Institution: Imperial College London

Unit of Assessment: 02 Public Health, Health Services and Primary Care

a. Overview

Research in UoA2 at Imperial College London aims to improve population health by strengthening the public health science base, training the next generation of public health leaders, and influencing health policies and programmes around the world. Building on our performance in RAE 2008, public health has continued to be a strategic priority for Imperial College over the REF period. To support our research mission we continue to invest in four key elements: strategic investment in people and infrastructure; focusing fundraising in key areas of research strength; developing our people through training, promotion and recruitment; building relationships with key stakeholders. In 2008-9, we launched two MRC Centres and the Imperial Clinical Trials Unit (ICTU), now fully UKCRC accredited. We have grown from 33 FTE submitted in RAE 2008 to 54.6 FTE submitted here, with annual research income awarded doubling over that time to over £44M in 2012-3. We have 3 research groups which span *infectious disease epidemiology*, *chronic disease epidemiology*, and *clinical trials and evaluation*, including primary care and public health.

b. Research strategy

The Unit provides a coherent academic identity and home for the broad range of multi- and inter-disciplinary research we believe is essential for delivering scientific innovation in public health. Our mission is to deliver world-class research at the local, national and international level, translating scientific advances into improvements in health policy, prevention and treatment of major infectious and chronic diseases, health services and primary care. The strategic commitment of the College to delivering this mission is evidenced by the establishment of the Imperial College School of Public Health (SPH) in 2010 and College investment of £6M in nine new academic posts in support of the two MRC Centres and ICTU (e.g. *Ashby, Ezzati*) and £3.3M in resources (e.g. genomic laboratory, refurbishment) since RAE 2008.

Our research is undertaken in the broader context of the Imperial College Academic Health Sciences Centre (AHSC), founded in partnership with Imperial College Healthcare NHS Trust (ICHNT) in 2007 and formally designated by the Department of Health (DoH) in 2009 nested within an Academic Health Science Network (AHSN) (Imperial College Health Partners established 2012). The AHSC and AHSN provide a framework for the continuum of research from discovery to first-in-man clinical trials, population-based trials, implementation and dissemination.

Research groupings, their activities, rationale, how they operate and main achievements

Our research is structured into three broad areas, each with the aim to achieve long-term sustained capability and internationally competitive programmes in our areas of strength. Our Early Career Researchers are underlined. Staff returned within other UoA submissions are not italicised.

Infectious disease epidemiology: Research spans a wide range of disease areas, including: influenza, emerging infectious diseases, polio, malaria, HIV, sexually transmitted infections, TB, neglected tropical diseases (NTDs), bacterial infections and fungal infections, with approximately £42M research income over the REF period. Significant funders include MRC (*Ferguson* [Centre Director], Fisher [UoA5]*, Ghani, Riley*), Bill and Melinda Gates Foundation (BMGF; *Fraser, Ferguson, Ghani, Grassly, Hallett*); European Union Framework 7 (EU FP7; *Aanensen, Ferguson*); European Research Council (ERC; *Fraser*), US National Institutes of Health (NIH; *Ferguson, Fraser, Hallett, Riley*), Wellcome Trust (*Aanensen, Basanez,* Gregson [UoA1]). Formal partnerships include: World Health Organization (WHO; Collaborating Centre status); Public Health England (PHE; influenza, TB, HIV); US Centers for Disease Control and Prevention (CDC; influenza, outbreaks). We have increased capacity in the burgeoning fields of molecular and evolutionary epidemiology, a key priority over the REF period, reflected in recent academic appointments (*Aanensen, Didelot, Volz*). Our collaborative environment supports integration and collaboration between staff undertaking field/intervention research and those working on mathematical and statistical modelling. Public health translation is a key motivation for all staff.

Our three main approaches to tackle the research challenges are as follows:

- *mathematical modelling* of infectious disease through a multidisciplinary approach to support policy planning and response operations against emerging and endemic disease threats.
- *genetics and evolution*, with a focus on developing methods for the integrated analysis of epidemiological and sequence data, understanding the co-evolution of virulence and transmission fitness of HIV, and analysing the structure and evolution of bacterial populations.

- *global health interventions* including one of the largest malaria modelling research groups world-wide (*Ghani* [leader]), which works closely with a wide range of Global Health partners to inform control and elimination efforts for malaria; and the Wellcome Trust funded Manicaland cohort study (Gregson [leader]) which has been researching behavioural determinants and evaluating interventions for the HIV epidemic in Zimbabwe for over 20 years.

Key research achievements include:

- Publications in leading journals (e.g. 4 papers in NEJM, 3 Lancet, 1 Nature, 3 Science, 14 PNAS, 15 PLoS Medicine, 2 Lancet Infectious Diseases) and 7 papers cited 100 or more times in the REF period (1 over 200, 1 over 500).
- MRC Centre for Outbreak Analysis and Modelling (*Ferguson* [Director]). Its mission is to be an international resource and centre of excellence on the epidemiological analysis and modelling of infectious diseases. The Centre has published over 350 scientific papers since launch in 2007. In 2013 it was renewed by MRC, achieving the maximum score with increased funding.
- We brought research capacity to tackle urgent public and global health priorities, e.g. the 2009 H1N1 flu pandemic (*Ferguson* Science, NEJM, Lancet, PNAS, BMJ 2009-10); polio eradication (*Grassly* NEJM 2008, Lancet 2012); HIV (*Hallett*, *Fraser* Lancet, PLoS Medicine 2008-12).
- We have built close and successful partnerships with key public health agencies. We were awarded the first WHO Collaborating Centre for Infectious Disease Modelling (co-authoring 30+ papers with WHO colleagues), and assisted US CDC in creating a modelling unit (co-authoring >20 papers with CDC staff).

Future plans:

- Develop closer collaborative partnerships between the MRC Centre for Outbreak Analysis and Modelling and key national (e.g. PHE via the NIHR Health Protection Research Units [HPRUs]) and international public health agencies (e.g. China CDC, Public Health Foundation of India).
- Reinforce and enhance capacity and capability in integrated genetic and epidemiological analysis, advanced biostatistics and health economics, via focussed recruitment of research and academic staff.
- Build on the recent award of a Wellcome Trust Doctoral Training programme, develop our integrated 4 year PhD training programme by adding an initial one year MRes option and expand opportunities for student placements with external collaborators.

Chronic disease epidemiology: Within the chronic disease epidemiology group we undertake leading research to advance understanding of the causes and effects of the major chronic diseases and thereby influence policy for improving health locally, nationally and globally (cf. key reviews by *Ezzati* and *Riboli* NEJM 2013;369:954-64, Science 2012;337:1482-7). We promote cross disciplinary approaches, e.g. epidemiology, environmental science, laboratory science, and a high quality environment to develop the next generation of research leaders. We hold major grants from MRC, NIHR, Home Office, Wellcome Trust, British Heart Foundation, ERC, PHE among others, with £67M of research income over the REF period. Key themes focus on: aetiological studies, notably on cardiovascular disease (and its risk factors), type-2 diabetes, respiratory disease and cancers; application of omic technologies to understanding disease causation and pathogenesis; environmental epidemiology, including through the UK Small Area Health Statistics Unit (SAHSU); analysis of international trends in chronic disease and risk factors. We house major cohort studies including UK COSMOS (100,000 participants), Airwave (police cohort, 40,000), INTERSALT and INTERMAP (15,000), European Community Respiratory Health Survey (ECHRS, 10,000), LOLIPOP (30,000), Northern Finland Birth Cohorts (NFBC) 1966, 1986 (20,000). Our cohorts combine variously genomic, metabolomic, epigenomic, transcriptomic data with rich clinical data. We coordinate the 500,000 person EPIC study; we lead the scientific design and oversee implementation of the Qatar Biobank (*Riboli, Elliott*), undertaken in parallel with biobanking activities at Imperial. We coordinate a number of EU-FP7 multi-omic projects (Exposomics [*Vineis*], Epi-Migrant [*Chambers*], Combi-Bio [*Elliott*]).

Key research achievements include:

- Publications in leading journals (e.g. 5 papers in NEJM, 4 Lancet, 6 Nature, 18 Nature Genetics, 1 Science, 3 PNAS, 2 JAMA, 12 JNCI, 7 BMJ) and 23 papers cited 100 or more times in the REF period (15 over 200, 3 over 500).
- Establishment in 2009 of the MRC-PHE Centre for Environment and Health (*Elliott* [Director])

jointly with King's College London (KCL), closely linked to the MRC-NIHR National Phenome Centre (Nicholson [UoA1], *Elliott*) set up in 2012 for molecular phenotyping at scale through the analysis of large epidemiological cohorts. The MRC-PHE Centre comprises over 50 investigators and ~300 associated research staff and students with publication of over 1300 peer reviewed papers since the Centre was established. Its research is contributing to the evidence underpinning environment and health policies nationally and globally.

- We played lead roles in large international consortia undertaking Genome-wide Association (GWAS) and functional studies of major chronic diseases and traits including type-2 diabetes, asthma, Alzheimer's, blood pressure, C-Reactive Protein, cardiac conduction, growth, adiposity, blood glucose and bone mineral density (*Andrew, Bertram, Chambers, Coin, Cookson, Elliott, Evangelou, Froguel, Jarvelin, Prokopenko*; NEJM, Nature, Science, Nature Genetics, Lancet, JAMA, 2008-12), and developed the concept of the Metabolome-Wide Association Study (*Elliott,* Nicholson, Holmes [UoA1] Nature 2008) and Nutrient Wide Association Study (*Tzoulaki, Elliott* Circulation 2012).
- We play a key leadership role in the Global Burden of Disease study (*Ezzati*). We carried out extensive analyses of the risks associated with measures of adiposity, and the emergence of the obesity and blood pressure epidemics worldwide (*Riboli* NEJM 2008; *Ezzati* Lancet 2011).

Future plans:

- Further development of the MRC-PHE Centre for Environment and Health as a leading national and international centre for research and policy translation on environment and health risks.
- Further follow-up of our cohorts and carry out deep exploration through multi-omic approaches to improve understanding of disease aetiology and pathogenesis.
- Expand and develop our successful PhD training programme and build a junior fellowship programme (6 fellows, £1M) linked to the MRC-PHE Centre.

***Clinical Trials and Evaluation*:** We aim to be at the forefront of evaluation of the benefits and risks of treatments/interventions, through clinical trials, pharmaco-epidemiology and evaluations of health service performance, with £32M of research income over the REF period. Our return in UoA2 reflects the strong history of clinical trial involvement across a broad base e.g., cardiovascular and metabolic disease (*Collins, Greenhalgh, Neal, Peters, Poulter, Thom*), mental health (*Ritchie*), HIV & Infection (*Gilks, Maitland, Weber*). During the REF period, we set up the Imperial Clinical Trials Unit (ICTU) and recruited statistical leadership (*Ashby, Warwick*). This grouping also includes local, national and international evaluations of health services and health service performance, with strong links to the NW London CLAHRC (*Majeed*) and the London Research Design Service (RDS; *Majeed, Ashby* [local leads]), Dr Foster Intelligence (*Bottle;* Aylin [UoA1]), and the Global E-health Unit (*Car*).

Key research achievements include:

- Publications in leading journals (e.g. 10 papers in NEJM, 10 Lancet, 1 JAMA, 13 BMJ, 5 PLoS Medicine) and 18 papers cited 100 or more times in the REF period (10 over 200, 1 over 2000).
- Establishment in 2010 of the Imperial Clinical Trials Unit (*Poulter, Ashby* [Directors]) which was fully UKCRC accredited in 2012.
- Lead roles in major trials including HIV (*Gilks* NEJM 2010; *Weber* NEJM 2013), glucose control (*Poulter, Neal* NEJM 2008; *Neal* NEJM 2010), aneurysm (*Greenhalgh* NEJM 2010), blood pressure (*Peters* NEJM 2008*; Neal* NEJM 2013*; Thom, Poulter* JAMA 2013), coronary disease (*Collins* Circulation 2008-10), infection (*Maitland* NEJM 2011), Alzheimer's (*Ritchie* NEJM 2012).
- Analyses of Hospital Episode Statistics showing variation in surgical performance (*Bottle* BMJ 2010-11, 2013) and of the General Practice Research Database providing evidence of the long-term effects on cardiovascular disease of anti-diabetes drugs (*Majeed* BMJ 2009).

Future plans:

- Further develop ICTU as a centre of excellence for trials in the College across all therapeutic areas through training of staff and the next generation of clinical trial specialists.
- Carry out a randomised trial of salt substitute and stroke in rural China (*Neal*, *Elliott*).
- Consolidate and expand our capability in health service performance monitoring/ evaluation.

***Sustaining and developing an active and vital research culture**:* We believe that success

should be facilitated and rewarded, with balanced recognition of individual and group contributions. Sustaining and enhancing our current vibrant research environment has three elements:
Building a research community: We have implemented a range of activities to further support and strengthen our research community, including active weekly or bi-weekly seminar programmes (at Department and Centre levels) attended by 30-40 researchers, away days, annual Centre Research Showcases (80-100 attendees), regular social activities, monthly departmental staff meetings. The two MRC Centres each provide a thematically coherent home for a number of our research groups and a mechanism and motivation for broader collaboration. A notable example is the work of the MRC Outbreaks Centre in the 2009 H1N1 pandemic, where almost 50 staff (from the research groups of 5 senior academic staff) contributed to a collective effort to undertake real-time analysis of the emerging epidemic. More generally, researchers in a number of research areas (e.g. HIV, evolutionary epidemiology, exposome and health, small area studies) organise regular meetings which span PI group boundaries and give an opportunity for early career researchers to present and discuss their research among their peers.

Empowerment and motivation: Staff at all seniority levels are given opportunities to provide input into the strategic development of our research priorities and as much personal responsibility as possible within their own roles. This is facilitated by the tiered management structure (e.g., SPH Executive Committee, Centre Executives, Departmental staff meetings), plus a strong culture of regular 1-to-1 meetings between Heads of Departments and academic staff. In addition, SPH and the MRC Centres hold annual away days at which staff and students discuss and influence research strategy and priorities. Early career researchers are supported and encouraged to take an active role in external interactions – such as representing their research groups at meetings with public and global health stakeholders (e.g. WHO, BMGF, PHE), attending at least one international conference per year, and participating in outreach activities (e.g. Science Fairs, the annual Imperial Science Festival, MRC-PHE Centre Researchers' Society).

Career development and support: a key emphasis is on recognising and nurturing talent, through technical and research skills training, provision of career advice (e.g. via career days) and encouraging and enabling the most talented postdoctoral researchers to obtain individually-held research fellowships (section d.).

Evidence of multi- and/or interdisciplinary developments: Our research in UoA 2 is intrinsically multi- and inter-disciplinary. All three research groupings draw on expertise in clinical research, biology, epidemiology, biostatistics, mathematical modelling, genetics, bioinformatics, computational biology and health economics. We recruit staff from a wide range of academic backgrounds, and provide informal workshops (e.g. phylogenetic analysis), intensive training and short courses (e.g. Bayesian statistics, nutritional epidemiology, geographical information systems [GIS], global health).

Responsiveness to national and international priorities and initiatives: The work of UoA2 researchers is used extensively for policy purposes. Through large-scale international collaborations, we informed the global response to the H1N1 pandemic through real-time epidemiological analysis of the emerging outbreak, by close collaboration with organisations such as PHE, US CDC and WHO. Following that pandemic, we dedicated staff to the relationships with US CDC (situating a researcher permanently in Atlanta) and WHO, to facilitate collaboration and the bilateral flow of information. Other examples include: undertaking a large-scale modelling effort on malaria elimination strategies in response to the BMGF initiative for malaria eradication (*Ghani*); real-time analysis of the ongoing Middle East respiratory syndrome coronavirus outbreak in response to calls from WHO and US CDC (MRC Outbreaks Centre); undertaking a short-timescale evaluation of the burden of disease from Yellow Fever for WHO and GAVI (*Ferguson*); analyses underpinning WHO guidelines on sodium and potassium intakes (*Elliott* BMJ 2013;346:f1326 and 346:f1378); development of the SAHSU Rapid Inquiry Facility for use in the US Environmental Public Health Tracking Program (US CDC); leading the Global Burden of Metabolic Risk Factors of Chronic Diseases (*Ezzati*) with results adopted as official WHO statistics, presented at the Global Ministerial Conference on Healthy Lifestyles and Noncommunicable Disease Control (2011), and used to set global targets following the UN High-level Meeting on Noncommunicable Diseases (2011). More generally, we maintain a huge breadth and depth of collaborative partnerships with public and global health institutions across the world (section e.).

Effective mechanisms for the development, promotion and dissemination of research: The SPH, our two MRC Centres and several of our cohort studies disseminate results of our work to the scientific community, stakeholders and the public via dedicated websites. We engage actively with the print and broadcast media, both via individual journalists and the Science Media Centre. For example, the SAHSU study on aircraft noise near Heathrow (Hansell [UoA1], *Gulliver, Elliott,* BMJ 2013) featured widely in the media and was raised in Prime Minister's questions. We present our research at Science Fairs, the MRC Centenary Science Museum special exhibit, the Imperial College Science Festival, Cheltenham Science Festival, British Science Association; give public lectures (e.g. at the Royal Society); undertake school and other outreach activities, e.g. exhibition on the concourse of Paddington station as part of the MRC Centenary celebrations (2013).

c. People

i. Staffing strategy and staff development:

Our people are our primary asset and so we place the highest priority on attracting and retaining those who are (or have potential to be) world-leading academic, research and professional support staff. This, in turn, fosters an intellectually challenging and inspiring environment.

Evidence of how the staffing strategy relates to research strategy and physical infrastructure: Our staffing mission is twofold: to recruit and retain top quality staff who can deliver and support sustained success in education, research and translation; and to develop the capability of all our staff. Recognising that motivation and retention of talented staff is key to our success, we support the full life-cycle of staff engagement from recruitment, to reward and retention, performance interventions, development and career planning. We identify talent, provide clear career pathway advancement, and ensure development activity fills skills gaps and equips staff for organisational change so they can be agile and responsive to new ways of working. To facilitate the public health translation of our research, we make strategic joint appointments (e.g. White [UoA1], joint appointment with PHE Modelling and Economic Unit; *Van Kerkhove* MRC Outbreak Centre liaison with WHO) and encourage secondments with external partners (e.g. *Cauchemez*, US CDC). We are jointly bidding with PHE to run Health Protection Research Units for Environmental Hazards (*Elliott*) and Modelling Methodology (*Ferguson*). We have made a number of international joint appointments, for example, *Car* will be jointly employed with the Lee Kong Chian Medical School, NTU, Singapore, an Imperial/NTU joint venture, from 1 January 2014; other international collaborations include *Peeters* with University of Utrecht, *Neal* with George Institute, Sydney.

Implementation of the Concordat to support the career development of researchers: The College has implemented fully the Concordat to Support the Career Development of Researchers and was awarded the European HR Excellence in Research Badge in 2012. The importance of our researchers' personal and career development, and lifelong learning, is recognised and supported at all levels. Each year every non-clinical member of College staff undertakes a Personal Review and Development Plan (PRDP), a two-way discussion between the staff member and manager, with joint job planning between University and ICHNT for clinical staff. The College's flexible working policy is applicable to all staff.

Supporting equality and diversity: SPH achieved an Athena SWAN Silver award in 2010 with Imperial College as a whole gaining Silver award in 2013. We established an Academic Opportunities Committee to explore new ways to tackle barriers in academic appointments, career advancement, and job satisfaction. The Faculty of Medicine Ambassadors for Women scheme provides high-profile role-models and helps support and advise academic women. The College offers 12-month Elsie Widdowson Fellowships to female academics to concentrate fully on their research on returning from maternity/adoption leave (3 awarded to our staff within the REF period).

More generally, Imperial College is committed to supporting equality-related activities which are championed by the Vice Provost (Education). The College resources a dedicated Equality and Diversity Unit mandated to promote and embed all aspects of equality throughout the College's communities, including Imperial as One (race), Imperial 600 (LGBT), and Disability Staff and Student Forums. The College's internal leadership programme for black and minority ethnic (BME) staff, iLead, has been so successful that Stellar HE, a development programme for diverse (BME) leaders across 10 higher education institutions was modelled on it. The College established a leadership programme for disabled staff, Calibre, which undertakes an annual Disability Survey and continues to be a Stonewall Diversity Champion.

Effective integration and role of clinical academics and NHS employed active researchers: Clinical academic staff make a vital contribution to our research; 20 clinical academics are returned and fully integrated in this submission. A Public Health and Primary Care directorate, headed by the Trust medical director, a clinical Public Health specialist, has been established in ICHNT. This provides an effective forum for joint job planning, clinical appraisals and revalidation for clinical academic staff in Public Health and Primary Care. Both College and Trust are represented on all clinical academic appointments. The College is a nominating body for the Advisory Committee on Clinical Excellence Awards (ACCEA). ICTU has a substantial NHS training function around the design of clinical trials and works with the Pan-London NIHR Research Design Service (*Majeed, Ashby* [local Directors]). We are an accredited research training location in both Primary Care and Public Health (*Majeed, Millett* [co-Directors,) and host around 11 clinical trainees per year.

Evidence of a sustainable staff structure and career development: In this UoA within the REF period, 17 academic staff were promoted and five internal research staff appointed to academic posts following a competitive recruitment process. We have development and succession plans in place for senior staff and an appropriate and growing supply of suitably qualified and skilled staff to apply for, and be eligible for appointment to, senior roles. We build management capability through Imperial Expectations; pragmatic and practical statements regarding how the College expects its managers, leaders and supervisors to conduct their duties. To facilitate succession planning, increase diversity, support retention and enhance our overall performance, capacity building of middle leaders is delivered through selective and targeted talent development programmes (the Management Training Scheme, Horizon and Pegasus). To equip senior academic staff with the practical skills and awareness required for organisational leadership, the College runs the Senior Academic Leadership Programme, based on the National Occupational Standards for management and leadership and is accredited with the Chartered Management Institute.

Arrangements for the effective development and support of the research work of staff: The Learning and Development Centre (LDC) provides management and leadership programmes to all College staff and additional tailored development support for the academic community. This includes the Academic Development Centre (support for all aspects of academic achievement), the Female Academic Development Centre (support for women in academic positions), and the Senior Academic Leadership Programme. The 'In Conversation' Senior Academic Forum is where the College's academic leaders meet to discuss and form solutions to key challenges. We have a formal mentoring process for postdoctoral scientists applying for independent fellowships.

Development of early career researchers and support for integrating them into a wider, supportive research culture: 12 Early Career Researchers are included in this submission. We actively facilitate the progression of early career staff, both non-clinical and clinical, to research independence. We have appointed an Academic Lead (*Hodgson*) for Postdoctoral Researchers within the MRC-PHE Centre, and maintain a database of current postdoctoral researchers in UoA2 to facilitate specific targeting for fellowship applications. Eighteen postdocs in UoA2 have been successful in obtaining such fellowships between 2008 and 2012. Imperial College provides 3-year Junior Research Fellowships (JRFs) with no obligatory teaching or administration; 3 have been awarded in public health and epidemiology since 2009. The Wellcome Trust Institutional Strategic Support Scheme (ISSF) supports four, one-year clinical training fellowships p.a. in global health research, providing opportunities for the most promising early career clinical academics to develop bids for independent fellowships. The first cohort completed in 2013, of whom 2 have attracted external fellowships. Through both the ISSF and earlier Wellcome Trust Value in People funding we have provided bridging support for 12 early and mid-career researchers in UoA2.

The Postdoctoral Development Centre (PDC) offers a tailored programme of support to postdoctoral researchers, who spend a specified minimum of 10 days per year on professional development. The PDC provides skills and career development training, a personal development programme for women and a range of individual support, including coaching and mock interviews. Since 2009, 40 1-2-1 coaching programmes have been delivered to Early Career Researchers, and 13 mock interviews held within UoA2, in addition to those held at research group level. The PDC also runs a bespoke development scheme for JRFs, publishes guides on postdoctoral issues and hosts the multidisciplinary Postdoc Reps Network. In 2010, the PDC was shortlisted for "Outstanding Support for Early Career Researchers" at the Times Higher Education Awards.

A Researchers' Society run through the MRC-PHE Centre for Environment and Health

promotes the welfare and career development of researchers across the Centre. Mainly aimed at early career researchers with fixed term contracts (research staff and PhD students), the Society facilitates training and career development, promotes a collaborative community, supports their integration into the Centre and empowers researchers to identify their own training needs. Similar structures and activities are available in the MRC Outbreaks Centre. Both MRC Centres run an annual career development day for postdoctoral researchers which includes external speakers from e.g., industry, government, research councils, public health bodies, and science in the media.

ii. Research students

The training and supervision of postgraduate research (PGR) students: In the external Periodic Review of Research Degree Students (2013) we received unanimous praise for our research degree programme, its high academic standards and achievements and its excellent submission rates. The College Graduate School provides an award-winning professional development programme for all postgraduate students throughout their study period. Imperial is the only university to have twice won the Times Higher Education Award for Outstanding Support for Early Career Researchers. The Graduate School works with academics and students across College to help build an integrated, interdisciplinary environment and help postgraduates move on to the next stage in their careers. The Professional Skills Development programme offers staged learning to ensure all postgraduate students acquire basic research skills at the start of their doctoral studies (underpinning skills phase) and continue to develop as a well-rounded researcher (consolidating and completing phases). There is an Enrichment section with further workshops available at any stage; most students complete several more courses than the compulsory requirement. The Graduate School also organises a range of activities to bring students together in an interdisciplinary environment, including an annual Students' Summer Research Symposium with student posters, prizes and an invited speaker.

Effective and sustainable doctoral research training: Both MRC Centres within the UoA run successful PhD programmes supported by the MRC core grant, MRC DTA programme (2-3 students p.a.), matching College and other funded studentships, e.g., Wellcome Trust (including clinical studentships), BBSRC, ESRC, MRC Integrative Toxicology Training Partnership and NERC studentships (37 students recruited in the REF period). ICTU successfully attracted MRC Hubs for Trials Methodology studentships. A new Wellcome Trust funded 4-year PhD programme in the Epidemiology, Evolution and Control of Infectious diseases (*Ghani* [Director]) has been established. As a signatory of the RCUK Concordat we are fully committed to providing excellent researcher development to postgraduate students and postdoctoral researchers. The College encourages cross disciplinary teams to come together via establishment of inter-faculty research institutes, Centres for Doctoral Training (CDTs), Doctoral Training Centres/Programmes (DTC/Ps) and Industrial Doctoral Centres (IDCs). The Graduate School assists with provision of training opportunities for research council funded students; students who do not belong to a DTC (etc.) are given a comparable learning experience and support. The Graduate School's Doctoral Training Governance Committee acts as a forum to share good practice and provide oversight of the training provided.

Evidence of a strong and integrated research student culture: Students in the two MRC Centres receive support and training over and above that provided by the Graduate School, including dedicated research training days, seminar programmes, poster and oral presentations (with student prize events for best poster and best oral presentation), and intensive mentoring sessions and specific skills training (e.g., parallel programming, phylogenetic analysis, particle filtering methods, mathematics, Bayesian statistics, chemometrics, GIS). These events enable students to come together from across disciplines to strengthen research connections and peer support groups. Placements in public health agencies and large global health NGOs give motivated students the opportunity to gain experience in those environments. The MRC-PHE Centre Researchers' Society develops a broad programme of researcher-led training activities, and public engagement opportunities for Centre members. In addition, the Graduate School has developed a good practice Cohort Building website to facilitate cohort building within Departments. The School of Public Health provides comprehensive research training for all PhD students to complement the programmes described above. All students have at least two supervisors, who contribute substantively to the supervision and are trained through mentoring and compulsory formal training.

Evidence of CASE awards and application of technology generated by research students: Two BBSRC CASE studentships have been awarded in the REF period (1 current), with Oxitec Ltd (supervisor: Donnelly [UoA1]) and ASM Scientific Ltd (supervisor: *Fisher* [UoA5]) and in Bayesian clinical trials with Unilever (supervisors Richardson [now at MRC Biostatistics Unit], *Ashby*). Our students have developed novel software applications, e.g., Posma (Anal Chem 2012;84(24):10694-701), Campanella (submitted for publication).

d. Income, infrastructure and facilities

Income: The research groups were awarded grants in excess of £140M in the REF period, e.g., Airwave Study £6M, European Research Council advanced awards £5M, COSMOS £3M.

Nature and quality of the research infrastructure and facilities:

Since 2008, Imperial College invested £325M in world-class research facilities. Through the AHSC, joint capital planning has provided the infrastructure necessary to align our biomedical research with clinical services. A key example is the Imperial Centre for Translational and Experimental Medicine (ICTEM), a c£70M AHSC flagship centre for research and education at the Hammersmith Hospital campus. At its heart is the NIHR/Wellcome Trust Clinical Research Facility which is closely linked to ICTU for clinical trials design and management. The Trust has invested £900k in a clinical research facility at Charing Cross in support of the Imperial BioResource and Biobanking theme (*Elliott* [Lead]). Other facilities ***specific to UoA 2*** include:

- *Space*: The St Mary's campus was extensively refurbished to accommodate the two MRC Centres (£2.5M). Substantial new space at St Mary's, Charing Cross and Hammersmith has accommodated new research activities, including clinical and laboratory space, and the MRC-NIHR National Phenome Centre (£1.2M refurbishment costs).
- *Sequencing*: Next-Generation Sequencing is available through the NIHR Imperial Biomedical Research Centre (BRC; *Weber* [Director], £112M 2012-17) genomics facility and NIHR capital award (£2M) on the Hammersmith campus, used for validation of methylation markers arising from epigenome wide scans, and deep sequencing efforts to refine signals arising from GWAS.
- *High performance computing (HPC)*: The two MRC Centres run large HPC clusters (>500 cores each), tailored to their specific needs. These resources link to extensive College-wide HPC support; three large HPC systems are available, supported by the College (>£1M p.a.).
- *Clinical Trials management*: ICTU works across Imperial College and associated healthcare trusts to deliver world class clinical trials at all phases; it provides a unique opportunity to liaise with and harness Imperial's academic experts and key opinion leaders. Further support is provided by the RDS London, part of the NIHR infrastructure, which provides statistical consulting services and training in statistics and statistical software.
- *Biobanking*: The NIHR Imperial BRC has established both a tissue biobank with an integrated IT sample management system, and a population biobank to facilitate clinical research by investigators across the AHSC. The Imperial BRC is a partner in the pan-BRC BioResource, contributing over 35,000 participants with stored blood samples and extensive phenotypic data, and chairs the BioResource Infection and Immunity sub-group. We also partner the NIHR pan-BRC Health Informatics Consortium (NHIC) which is developing linked IT for research in five clinical areas across the 5 BRC NHS Trusts; Imperial leads on coronary heart disease (*Chambers*). NIHR has also provided capital funding to support molecular pathology, clinical imaging and robotics. In addition, as noted, we have developed a national BioBank in Qatar (*Riboli*, *Elliott*), supported by the Qatar Foundation.
- *Phenotyping*: The MRC-NIHR National Phenome Centre (£10M over 5 years plus significant industrial support from analytical technology companies; Nicholson [Director, UoA1], Co-PI, *Elliott*) based on the Hammersmith and South Kensington campus provides high throughput, quality controlled analytical capacity for large-scale metabolic phenotyping research.
- *Small-area statistics*: SAHSU maintains databases of over 300M geo-referenced national health records (by postcode or individual address) including deaths by specific cause, cancer incidence, births, stillbirths, hospital episode statistics; its Rapid Inquiry Facility enables the rapid analyses for government of health statistics related to sources of environmental pollution.
- *Cohorts.* As noted (section b.), UoA2 includes leading cohorts with extensive phenotypic data and stored biological samples.
- *Health service performance*. The UoA houses the Dr Foster Unit at Imperial College, which undertakes investigator initiated analyses of e.g., surgical performance across the NHS.

Evidence of cross-HEI share or collaborative use of research infrastructure: Though directed by Imperial College, both the MRC-NIHR National Phenome Centre and MRC-PHE Centre for Environment and Health are cross HEI centres (with KCL). Central to the mission of the MRC Centre for Outbreak Modelling and Analysis is its role as an international resource to support response operations against emerging and endemic infectious disease threats. Through the NIHR BRC Directors group we have extensive collaborations across the five major BRCs at Imperial, Oxford, Cambridge, UCL and KCL. In particular, we have a jointly administered BioResource of healthy, genotyped individuals with consent for recall by genotype and/or phenotype, administered through a single steering committee. The BRC Bio-Resource has expanded to include four sub-themes of neuroscience, cardiovascular, rare diseases and inflammation/infection. Joint projects such as CHERUB, an HIV eradication study, use a common protocol across all 5 BRCs to access specialised laboratory facilities together with access to highly phenotyped patients, with a single BioBank of consented and accessible samples. The BRC NHIC will use shared IT to access clinical information for research across the five BRC Trusts. Within the Clinical Trials and Evaluation grouping both the RDS and North West London CLAHRC are cross HEI endeavours.

Significant major benefits in kind*:* Waters Corp. and Bruker Biospin, major manufacturers of mass spectrometry and NMR spectroscopy systems respectively, have partnered with the MRC-NIHR National Phenome Centre to provide technical and scientific support, including for training (£10M). We have developed detailed protocols and a clinical data capture programme for use in the Qatar Biobank, with benefits to the BRC in its BRC biobanking theme and BioResource.

Policy and practice in relation to research governance: The AHSC has facilitated streamlining of research management; a Joint Research Office (JRO) established in 2008 acts as a one-stop shop for all clinical research across the AHSC. JRO provides advice and assistance with: creating and submitting an application, contract negotiation, setting up an award, financial management of a project through its lifetime and reconciliation and grant closure at the end of the project. Within JRO, the Joint Research Compliance Office helps researchers undertaking clinical studies meet requirements of research governance, including all legal, ethical and scientific obligations. We were the first UK university to introduce InForm Integrated Trials Management System, a comprehensive service to support the collection, management and analysis of data from clinical trials. A purpose-designed database, DOCUMAS, has been introduced as a single repository of all clinical study information across the AHSC. The successful harmonisation of research support in the JRO has facilitated a 20% increase in patient participation rates in trials since 2011-12.

e. Collaboration or contribution to the discipline or research base

UoA2 researchers make a full national and international contribution to public health, epidemiology and primary care research. We have 3 Officers of the Orders of the British Empire (*Ashby, Ferguson, Rushton*), 9 Fellows of the Academy of Medical Sciences (*Ashby, Burney, Cookson, Elliott, Ferguson, Froguel, Poulter, Riboli, Weber*), 6 NIHR Senior Investigators (*Ashby, Cookson, Elliott, Ferguson, Poulter, Weber*). *Froguel* is listed as one of the top 400 most influential biomedical researchers in the last 15 years (*Eur J Clin Invest* 2013). All staff are included in the following examples.

Examples of **grants committees** include: **European Research Council FP7** (*Riboli, Vineis* [expert evaluators]); **US National Cancer Institute** (Epidemiology and Genetics Research Program, *Gunter*); **NIHR Panels** (Research Methods Programme, *Ashby* [Chair]; Health Technology Assessment Commissioning, *Ashby*; Senior Investigators Appointments, *Ashby*; Next Generation Sequencing, *Chambers*; Population Health, Epidemiology & Health Services, *Majeed*; NIHR/MRC Efficacy and Mechanism Evaluation, *Weber*); **MRC Boards** (Infection and Immunity Board, *Grassly*; Strategic Skills Fellowships, *Ashby* [chair Biostatistics sub-panel], *Ghani*; Medical Bioinformatics, *Riley*; Stratified Medicine Initiative and DPFS/DCS panel, *Weber*) **Wellcome Trust** (Infection Panel, *Ferguson*). Membership of **scientific advisory boards** include: Cancer Research UK (*Warwick*); German National Centre for Respiratory Diseases (*Cookson* [Chair]); PEPFAR (*Hallett*), PepsiCo (*Neal*); World Cancer Research Fund (*Peeters, Riboli*); Alzheimer's Association Public Health Steering Group (*Ritchie*), Italian Association for Cancer Research (*Vineis*).

Keynote/**Plenary** lectures include: South Asian Regional Symposium on Evidence Informed Healthcare (*Atchison),* Sadoul Lecture (ERS, *Burney*), ANTEL European Congress (*Car*), AMATA (*Coin*), Association for International Cancer Research (*Cross*); International Symposium on

Pneumococci and Pneumococcal Disease (*Croucher*); French Microbiology Society Congress (*Didelot*); American Society for Nutrition (*Elliott*); Tsinghua Global Vision Lecture (*Ezzatti*); Retroviruses and Opportunistic Infections (*Fraser*); Keystone Diabetes (*Froguel*); Society for Clinical Vascular Surgery (Greenhalgh), Michael DeBakey Memorial Lecture (*Greenhalgh*); World Federation of Pediatric Intensive and Critical Care Societies (*Maitland*); Lennart Hansson Memorial Lecture (European Society of Hypertension, *Poulter*); Rising Star Symposium Lecture (European Association for the Study of Diabetes, *Prokopenko*), World Oncology Forum (*Vineis*); Infectious Disease and Global Health, Sanger Institute (*Volz*); Microbicides (*Weber*).

Editorships and **Editorial boards** membership include: BMJ (*Ashby, Car, Majeed*); Statistics in Medicine (*Ashby*); Statistical Methods in Medical Research (Ashby); Bayesian Analysis (*Ashby*); Advances in Parasitology (*Basanez*), Trends in Parasitology (*Basanez*), Parasites and Vectors (*Basanez*), PLoS Neglected Tropical Diseases (*Basanez*), Human Mutation (*Bertram*); European Journal of Clinical Investigation (*Bertram*); International Journal of Molecular Epidemiology and Genetics (*Bertram*); Journal of Clinical Epidemiology (*Burney*); Journal of Epidemiology and Global Health (*Burney*); Cochrane Consumers and Communication Group (*Car*); Journal of Global Health (*Car*); BMC Infectious Diseases, Epidemiology (*Cauchamez*); BMC Public Health (*Conteh*); Mutagenesis (*Cox*); Proceedings of the Nutrition Society (*Cross*); Frontiers in Cancer Epidemiology and Prevention (*Cross*); Frontiers in Oncology (*Cross*); Environmental Research Letters (*Ezzati*); Heart (*Ezzati*); PLoS Computational Biology (*Ferguson*), PLoS Pathogens (*Ferguson*); Journal of the Royal Society Interface (*Ferguson*), Epidemics (*Ferguson*); Biology Letters (*Fraser*); PLOS Computation Biology (*Fraser*); American Journal of Epidemiology (*Fraser*); European Journal of Clinical Investigations (*Froguel, Vineis*); Statistical Communications in Infectious Diseases (*Ghani*); Annals of Surgery (*Greenhalgh*), Journal of Vascular and Endovascular Therapy (*Greenhalgh*), Cancer Research (*Gunter*); Malaria (*Maitland*); Health Statistics Quarterly (*Majeed*); BMC Medicine (*Maitland*); Journal of Ambulatory Care Management (*Majeed*); Journal of Hypertension (*Peters*); Global Heart (*Poulter*); Journal of the American Society of Hypertension (*Poulter*); Blood Pressure (*Poulter*); European Journal of Cardiovascular Prevention and Rehabilitation (*Poulter*); Journal of Human Hypertension (*Poulter*); British Journal of Diabetes & Vascular Disease (*Poulter*); European Journal of Human Genetics (*Prokopenko*); Journal of Alzheimer's Disease (*Ritchie*); International Psychogeriatrics (*Ritchie*); Therapeutic Advances in Chronic Disease (*Ritchie*); Occupational and Environmental Medicine (*Rushton*); Journal of Cancer Epidemiology (*Vineis*); International Journal of AIDS and STD (*Weber*), and Sexually Transmitted Infections (*Weber*).

Awards include: Special-Award of the Hans-und-Ilse-Breuer Foundation for Research in Alzheimer's Disease (*Bertram*, 2010); DoH & NHS Institute for Innovation and Improvement; Health and Social Care (*Car*, 2010); University of Queensland Research Excellence award (*Coin*, 2013); NIH Merit Award for Leadership (*Cross*, 2010); BMA Medical Book Awards (*Elliott, Toledano*, 2013, commended), Sight and Life Nutrition Leadership Award (*Ezzati*); Honorary Doctorate, University of Utrecht (*Ferguson*, 2012); Lifetime Achievement Award Arizona Heart Institute (*Greenhalgh*); Lifetime Achievement Award Miami Heart Institute (*Greenhalgh*); Finnish Epidemiologist of Year (*Jarvelin*, 2012); BMJ Research Paper of the Year (FEAST trial, *Maitland*, 2011); Society for Clinical Trials Trial of the year (HYVET, *Peters*, 2009); International Hypertension Society (*Tzoulaki*, 2010); Enrico Fermi Award Public Understanding of Science (*Vineis*, 2010).

Examples of **Fellowships** include: Australian Research Council Future Fellowship (*Coin*); Axa (Postdoctoral, *Croucher*); MRC (New Investigator, *Andrew;* Methodology, *Griffin, O'Reilly*; Population Health, *Okell*); Porfyrogenis Foundation (*Evangelou*); Global Royal Society (University, *Grassly*); ERC (Advanced, *Fraser, Froguel*); Leverhulme (*Millett*); Wellcome Trust (Sir Henry Wellcome; *Ratmann*).

Examples of our contributions to **responsiveness to national and international priorities and initiatives** include: Indian National TB Programmes (*Arinaminpathy* [advisor]); US CDC influenza collaboration (*Arinaminpathy*); EMA/ Highly Active Anti-Retroviral Oversight Committee (*Ashby*); AMS Review of the Regulation and Governance of Medical Research (*Ashby*); RCUK Global Uncertainties Strategic Advisory Group (*Ferguson*); UNAIDS Country Coordinator (*Gilks*); UNAIDS Reference Group on Estimates, Modelling and Projections (*Hallett*); NICE Guidelines in Hypertension (*Poulter*); secondment to WHO (*Van Kerkhove*). We are members of numerous

WHO advisory committees: WHO Stop TB Partnership (*Arinaminpathy*); Onchocerciasis Elimination Programme for the Americas (*Basanez*); Global Status Report on Noncommunicable Diseases (*Ezzati*); Drug resistance (*Conteh*); Global Technical Strategy for Malaria (*Conteh*); Sodium, Potassium Guidelines (*Elliott* [advisor]), Emergency (advisor H1N1, *Ferguson*); Antiretroviral Therapy Guideline Development (*Gilks, Hallett)* Global Polio Eradication Initiative (*Grassly*); Malaria Policy (*Ghani*); Malaria Vaccine Development (*Griffin*); Alliance for Patient Safety (Information Technology for Patient Safety, *Car, Majeed* [Chair]); Review Group on the Use of Malaria Diagnostics in Low Transmission Settings (*Okell*); Expert Review of Poliomyelitis in Afghanistan (*O'Reilly*).

Indicators of our **wider influence or contributions to the research base** include leading roles within **learned societies**, e.g. British Pain Society scientific committee (*Burney*); Diabetes Society (French speaking, *Froguel* [Director]); International Society of Environmental Epidemiology (Council, *Hodgson, Toledano*); World Hypertension League Board (*Neal*); International Society of Cardiovascular Disease Epidemiology and Prevention Council (*Neal, Poulter* [Chair]); International Society of Hypertension Council (*Poulter*). Further examples include UK Biobank Steering Committee (*Elliott*); Qatar Biobank (*Elliott, Riboli,* Scientific Directors); Qatar Genomic Medicine and Systems Biology Research Center (Scientific Director, *Froguel*); European Genomic Institute for Diabetes (*Froguel*); International Diabetes Federation (*Majeed* [Chair]); EPIC Steering Committee (*Riboli* [Chair]); Academy of Medical Sciences Council (*Weber*). Indicators of contributions to **guideline development** include WHO EPHO 7 European Action Plan (*Car*); WHO guidelines on HIV testing and treatment (*Fraser*, cited); WHO Technical Expert Group on Management of Severe Malaria (*Maitland*); WCRF/AICR Lifestyle Recommendations for Cancer Prevention & 3rd European Code Against Cancer on Diet, Physical Activity and Body Weight (*Norat*); British Hypertension Society Guidelines & Information Service Working Party (*Poulter* [Chair]); European Medicines Agency Guidelines on Data Integration and Pooling of Studies in Pharmacoepidemiology (*Tzoulaki*).

Extent of collaboration or integration with external bodies (NHS, Government, Industry): PHE next generation sequencing expert panel (*Aanensen*); UK Commission on Human Medicines (*Ashby*); European Medicines Agency (Expert advisor, *Ashby*); NHS Hospital Mortality Indicator technical group (*Bottle*); NHS Connecting for Health Evaluation Programme (*Car*); HPA Sub Committee on Radiation, Chemical and Environmental Hazards (*Elliott*); German National Cohort Study Advisory Board (*Elliott*); Life Study Steering Committee (*Elliott*); Smoking-Attributable Mortality, Morbidity, and Economic Costs, US CDC (*Ezzati*); DoH Pandemic Influenza Scientific Advisory Group (*Ferguson*); UK & Ireland Exposure Science committee (*Hodgson*); Advisory Group on the use of ONS data for Medical Research (*Majeed*); Chief Medical Officer's Inter-Departmental Group on Public Health (*Majeed*); NIHR CLAHRC for NW London (*Majeed* [co-Director]); National Medicines for Children Research Network (Primary Care Lead, *Majeed*); NIHR London Research Design Service Team (*Majeed*); Public Health Information and Intelligence Task Force (*Majeed*); UK Diabetes Research Network (*Majeed* [Associate Director Primary Care]); Dutch HIV Monitoring Foundation (*Ratmann*); NW London CLRN (*Ritchie* [co-Director]); DeNDRON (*Ritchie* [Board]); DoH Committee of Carcinogenicity of Chemicals (*Rushton, Vineis*); European Commission Scientific Committee on Emerging and Newly Identified Health Risks (*Rushton*); NW London Diabetes Research Network (*Thom* [co-Director]); National Board of Health, Italy (*Vineis*). **Industry collaborations** include with Dr Foster (*Bottle*); BGI-Shenzhen (*Coin*); Evogene (*Coin*); Novartis (*Croucher*); Astra Zeneca (*Elliott*); European Industrial Minerals Association (*Rushton*); Oil Industries (CONCAWE, *Rushton*); Waters, Bruker (MRC-NIHR National Phenome Centre). Examples of **effective mechanisms to promote collaborative research** include **open access software provision**, e.g. copy number variant association for quantitative traits in families (famCNV, *Falchi*); WHO Clinton Health Access Initiative malaria transmission model (*Griffin*); FP7 GENeric European Sustainable Information Space for environment GIS Software (*Gulliver*); outward **visiting professorships**, e.g. Shiga University (*Elliott*); University of Ghent (*Majeed*); Public Health Foundation of India (*Millett*); Stanford University (*Tzoulaki*); University of Oxford (*Weber*); **research networks**, e.g. EU wide MRSA network (*Aanensen*); NIGMS MIDAS initiative (*Ferguson*), BMGF Vaccine Modelling Initiative (*Ferguson*), BMGF HIV Modelling Consortium (*Hallett*); International network of HIV epidemiologist and modelers (*Hallett*).