigned to female staff and 15% to BME staff which closely matches the overall UoA2 submission (39% female, 19% BME).

3. Income, infrastructure and facilities

3a. Income

We employ a diverse range of strategies to generate income. During this REF period, investigators in UoA2 have a research spend of £282m equating to £510k per FTE/yr, with a yearly average funding growing from £26.2m in 2014 to £40.2m in this REF period, a 55% increase. Including £27m from Research Councils, £77m from Government (including NIHR/DHSC), and £68m from charities (UK and overseas). We employ a diverse range of strategies to generate income.

Supporting individuals through personal awards: we provide mentorship through departments and the PFDC, internal peer review at departmental level, strong institutional support reflected in meaningful letters of support, and mock interviews focussing both on science and presentation skills. Our success has been demonstrated through Wellcome Trust Investigator Awards (Ghani, Hauck, Riley, Volz); five NIHR senior/Emeritus investigators (Ashby, Elliott, Ferguson, Poulter, Ward); ERC Advanced Grant (Fraser); NIHR Professorship to Millett; Marie Skłodowska-Curie Fellowships to Blanquart, Dagnino, Plusquin; and 12 ECR fellowships (**Section 2.b**).

Supporting underpinning research: to improve our grant success rates, we undertake rigorous internal peer review and have recently established "shadow panels" for all project grant applications to the four standing research boards at the MRC. In this REF period, we have secured over 700 grants from a range of funders including MRC (£23m), NIHR (£34m), Wellcome (£18m) and BMGF (£18m). Twenty-one of our researchers have been successful in a range of externally funded COVID-19 calls (MRC, NIHR, Wellcome).

Developing strategic opportunities: through building partnerships within and across faculties as well as between institutions, our researchers lead on various national and international strategic partnerships. As noted, three NIHR/PHE HPRUs are held in UoA2 [leads Ferguson, Elliott and Kelly [UoA14]] (£12m total income) and our two MRC Centres were extended beyond their 10-year tenure as a mark of quality and their unique position in the UK landscape (£20m total income this REF period).

Fundraising: Working with Imperial alumni, our Advancement team raises funds for scholarships, academic positions, research centres and capital projects. This can take the form of unsolicited gifts through to larger donations built around fundraising campaigns. Over this REF period, UoA2 have raised £53.5m, supported by a successful campaign which brought in investment to establish The Mohn Centre for Children's Health and Wellbeing and the Mohn Chair, the Battcock Chair in Community Health and Policy and J-IDEA.

3b. Infrastructure

Since 2014, Imperial College has committed £59.8m on building and estates projects for UoA2, with a spend to date of £15.1m. Targeted philanthropic fundraising programme, by the end of this REF period, we secured £25m to fund a new purpose-built home for SPH on the recently transformed White City Campus enabling the co-location of the School's researchers for the first time. The new school will include collaborative, flexible and interactive spaces for our academics, collaborators, students and the local community. Fundraising continues and has now reached £57m.

To support innovation and entrepreneurship, we have created a network of innovation spaces for businesses of all sizes – major corporations, high-tech and high-growth companies, SMEs, start-ups and entrepreneurs – to work alongside Imperial researchers at every stage of their development and growth. The Translation and Innovation Hub (iHUB) located on the White City Campus, provides space and facilities for companies of all sizes to work alongside our researchers to accelerate growth. In 2020 we opened the Scale Space, 20,000 sqm technology and innovation centre to support new high-growth technology companies.

3c. Facilities

Given the quantitative nature of our research, one of the biggest growth areas for UoA2 researchers has been in data science. Our researchers lead several major initiatives in this area including the UK MEDical BIOinformatics partnership (UK MED-BIO; Elliott) with the Institute of Cancer Research. We are a substantive site in Health Data Research UK London (Lead, Elliott). We were a pioneer site for the NIHR Health Informatics Collaborative linking patient data via the electronic health record systems including clinical information, diagnostic tests and imaging data across 5 NIHR Biomedical Research Centres (BRC; Cooke [UoA1], Elliott, Kaura [ICHT], Mayet [ICHT]) and are leading partners in the HDRUK Discover-NOW Hub for Real World Evidence.

Data Storage and Processing: Imperial has invested in a suite of secure storage and processing facilities to accommodate a range of sensitive datasets (de-identified and identifiable data) including the Institute of Global Health Innovation (IGHI) Big Data & Analytical Unit (BDAU), Data Science Institute (DSI), the Secure Enclave and the Research Computing Service (RCS) environment. The BDAU currently manages over 130 datasets for researchers across Imperial College. The Imperial Secure Enclave allows the storage of identifiers to facilitate data linkage. Internal collaborators include the DSI and we make use of the College high-performance computing (HPC) environment that provides world-class supercomputing clusters, providing a secure, flexible and scalable platform supporting data analysis.

In collaboration with UKCloud and Bluematrix, the NIHR Imperial BRC generated a high performance, cloud-based, informatics solution allowing NHS Trust staff and College researchers to access de-identified data with enhanced tooling, compute power and security. This system provides the ability to manage access control to specific data resources allowing full audit of every action that staff take when using Trust data.

Data Sources and Collection: researchers draw on many different data sources including administrative data, bespoke data collected from deployed digital interventions, clinical trials, cohort studies and multiple qualitative datasets. Imperial has strong relationships with large data controllers including NHS Digital (NHS), the Medicine and Healthcare Regulatory Agency (MHRA), WSIC and ICHT. Imperial currently holds national linked data at a person level for hospital encounters, mental health care, general practice consultations and specific condition registry data from cancer to diabetes with agreements to allow bespoke linkage for novel datasets. The College holds a Clinical Practice Research Datalink (CPRD) GOLD license, with access to over 35 million patients' longitudinal linked records. Imperial is also pioneering the analysis of the WSIC dataset which covers 2.2 million patients in North West London (NWL) with linked records across primary, secondary, mental health and social care records allowing unique

Unit-level environment template (REF5b)

insights into local population health and supporting the development of information dashboards to assist the management of health and social care across the sector.

Data Protection: The College has established information governance structures to provide assurance to data providers, research subjects and patients that data are held and used appropriately. Systems holding sensitive data are ISO27001:2013 certified, and those hosting NHSD data are compliant with NHSD's Data Security and Protection Toolkit. Staff are trained in GDPR and Good Clinical Practice (GCP/GxP) to ensure that all legal and ethical obligations are met. All mobile apps used for data collection are GDPR compliant with support from Imperial College's Data Protection Officer and Compliance Manager, and meet criteria based on NHS Digital Assessment Questions covering data storage and privacy, authentication and session management and network communication.

Data Transformation and Analysis: Imperial has robust and reproducible methods for data transformation ensuring that data integrity and availability is maintained throughout research programmes. An original immutable copy of each dataset is stored to ensure integrity of data and enable auditing of changes downstream. We utilise Github and SVN for version control of custom coding where applicable. We work with researchers to produce metadata for new and existing datasets to allow for continued reuse of data. Maintaining data quality and integrity is a key objective of our data management processes, ensuring that data can be used with confidence. Imperial hosts several analysis tools ranging from traditional quantitative tools to novel big data tools such as KNIME, HADOOP and custom natural language processing (NLP).

Data Sharing, Dissemination and Archiving: Imperial facilitates data sharing with the wider research community ensuring that data are used to maximum potential for the benefit of patients and healthcare. Ensuring that data are findable, accessible, interoperable and re-usable (FAIR) enables this. The Imperial AHSN works with other regional AHSNs to share and utilise data for healthcare research and improvement across the entire UK. We use our Archives and College Records Unit (ACRU) internally for data archiving. Working with researchers we also create de-identified datasets for use by the wider scientific community.

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

4a. Research Collaborations, Networks and Partnerships

Examples of interdisciplinary collaborations within Imperial College are provided in **Section 1**.

Internationally, our collaboration with NTU in Singapore to create a new medical school, the LKC School of Medicine, has flourished and our first students graduated in 2018. We have also built our research partnerships, making key joint appointments and visiting positions between our institutions in strategically important areas for both organisations. There are four joint appointments between UoA2 staff and LKC (Car and Chambers based in Singapore, Elliott and Riboli based in London). Examples of collaborative research include:

- Health for Life in Singapore (HELIOS) a large population study of 100,000 Singaporeans to understand the role of diet/lifestyle/physical activity/and diseases (Chambers, Elliott, Riboli) in collaboration with Associate Professor Joanne Ngeow (LKC).
- E-Health - using e-health tools and technology for health system innovations for quality improvement (e.g. integrated care), and investigation of management of long-term diseases (Car, Majeed).
- Cardiometabolic disease - identifying mechanisms underlying high rates of diabetes and cardiovascular disease amongst South Asians and East Asians and developing new strategies for prediction and prevention (Chambers).

The recent transfer of The George Institute for Global Health UK to Imperial presents exceptional opportunity for 'value added' for both partners, leveraging The George's excellence in policy-related research and international clinical trials with UoA2's wide research portfolio in both infectious and chronic disease and in clinical trials.

Staff hold joint or honorary research appointments with academic institutions in the UK and across the world: LSHTM (Baguelin, Jombart, Vineis), University of Oxford (Donnelly, Faria), University of Bristol (Tsilidis), PHE (White, Saxena), NICE (Greaves), Joint Biosecurity Centre (Greaves), University of Ioannina, Greece (Evangelou, Tsilidis) Barcelona Institute for Global Health, ISGlobal Spain (*Sicuri*), Centre d'Economie de la Sorbonne, France (*Sicuri*), University of Ljubljana, Slovenia (Car), University of Washington, US (Ezzati, Hallett), Harvard School of Public Health, US (Ezzati), Columbia University, US (Vineis), Johns Hopkins University, US (Woodward), University of Laval, Canada (Boily), Biomedical Research and Training Institute, Zimbabwe (Gregson), University of Ghana (Ezzati), Shiga University of Medical Science, Japan (Chan Q, Woodward), Manipur Academy of Higher Education, India (Jha), National Institute for Medical Research, India (Arinaminpathy), Peking University Health Science Centre, China (Norton), Mahidol University, Thailand (Woodward), University of Sao Paulo, Brazil (Faria).

We lead on a number of international cohorts including EPIC (Riboli), INTERSALT/INTERMAP (Chan Q, Elliott), COSMOS (Elliott, Toledano) and have leading positions on international trials (e.g. Finfer, Neal, Poulter, Ray, **Section 1.b**) and the NCD-RisC collaboration (Ezzati). We lead the UK National Neonatal Research Database (Modi) and the European Atherosclerosis Society Familial Hypercholesterolaemia Studies Collaboration (*Vallejo-Vas*). We participate in steering committees of the Cohorts for Heart and Aging Research in Genomic Epidemiology (CHARGE) consortium (Dehghan), the International HundredK+ Cohorts Consortium (IHCC, Elliott), the Australian Sepsis Network and Asia Pacific International Sepsis Forum (Director, Finfer).

We lead and participate in many international modelling consortia. We established and hosted the secretariat for the BMGF-funded HIV Modelling Consortium (Hallett, Eaton, Boily), led the BMGF-funded Diagnostics Modelling Consortium (2014-2016, Ghani, Hallett, Arinaminpathy) and host the secretariat for the Vaccine Impact Modelling Consortium, a joint initiative between BMGF and Gavi (Ferguson, Garske, *Gaythorpe*, Ghani, Grassly, Hallett). We are active members of the BMGF-funded TB Modelling Consortium TB-MAC (Arinaminpathy), Malaria Modelling Consortium (Bhatt, Churcher, Ghani, Walker, *Winsky-Sommerer*) and NTD Modelling Consortium (Anderson, Basanez, *Turner*). Through these consortia we have contributed to collaborative publications that directly inform global policy - including a special issue on Diagnostics Modelling (Ghani et al., Nature 2015), multi-model comparisons for HIV, malaria and NTDs, and the Lancet Commission on Tuberculosis 2019. We co-lead the London Centre for NTDs (Anderson) and the HPTN Modelling Centre (Boily).

Staff engage with a range of networks e.g.: Worldwide Antimalarial Resistance Network (Okell), COVID-19 Genomics UK Consortium (Volz), The Global Pneumococcal Sequencing Project (Croucher), the MoxiMultiDoseMod Consortium (Basanez), The APLHA and AHISA Networks (Gregson), the UK Vaccine Research Network (Ferguson), The Cancer and Nutrition NIHR Infrastructure Collaboration (Cross), International Consortium for Blood Pressure Genetics (Elliott, Evangelou), China Kidney Disease Network (CK-NET, Jha), the Genetics and Epidemiology of Colorectal Cancer Consortium and the Breast and Prostate Cancer Cohort Consortium (Tsilidis).

4b. Engagement with Research Users and Beneficiaries

We endeavour to make our findings broadly available in the research community through sharing of data, code and tools (**Section 3.b**). Examples of software tools developed to support the wider research community include the R-packages ODIN, EpiEstim, Outbreaker2 and Epidemia. Dissemination of these tools is aided by the R Epidemics Consortium (RECON) (Jombart) bringing together global researchers with those working in public health agencies.

Staff in UoA2 have established research partnerships with major pharmaceutical companies including GSK (Anderson), GSK Vaccines (Ghani), Sanofi (Ferguson, Ray), Janssen (Anderson, Middleton), Takeda (Ferguson, Grassly, Middleton), Pfizer (Pinder, Ray), Amgen (Woodward), The Medicines Company (Ray, see impact case study), Novartis (Middleton), AstraZeneca (Middleton), Nestle International (Modi). These research partnerships have been critical in

understanding mechanisms of action of new therapeutics and drugs and translating these insights to understand their utility, impact and cost-effectiveness at the population level.

Collaborations with start-ups/not-for-profit include Antigen Discovery Incorporated (a California-based startup, Croucher), MedAccess (a price guarantee company that facilitates access to public health technologies by lower-income countries, Churcher), Medicines for Malaria Venture (Okell, Ghani, Walker), Integrated Vector Control Consortium (Churcher, Ghani), PATH (a global not-for-profit aiming to improve public health, Churcher, Ghani, Walker, *Winskill*), Kyowa Kirin (development of genetic tests to improve healthcare, Woodward).

4c. Research Impact

Staff provide scientific advice to the UK government through membership of advisory panels including Committee on Medical Aspects of Radiation in the Environment (COMARE, Toledano), Committee on Toxicity (Toledano), Public Health England Adenoma Surveillance Guidelines Development Group (Cross), UK Scientific Advisory Group on Emergencies (Ferguson), New and Emerging Respiratory Virus Threats Advisory Group (Ferguson), Advisory Group on Dangerous Pathogens (Ferguson), Scientific Pandemic Influenza Subgroup on Modelling, SPI-M (Baguelin, Ferguson, Riley), Independent Scientific and Technical Advice register for the Ministry of Defence (Arinaminpathy), Expert Advisory Group to the International Comparators Joint Unit for assessing responses to the COVID-19 pandemic, The Cabinet Office and FCO (Hauck), UK Panel for the Certification of Elimination of Polio, Measles and Rubella (Grassly), Expert Scientific and Clinical Advisory Panel NHS Health Check (Greaves), Clinical Digital Council NHSX (Greaves), NICE Guideline Committee on Babies, Children and Young People's Experience of Healthcare (Hargreaves), Chair, Clinical and Technical Expert Group on Integrated Development for Global Dementia Strategy 2014-15 (Middleton). In addition, during the COVID-19 pandemic, students and staff were seconded to government and PHE: *Atchison* (PHE), Imai (Government Office for Science), and Blangiardo, Green (Wellcome Trust-funded PhD student) to the UK Joint Biosecurity Centre.

Staff play a prominent role in WHO standing advisory committees across a range of infectious and chronic diseases: a non-exhaustive list includes WHO SAGE Working Group on COVID-19 vaccines (Grassly), WHO Malaria Policy Advisory Committee (Ghani) and Malaria Evidence Review Groups (Churcher, Ghani, Okell, Walker), WHO Reference Group on Health Statistics (Eaton), WHO Strategic and Technical Advisory Committee for Tuberculosis (Arinaminpathy), WHO Guideline Development Group for Cervical Cancer Pre-Lesions (Boily), WHO Development Committee on Guidelines for Antenatal Surveillance (Gregson), Environmental Working and Cessation Risk Task Teams of the WHO Global Polio Eradication Initiative (Blake), WHO Reference Group on Health Statistics Task Force on Risk Factors (Ezzati), WHO / Global Sepsis Alliance, Sepsis Task Force (Finfer), WHO Advisory Group on Classification of Diabetes Complications (Gregg), WHO Task Force on Donation and Transplantation of Human Organs and Tissues (Jha), WHO Expert Advisory Panel on Human Cell, Tissue and Organ Transplantation (Jha), WHO Risk Reduction of Cognitive Decline and Dementia, Guidelines Development Group (Kivipelto).

Staff provide advice internationally to global health agencies and foreign governments. The former include The World Bank (Ferguson), Gavi, the Vaccine Alliance (Ghani), The Global Fund (Arinaminpathy, Churcher, Ghani, Hallett, Hauck, *Winskill*), US Centers for Disease Control and Prevention (Eaton, Ghani, *Winskill*), US President's Emergency Plan for AIDS Relief, PEPFAR (Eaton), US President's Malaria Initiative (Churcher, Walker), US Department of Health and Human Services and White House Homeland Security Council (Ferguson), International Decision Support Initiative (Hauck), World Cancer Research Fund (*Chan D*), the Global Sepsis Alliance (Finfer), Tobacco Control Committee of the European Respiratory Society (Filippidis), Expert Advisory Panel, Alzheimer Europe and Alzheimer Disease International (Kivipelto). The latter include New York State (Bhatt, appointed special advisor on COVID-19 pandemic modelling), International Advisory Panel to Hong Kong Government (Neal), the Minister of Health in Italy

(Vineis), Zimbabwe Ministry of Health COVID-10 Researchers Consortium (Gregson), National Institute of Medical Research, India (Arinaminpathy), Health Services Executive in Ireland (Bottle).

The submitted impact case studies highlight a subsection of these extensive national and international interactions.

4d. Public Engagement

Sharing our research with the public is a crucial part of our mission. We participate in a range of activities including science festivals (including the annual MRC and Imperial Festivals), school outreach projects (including sessions in which school students visit the campus, scientists visiting schools and hosting year 12 students for summer projects), and numerous public talks. Examples include participation in “I’m a scientist get me out of here” (Donnelly), establishment of the LOL-lab bringing together local community, scientists and comedy, expert advice to the “Mumsnet Babies Podcast” and running “Pint of Science” events. In addition, PERC have further supported public engagement training, with 641 researchers and students and 91 members of the public participating since 2017. Staff members also gave regular talks and briefings to UK MPs in parliament (e.g. via All-Party Parliamentary groups) and regularly engage with the media

PERC manage VOICE, an online platform for public and patient involvement and engagement. From January 2019 PERC hosted 106 opportunities on the [VOICE online platform](#) that have collectively involved at least 628 public members.

COVID-19 and Public Engagement

The COVID-19 pandemic put much of our research in the limelight and it was essential that we regularly communicated our findings to the public in a clear and unambiguous manner. Alongside early release of open-access online reports and preprints, we translated all report summaries into seven languages to ensure global accessibility. For key reports, we additionally generated videos distributed via social media and YouTube and co-published two reports in the Science Journal for Teens. In collaboration with Oxford Sparks, we contributed to an animation explaining COVID-19 transmission and control, and through a partnership between PERC and the Burnt Orange Theatre Company, engaged 20 young creatives resulting in short films about five reports alongside their personal experience of the pandemic. We released 18 webinars updating the science posted on YouTube up to 31 July 2020 and participated in 17 external webinars for the public through global agencies and think-tanks (e.g. World Economic Forum, International Monetary Fund, The World Bank, Chatham House) and the media (BBC, Bloomberg, The Economist)

In partnership with Coursera, we developed the “Science Matters: Let’s Talk About COVID-19 Q&A” open online course, regularly updating material and adding modules throughout 2020. With over 138,000 registered users, the course was the most popular launched on Coursera during Europe’s first lockdown in the first half of 2020.

Since March 2020, PERC have involved 4,812 members of the public in a range of [COVID-19 community involvement activities](#). Online, 420 people responded to a community involvement survey where they shared their views, experiences, and unmet needs on COVID-19 to guide research.

Our COVID-19 research findings, publications and activities are shared on social media platforms including YouTube, Twitter, LinkedIn, Instagram and Facebook. This has massive reach; all tweets received over 14 million impressions in 2020, with Report 9 on the impact of nonpharmaceutical interventions reaching nearly half a million people. We regularly engaged with the UK and international media, responding to over 1000 media queries from 49 countries including regular newspaper, radio and television interviews with the BBC, ITV, Channel 4 and Sky.

4e. Sustainability

Unit-level environment template (REF5b)

We undertake training of researchers across the globe. We run three on-campus Masters courses in Epidemiology, Public Health, Health Data Analytics and Machine Learning, and in partnership with Coursera, we established the first fully online Global Masters of Public Health. This experience with online learning helped us to transition to online teaching during the pandemic. All courses include grounding in research methods and offer the opportunity to undertake a research project.

We are committed to supporting the expansion of our discipline in LMICs. We run a number of popular short courses in epidemiology, statistics, modelling, data analytics and e-Health for researchers and public health specialists. With local partners, we have run training workshops in Colombia (2017,2019) supporting participants across Latin America, in Africa (in partnership with AIMS for example in Cameroon in 2019), and in Asia (for example, supporting capacity building for mathematical modelling in India).

Our research is highly inter-disciplinary. External collaborations are described in **Section 4.a**. Examples within Imperial include the Target Malaria project, an \$80m 5-year grant to develop gene-drive strategies to eliminate malaria-carrying mosquitoes led by Faculty of Natural Sciences (Burt [UoA5], Crisanti [UoA5], Ghani, Ferguson, Mumford [UoA14]); and the MRC-funded Digital Diagnostics for Africa Network, involving colleagues in all Faculties (Baum [UoA5], Cunnington [UoA1], Georgiou P [UoA12], Ghani, Okell, Rodriguez-Manzano [UoA1]). We collaborate closely with colleagues in the Department of Mathematics in the development and application of statistical and mathematical methods (including Filippi [UoA10] who is a member of the MRC Centre for Environment and Health, Flaxman [UoA10], Gandy [UoA10], Ratmann [UoA10]) and with the Business School (Sassi [UoA17]).

Through our engagement with UK government and international organisations, our research is highly responsive to national and international priorities in health. Nationally, through our NIHR HPRUs and other units, we work collaboratively with PHE addressing UK priorities, for example, evaluating the impact of air quality on health, the emergence of antibiotic resistance and antibiotic management, support for diabetes care and the growth of mental health issues in adolescents. Internationally, examples include support for WHO guidance and policy in relation to emerging outbreaks (Ebola, MERS, COVID-19), endemic diseases (HIV, TB, Hepatitis, malaria, polio, NTDs, sepsis) and NCDs (via NCD-RisC). We also work closely with global health partners including The World Cancer Research Fund, The World Bank, The Global Fund and Gavi to support delivery of core interventions.

4f. Contribution to the Research Base

UoA2 researchers contribute extensively to support the national and international research base in epidemiology, public health, health services, policy and primary care research. Non-exhaustive examples are provided here.

Honours (since 2014):, Commander (Donnelly) of the Order of the British Empire; Knight (Vineis) and Officer (Riboli) of the Order of the Star of Italy; Officers of the Order of Australia (Finfer, MacMahon, Norton); Fellow of the Royal Society (Donnelly), Foreign Member of the US National Academy of Medicine (Ferguson); Fellows of the Academy of Medical Sciences (Donnelly, Ezzati, Ghani, Hallett, Modi, Woodward); member of the Italian Academy of Science (Vineis); Fellows of the Australian Academy of Health and Medical Sciences (Finfer, MacMahon, Neal, Norton, Woodward); NIHR Senior Investigator (Ward).

Learned Societies: council member of the Royal Society (Donnelly); council member of the Academy of Medical Sciences (Modi); President-elect 2020-21, British Medical Association (Modi); President, Royal College of Paediatrics and Child Health 2015-2018 (Modi); President 2019-2020 (Ashby) and council Member (Donnelly) of the Royal Statistical Society; Vice-President (2016-2018) and President (2019-) of the British Society for Parasitology (Basanez); board member of the International Society for Sexually Transmitted Disease Research (Ward); President of the International Diabetes Epidemiology Group 2019-20 (Gregg); Vice-Chair of the Ethics Committee

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for the International Agency for Research on Cancer (Vineis); President of the International Society of Hypertension (Poulter); President Elect 2020, European Atherosclerosis Society (Ray); Founder and co-lead of the NIHR Statistics Group (Cornelius), President (2016-), European Prevention of Alzheimer Dementia Academy (Kivipelto). Associated activities: Academy of Medical Sciences reports on “Multimorbidity: A Priority for Global Health Research” (MacMahon - Chair, Ezzati), “Preparing for a challenging winter 2020/21” (Ghani, Riley) and “Adaptive Trials” (Chair, Ashby); US National Academies Consensus Study Report on Dietary Reference Intakes for Sodium and Potassium in 2019 (Elliott).

Grants Committees: UKRI (Ashby, Donnelly, Elliott, Ghani), Wellcome Trust (Arinaminpathy, Churcher, Donnelly, Elliott, Ferguson, Ghani), The Royal Society (Ferguson, Ghani), Longitude Prize Advisory Panel (Ghani), World Cancer Research Fund (Cross), Cancer Research UK (Ashby, Cross, Filippidis), British Heart Foundation (Elliott), European Commission (Fecht [UoA14]), NIHR (Ashby, Bottle, Cornelius, Costelloe, Greaves, Lavery, Millett, Saxena), Health Research Board Ireland (Ashby), Swedish Research Council (Kivipelto), European Research Council Advanced Grants (Middleton).

Prizes: International Diabetes Federation Award Lecture (Gregg), American Diabetes Association Kelly West Award (Gregg), Robert Austin Award (Lees), Times Higher Education “World’s Most Influential Scientific Minds 2015” (MacMahon), Emerging Leader Award of the World Heart Foundation (Peters), Australian Financial Review 100 Women of Influence 2019 (Norton), Suffragette Science Award for Women in Mathematics (Donnelly), Royal Society of Tropical Medicine and Hygiene Chalmers Medal 2017 (Ghani), Zoological Society Frink Medal 2020 (Donnelly), Finnish Neuroscientist of the Year 2018 (Kivipelto), Asian Woman of the Year Science Finalist 2019 (Saxena), Young Investigator Award 2019, European Atherosclerosis Society (Vallejo-Vas), Woman of the Year GG2 Leadership Award 2018 (Modi).

Keynotes: CEE-ZSL Julian Huxley Memorial Lecture 2017 (Donnelly), G20 summit on digital health (Volz), Invited Keynote MRC Lecture Society of Toxicology (Elliott), American Heart Association (Elliott), Keynote Lecture, Gordon Research Conference on Malaria 2019 (Ghani), American Statistical Association (Ashby), World Economic Forum (Hauck), Alzheimer Association International Conference 2018 (Kivipelto), G7 Global Dementia Conference 2014 (Middleton).

Editorial Boards: PLoS Medicine (Hallett), Philosophical Transactions of the Royal Society B (Donnelly), e-life (Senior Editor, Ferguson), Royal Society Interface (Ferguson), Science Translational Medicine (Ferguson), *Gene (Lill)*, PLoS Biology (Riley), PLoS Neglected Tropical Disease (Churcher), Journal of the Royal Society of Medicine (Majeed), PLoS One (Tsilidis, Jha), Frontiers of Neurology (*Lill*), Environmental Research Letters (Ezzati), Guest Editor (Critical Care) New England Journal of Medicine (Finfer), Statistics in Medicine (Woodward), Women’s Health (Editor, Woodward), BMJ Global Health (Peters), International Journal of Cancer (Vineis), European Journal of Epidemiology (Vineis), Frontiers in Public Health (Editor, Vineis), Commissioner on the Lancet Commission on TB (Arinaminpathy), Lancet Clinical Commission on Diabetes (Ezzati), Lancet Commission on Non-Communicable Diseases in the Poorest Billion (Ezzati), Lancet Commission on Obesity (Ezzati), Lancet Commissioner for Liver Disease in the UK (Pinder), Editor, Epidemics (Riley), Guest Editor, Special Issue on Diagnostics Modelling, Nature (Ghani), Subject Editor, Oxford textbook of Clinical Nephrology (Jha), Bulletin of the World Health Organisation (Jha), BMJ (Saxena), BMC Medicine (Bottle), BMC Public Health (Filippidis), EBioMedicine (Modi).

4g. Enabling Best Research Practice

Our approach is described in **Section 1.e**. Example of independent validation of research methods: two COVID-19 reports (Report 9 and Report 13) have been certified as reproducible by CODECHECK (www.codecheck.org.uk), a collaborative project between the Universities of Cambridge and Munster, Germany, to increase the availability and reproducibility of code used for scientific research. The research findings of these two high-profile reports have also been

independently verified and re-published in the BMJ (led by University of Edinburgh researchers) and at www.turing.ml (by University of Cambridge researchers).

4h. Collaboration with External Organisations

Connections with the NHS, industry, government bodies and non-governmental agencies are maintained through honorary positions. Examples include: Dr Maria Van Kerkhove (COVID-19 Technical Lead at WHO), Dr Valerie Delpech (Consultant Epidemiologist at Public Health England), Professor Jeremy Farrar (Director of The Wellcome Trust), Dr Bhargavi Rao (Infectious Diseases Lead, Medecins Sans Frontiere), Dr Anand Shah (Consultant Respiratory Physician at Royal Brompton and Harefield NHS Trust), Dr Hannah Slater (Epidemiologist, PATH), Mrs Ronke Akerele (Executive Director of Innovation and Transformation at Hertfordshire Partnership Foundation Trust), Dr Martin Block (Health Education England), Dr Sophie Coronini-Cronberg (Public Health Consultant, Chelsea & Westminster Hospital), Dr Sharif Ismail (Health Adviser, Foreign, Commonwealth and Development Office), Dr Maria Kinali (Consultant Paediatric Neurologist, Chelsea and Westminster Hospital), Dr Sabita Uthaya (Consultant in Neonatal Medicine at Chelsea and Westminster Hospital), Prof. Paul Aylin (Board Member, West London Mental Health Trust), Prof. Azeem Majeed (Head, Public Health Directorate, ICHT).