

Institution: Queen Mary University of London
Unit of Assessment: UoA1
<p>1. Unit context and structure, research and impact strategy</p> <p>1A. Queen Mary's step change in clinical medicine research and impact strategy.</p> <p>Queen Mary (QM) joined the Russell Group of elite UK Universities in 2012 acknowledging a strong upward trajectory in research excellence across the University. Since 2014, we have made a further step change in the quality, critical mass, and impact of our leading-edge clinical medicine research. In REF2014, 90% of the research returned to UoA1 was rated as world-leading (4 star) or internationally excellent (3 star) and we were in the top ten for research power and impact. The UoA1 Panel commented on the excellence and critical mass of our cardiovascular and cancer research.</p> <p>Since 2014, our new strategy has enabled us to take cardiovascular and cancer research to completely new levels of success. We have made major investments in genomics, inflammation, trauma, and population health sciences with new faculty, partnerships, and infrastructure leading to high calibre research with demonstrable clinical impact. Our strategy in clinical medicine is built on key strategic national and global partnerships attracting new international leaders to QM and greatly expanding our training opportunities with new doctoral and post-doctoral programmes fostering a culture of "Team Science".</p> <p>At QM, Clinical Medicine research activities are based in four Institutes in Barts and The London School of Medicine and Dentistry (SMD). The Barts Cancer Institute (BCI), led by Nick Lemoine FMedSci focuses on leading edge molecular and translational cancer research. The Blizard Institute (BI), led by Tim Warner, focuses on inflammation and trauma (skin disorders; gastrointestinal and liver diseases; and multiple sclerosis). The William Harvey Research Institute (WHRI), led by Amrita Ahluwalia & Sir Mark Caulfield FMedSci, and now Panos Deloukas FMedSci, undertakes cardiovascular, inflammation and endocrine research leading to therapeutic innovation. The Wolfson Institute of Preventive Medicine (WIPM), led by Jack Cuzick FMedSci, FRS, focuses on cancer prevention and screening. Our research is increasingly multidisciplinary and is strengthened by cross-faculty links to the faculties of Science and Engineering, and Humanities and Social Science. As a result of our strategy we have achieved a 35% growth in our UoA1 return for REF2021 and are returning 222 FTE faculty compared to 144 FTE in REF2014. There has been a 50.8% increase in international diversity in this return and we renewed our Athena Swan Silver Award in 2019.</p> <p>The strength of QM's clinical medicine research portfolio, such as the role of cladribine in multiple sclerosis, played a significant part in the recent successful re-designation of the UCL Partners Academic Health Sciences Centre in 2020 (Thornton, Deputy Director). Since 2013, QM has hosted Genomics England Ltd, a wholly owned Department of Health and Social Care (DHSC) Company. We have provided academic strategic leadership and faculty who have partnered with the NHS and UK universities to successfully complete to time and target the world-leading 100,000 Genomes Project. As evidence of the upward trajectory of QM's research we partnered multiple universities in the Farr Institute London and the MRC-funded Informatics platform "eMedLab" (£18.9M) leading to QM joining the Alan Turing Institute (48 fellows) and hosting part of the pan-London node of Health Data Research UK in 2017. Furthermore, we have mobilised one of the largest linked primary and secondary care datasets in the UK covering 2.5 million in East London</p>

(Discovery) and are now extending this linkage across London to a population of 6 million.

Since 2014, we have made major discoveries in the fields of genomics, cardiovascular disease, cancer, hepatitis C, haemophilia, and HIV. These are the result of a forward-looking integrated clinical medicine research strategy that capitalises upon the £1.2 billion state of the art rebuild of our partner Barts Health NHS Trust hospitals at the Royal London (Whitechapel campus) and St Bartholomew's sites (Barts/Charterhouse campus). This transformation was completed in 2015, and QM with Barts Health now extend across a uniquely diverse community of between 2.5 and 6 million people (depending on the service), representing 97 nationalities, with whom we have strong trusted connections and engagement in research. As evidence of the power of this platform, our Barts Cancer Institute hosts three Cancer Research UK (CRUK) Centres and the William Harvey successfully united three hospitals, and the cardiovascular faculty of two universities (QM and University College London), to create the £400M Barts Heart Centre in 2015 (see below).

This shared patient-centred vision for biomedical research underpins our partnership, uniting Barts Health NHS Trust, the DHSC and Tower Hamlets, enabling the launch of a major £600M investment, known as Barts Life Sciences. This initiative mobilises 1.5 million square feet of space at our Whitechapel campus adjacent to the rebuilt Royal London Hospital. We will focus on multi-disciplinary biomedical life sciences research and training related to digital precision healthcare. This major expansion of the UK Life Sciences estate represents an £80M DHSC investment in the site establishing a new bio-incubator in partnership with QM Innovation. It is designed to fuel rapid translation into clinical care across a diverse community through academic-industry-NHS-community partnership. As a designated University Enterprise Zone, it will be a major facilitator of industrial knowledge exchange and translation, whilst improving the economic and health outcomes for our local population and beyond.

1B. Strategic Aims and Impacts post-REF2014

Following REF2014, QM made a strategic plan to enhance research capacity and strengthen local, national and international collaboration focused on discoveries likely to translate into improved healthcare with major impact. We achieved this by attracting and developing current and new staff as well as integrating patient and public engagement and involvement into the heart of all that we do. Together with those strategic priorities set out in UoA2, which complement this submission, we have focused on five key thematic areas agreed with our local NHS partners:

- Genomics (crosscutting theme)
- Cancer
- Cardiovascular Medicine
- Inflammation and Trauma
- Population Health and Prevention (also in UoA2)

This strategy has paid dividends and key examples of success are described below:

QM's major expansion in faculty talent

- Since 2014 we have continuously expanded high calibre senior and junior faculty to develop future research leaders (see above).
- QM provided junior scientists holding prestigious fellowships with their first academic post (more than 30 fellows made lecturers).
- With £6.5M from the Barts Charity, we attracted fifteen new Early Career Researchers to lectureships, who will be mentored and supported during their careers.

- Over this REF period, UoA1 staff were awarded £413M with a research spend of £379M. This equates to a research spend of £1.71M per returned FTE.
- Our work has been highly cited in national (SciVal2016: first in the UK for weighted citations in medicine), and international tables (QS world ranking; fourth for citations in medicine in 2020).

QM's contribution to national initiatives with world-leading healthcare impact

- Since 2013, QM has hosted and seconded faculty to **Genomics England (GEL)** leading to on-time completion of the 100,000 Genomes Project in 2018 (£300M; see below).
- QM faculty led a multi-university partnership to create the £24M **UK Collaborative Genomics Data Centre for the 100,000 Genomes Project** bringing together more than 3,000 researchers from Universities in 33 countries.
- In Covid-19 the east London community were disproportionately affected so we pivoted our Biomedical Research Centre to coordinate studies, training 120 researchers who enrolled 10,571 patients including 8,000 in Urgent Public Health Priority Studies. We opened the Barts Vaccine Trial Centre in Bethnal Green Library which is the world-leading site for enrolment into the Janssen vaccine trial (27% from BAME communities). At national level, Lemoine chaired the oversight for NIHR of Urgent Public Prioritisation and is a co-author on the RECOVERY studies.
- In response to the pandemic, QM faculty through GEL partnered with GenOMICC (Edinburgh) and the REACT studies (Imperial) to raise £27M (DHSC £7.8M, Lifearc £5M, MRC £4.5M, Illumina £9.89M) for whole genome sequencing of up to 20,000 severely ill, and 15,000 mild or asymptomatic Covid-19 patients. We published 7 novel loci for Covid severity, identifying 3 repurposing opportunities leading to the incorporation of Baracitinib into the RECOVERY trial ([Nature 2021](#)).
- With Wellcome funding (£6M), we renewed and expanded the flagship **East London Genes and Health Consortium** cohort study (van Heel with Finer [UoA2]), which has enrolled 50,000 British-Bangladeshi and British-Pakistani volunteers. In 2016, we won a £5M Catalyst Award (HEFCE) to establish the Centre for Population Genomic Medicine for precision phenotyping, with QM leading and KCL and UCL as partners.

Our success in hosting national research infrastructure and partnerships.

- As evidence of QMs excellence in cancer medicine we were awarded three **Cancer Research UK (CRUK)** and **Brain Tumour Charity Centres** (£33M).
- QM was the academic lead for the **£400M Barts Heart Centre** providing the platform for our **NIHR Biomedical Research Centre (BRC)** (Barts Health and QM). With a further £10.2M from the Barts Charity we established new faculty and the multidisciplinary Cardiovascular Devices Hub with European Regional Development (£3M) and Charles Wolfson (£750K) funding.
- In 2012, we were a major contributor to the strategy for the London node of the **MRC Farr Institute** providing a collaborative health data science platform leading to award of a **pan-London node of the Health Data Research UK Institute** (see below) and QM joining the Alan Turing Institute.
- As part of **UCL Partners Academic Health Sciences Centre and Network**, we have supported re-designation and initiatives across north east London reaching 6 million patients. This underpinned our successful application for an NIHR Collaboration for Leadership in Applied Health Research and Care (CLAHRC) North Thames 2014 and subsequent **NIHR Applied Research Collaboration (ARC)** North Thames 2019.

Our success in research training and development.

- In 2014, QM won a €6.5M EU Marie Curie Co-Fund Postdoctoral International Exchange Fellowship Scheme. We oversaw the award of 67 post-doctoral fellowships from 24 countries. 54% were women and they published 100 papers (10% in Nature Journals).
- To train clinical academics, we won more than 45 fellowships (15 from MRC), 107 Academic Clinical Fellows (95 NIHR funded) and 46 Academic Clinical Lecturers (37 NIHR funded).
- Since 2014, QM has secured doctoral training programmes from the British Heart Foundation (5 students/year- renewed in 2014, 2017, 2021), the MRC (Translational Immunology with Southampton; 4/year; renewal submitted in January 2021), Wellcome (PhD Programme in Health Data Science; 5/year from 2020). We led or partnered four Marie Curie Innovative Training Networks. This has enabled us to dramatically expand our postgraduate student numbers in clinical medicine by 52% to 537 students by 2020.

Public and Patient Involvement in Research (PPI).

UoA1 staff are engaged in multiple local and national initiatives with patients and the public. Some key activities are detailed below, with further examples in section 1B-4.

- We have extended our **Centre of the Cell**, the first science engagement centre within a medical research laboratory by building a new Neurone Pod. This has engaged more than 155,000 young visitors in science and we have had 100 million website hits from 160 countries.
- East London Genes and Health Consortium engaged with our diverse community enrolling more than 50,000 South Asians for research studies.
- Our **'Arthritis and Art'** exhibition at the Tate Modern attracted 2000 visitors with interactive workshops with artists and patients.
- **Trials Connect** is a patient-led initiative coordinated by our NIHR Biomedical Research Centre, where patients engage other patients in trials by sharing experiences. They co-organise the Barts-QM Science Festival reaching 400 school students. On the 70th Anniversary of the Nuremberg Code they introduced a new ethical framework for trials.

Our success in impact cases studies

QM has made assessment of Research Impact "business as usual" to maximise the evidence of our success in health, societal and wealth generation. We have returned 11 Impact Cases, 10 of which are new and 1 progressed from REF2014.

QM structure and governance to facilitate Clinical Medicine Research.

The research themes and activities of the SMD are led by the respective Institute Directors who report to the Vice-Principal (Health) and Executive Dean, Prof Steve Thornton (joined in 2016) via the Faculty Executive. The Vice-Principal is supported by the Dean for Research and Impact (Prof Mauro Perretti) who formed a School Research Deanery in 2016 to maximise cross-cutting multi-disciplinary research. The Deanery liaises with other areas of the University, including the Principal and President of QM (Prof Colin Bailey), the Vice-Principal Research & Innovation (Prof Andrew Livingston) and Vice-Principal International (Prof Colin Grant). As evidence of the success of this structure we were able to expedite offers to host Genomics England at QM, rapidly facilitate a cross-faculty commitment to join the Alan Turing Institute, and establish the Digital Research Environment Institute for advanced analytics (Slabaugh) with expertise in artificial intelligence.

1B-1. Strategic Research Themes and Impact

Our major research themes are Cancer, Cardiovascular, Inflammation & Trauma, and Population Health. The cross-cutting theme of Genomic Research is described first.

A) Genomic Research

Genomics England: QM hosted and provided the scientific leadership (Caulfield) and faculty that delivered the 100,000 Genomes Project, persuading the NHS to create 13 Genomic Medicine Centres, who enrolled 90,000 people with rare disease and cancer, and ensuring all the Devolved Nations were involved. We appointed Smedley, who developed and validated Exomiser, as part of the NIH Monarch Initiative (Smedley; *Nature Protocols* and *Am Journal Human Genetics* 2016, *Nature Comms* 2019). This improved variant prioritisation and enabled new rare disease diagnoses in 20% of 36,000 families (74,404 people) from the 100,000 Genomes Project. These advances were integrated into the Genomics England Rare Disease Pipeline for the NHS Genomic Medicine Service. In cancer, our academics (Jones, Caulfield) led the optimisation of fresh tissue cancer sample characterisation. They drove the adoption of 400 molecular pathology pathways into the NHS enabling the 100,000 Genomes Project to generate the largest high-fidelity cancer whole genome dataset worldwide (17,400 patients) for research and precision cancer care. As a result, 57M people have equity of access to the most advanced National Genomic Medicine service in the world and everyone will be asked to consent to participate in research.

Genes and Health: At QM, we have begun to address the under-representation of diverse communities in genomic research with our major Genes & Health programme where more than 50,000 British-Bangladeshi and British-Pakistani volunteers have enrolled following extensive community engagement. The programme, led by QM, has been extended from East London to Bradford and Manchester, with exome sequencing defining loss of function variants in consanguineous adults (van Heel, *Science* 2016), including those relevant to successful drug development. Genes & Health has completed a study with Alnylam Pharmaceuticals including safety and basic mechanism data on their lumasiran drug target HAO1 which was included in their successful FDA New Drug Application. Genes & Health has ongoing studies with Genomics PLC, AstraZeneca and several smaller biotech. Genes & Health expects to sign a £15M Industry Consortium to exome sequence its 50,000 volunteers in Q2 2021 (GSK, Takeda, BristolMyersSquibb and Merck). Our Genes & Health programme links live healthcare data across primary and secondary care with genomic analysis and phenotypic data. They secured major Wellcome and MRC funding (£6M) and led to HEFCE-Catalyst funding (£5M), creating a Population Health Science Centre (led by QM with Kings College and UCL) for recall by genotype of participants for experimental medicine studies.

To broaden this theme, we appointed Gurdasani (HDRUK-Rutherford Fellow and new Senior Lecturer) to build on her African Genome Variation Project and her work in Uganda (*Cell* 2019, *Nature* 2014), through our research window on the world in East London.

Disease focused genomics: We have international leaders in genomics in cardiovascular disease, cancer, inflammation and population health which are described within the themes below.

Major national centres and funding success in Genomics: We used experience gained through our MRC funded Farr Institute London (MRC £9.5M) to establish longitudinal life course electronic health record follow-up for the 100,000 Genomes Project. This created the platform for QM faculty to lead a multi-university partnership which was awarded £24M by MRC in 2014 to create the UK Collaborative Genomics Data Centre for the 100,000 Genomes Project. This

enabled QM to procure a data centre for Genomics England making available 3.8 billion clinical data points on more than 90,000 people with whole genome sequences. QM Faculty created the Genomics England Clinical Interpretation Partnership enabling more than 3000 researchers from 180 institutions in 33 countries to generate more than 140 publications, leveraged £50M in grants, and has enabled the translation of 300 new diagnoses for rare disease and cancer into healthcare. QM faculty (Jones, Caulfield) at GEL led the successful bid for £7.87M UK Life Sciences Cancer Whole Genome Strategy (Innovate UK) alongside trials involving 6 UK Universities with matched funds from charity and industry. Caulfield wrote the strategy for the next 5 years for Genomics England's Programme focused on unmet need in genomics in healthcare focused on diversity, pharmacogenomics, cancer and newborn diagnosis.

B) Cancer Research

QM's cancer research, led by Lemoine, has the primary goal of leading bench to bedside discoveries that make major insights into cancer biology informing precision medicine. With £10M from the Barts Charity we appointed new senior and junior faculty, and with our extant strengths this enabled us to secure £33.4M by winning, or renewing four major Cancer Research UK Cancer Centres (City of London, Barts Cancer Centre, Experimental Cancer Medicine Centre, and the Brain Tumour Charity Centre).

Genetics and the evolution of cancer: We have delivered high impact discoveries in the genomic architecture and evolution of cancer. In leading edge research, Fitzgibbon characterised the mutational patterns of progression and drivers to the B cell activation and Mammalian target of rapamycin (mTOR) response in follicular lymphoma funded by a £1.8M CRUK Programme (*Nature Genetics* 2014, *Nature Metab* 2019). With Wellcome Collaborative funding (£1.3M), Graham led major advances in understanding the evolution of the pan-cancer mutational landscape, the influence of tumour heterogeneity and neo-antigens in cancer evolution (*Nature Genetics* 2016, 2020 and *Nature Medicine* 2016). Alves Godinho described the role of centrosome activation on cellular invasion in malignancy (*Nature* 2014). Our molecular re-profiling of interleukin 12 conserved the potent immunotherapeutic efficacy as an anticancer treatment, but eliminating potential for lethal toxicity (Wang, Lemoine, *Nature Comms* 2017). With CRUK Programme funding, Kelsell published on oesophageal squamous cell carcinoma (*Nature Comms* 2017, 2018).

Cancer screening, prevention and early diagnosis: Cuzik, Manchanda and Duffy have made seminal contributions with substantial impact (see Population Sciences below).

Targeting the tumour microenvironment: Hovalala-Dilke FMedSci defined the role of targeting FAK in endothelial cells to sensitising tumours to DNA damage (*Nature* 2014). With a £2.1M CRUK Programme she described the role of B3 integrin in cross-talk between tumour cells (Hovalala-Dilke, *Cell* 2020). Sanz Moreno joined QM, and with a £2M CRUK Programme generated insights into how the cytoskeleton of cancer cells regulates transcriptional rewiring during tumour growth and dissemination (*Cell* 2019, *Nature Comms* 2014, 2018). In a 2.6M CRUK Programme, Balkwill demonstrated the potential of chemokine receptor antagonism by antibodies as an anti-cancer strategy which relies on adaptive immunity (*J Clin Invest* 2017).

Targeting Tumour Cells: Marshall described targeting integrins that mediate interaction between cells and the extracellular matrix in breast cancer (*J National Cancer Inst* 2014). Sharp discovered the role of the tumour suppressor protein LIM domain protein 1 (LIMD1) and its deregulation in normal tissue contributes to the development of lung, renal and breast cancer (*Embo Mol Med*

2018). In phospho-proteomics, Cutillas has used advanced proteomics to reconstruct the role of kinases in cancer (*Nature Biotech* 2020, *Nature Comms* 2015, 2018).

Therapeutic innovation in cancer: In seminal work Powles reported the efficacy of immunotherapy antibody to treat bladder and renal cancer (*Nature* 2014, *Lancet* 2018; *NEJM* 2015, 2019). This transformative advance in bladder cancer led the US Food and Drug Administration to give atezolizumab “breakthrough designation status” in 2014 due our research. This led to several ground-breaking translational and clinical studies in renal cell cancer (Powles). Szolasrek published translational studies of the arginine-depleting agent ADI-PEG20 in several clinical studies (ADAM, TRAP and ATOMIC studies; *JAMA Oncol* 2017). Schmid leads our cancer clinical trials and published major new advances for the therapeutic management of triple negative breast cancer (*NEJM* 2018, 2020)

QM has four major national cancer centres. A major development has been the award of the £14M **CRUK City of London Centre (RADNET)** focused on developing therapies for cancer. This unites 350 researchers from QM (Lead, Lemoine), the Crick, KCL, UCL, NHS Trusts, and national and international research networks. The Centre offers an unrivalled international platform for clinical trials spanning 10 million people (around 15% of the UK population) offering the scale to accelerate clinical trials. Successful delivery of our strategy led to the renewal of the **CRUK Barts Cancer Centre** (£12.4M) and the **CRUK Experimental Medicine Cancer Centre** (£2.4M). The strength of our glioblastoma programme led by Marino led to the renewal of **the Brain Tumour Charity Research Centre of Excellence** (£4.6M) and a CRUK Programme.

Major cancer awards: QM’s track record has enabled us to join the **CRUK Grand Challenge Award** ‘Cartography of Cancer through Multi-Scale Molecular Imaging’ (£16M; 2017-2022) led by the National Physical Lab, QM, Imperial, the Beatson, ICR, AstraZeneca, Cambridge, the Crick Institute and Weill Cornell. The partnership applies 3D-printer approaches to produce a faithful representation of the tumour microenvironment, amenable to Artificial Intelligence predictions, to accelerate target discovery. **STORMing Cancer** (£20M; 2019-2024) was awarded to a global team from QM (MacDonald; *Gut* 2014), Stanford University, Vanderbilt University, University of California San Francisco (UCSF), McGill University and Cambridge, to tackle chronic inflammation, a precursor to cancer.

C) Cardiovascular Research

Our academic vision for Cardiovascular care and research in North East London, enabled the successful unification of three hospitals, and uniquely, two universities (UCL and QM), to create the £400M Barts Heart Centre in 2015. The Barts Heart Centre is one of the largest in Europe serving 6 million people with 84,000 patient episodes per year offering the SMD and WHRI the scale to find niche populations. We have harnessed this opportunity to convert our two previous NIHR Cardiovascular Biomedical Research Units into a successful NIHR Biomedical Research Centre (BRC) in 2016, bringing £20M over the past 12 years.

Cardiovascular genomics: This is a major theme of our NIHR BRC, benefitting from three of the most highly cited researchers in the world in genomics (Deloukas FMedSci, Munroe and Caulfield FMedSci). Since 2014, we led multiple international consortia that have discovered more than 2,000 gene regions for rare inherited disease and complex cardiovascular traits (blood pressure, coronary disease, lipids and ECG traits) capitalising upon the Biobank UK cohort. In rare disease, Wald demonstrated that innovative population-based child-parent screening for familial hypercholesterolaemia is effective and feasible in primary care, and identified those at high risk of inherited premature cardiovascular disease for early intervention (Wald; *NEJM* 2016).

In complex cardiovascular traits, Deloukas, with Kanoni and Marouli (new Lecturers), discovered several new loci for lipid traits and coronary heart disease. In studies of over 1 million people, Caulfield, Barnes and Munroe, led the discovery of more than 700 common and rare gene loci for blood pressure (*Nature Genetics* 2017, 2018, 2020). Brown FMedSci, appointed in 2015, discovered somatic mutations leading to adrenal adenomas causing hypertension (*NEJM* 2015). In 2019, we appointed Traylor (new Lecturer), who identified multi-ancestry gene loci for stroke (*Nature Genetics* 2018). In multi-ancestry studies led by Munroe and Tinker FMedSci, more than 200 loci influencing ECG PR interval were identified (*Nature Comms* 2018, 2020). We lead on cardiovascular magnetic resonance imaging (MRI) phenotyping quality assurance for the Biobank UK study and have published 14 loci that effect left ventricular MRI parameters (Petersen *Circulation* 2019). These discoveries have enabled polygenic risk scores for coronary heart disease, blood pressure and stroke.

The microvasculature and cardiac inflammation: As a Wellcome Investigator (2014 and 2020), Nourshargh FMedSci has driven research into leukocyte migration from the vascular lumen into inflamed and/or injured tissues using advanced microscopy (*Immunity* 2018 and *JCI* 2020). The excellence of our cardiac inflammation research by Marelli-Berg has been recognised by the award and renewal of a British Heart Foundation (BHF) Chair, two BHF programmes and a BHF Accelerator Award of £1M (*Nat Comms* 2014, 2020; *Immunity* 2015, 2017). This links WHRI to myocarditis at the Barts Heart Centre and has attracted young talent, such as Longhi (appointed as lecturer in 2013, now Reader), who secured a BHF intermediate fellowship to investigate the role of dendritic cells in atherosclerosis (*PLoS Biol* 2014; *Cell Metabolism* 2017). Nadkarni secured a BHF intermediate fellowship to work on vascular inflammation in pre-eclampsia and is now a Lecturer (*J Clin Invest* 2014; *PNAS* 2016). Aksentijevic has secured a Wellcome Career Development Fellowship to join the group and works on cardiac metabolism (*Nature Comms* 2020).

Cardiovascular Therapeutic Innovation: The WHRI is one of the premier centres for translational pharmacology in Europe, benefitting from links to the Barts Heart Centre and the creation of a cardiovascular component of a UK CRC Clinical Trials Unit. In highly cited research, Ahluwalia, with Kapil and Jones, supported by genomics (Caulfield) demonstrated that dietary nitrate is effective treatment for hypertension and coronary ischaemia (*Hypertension* 2015; *Circ Res* 2015). Funded by a BHF Programme (£1M) and Apollo Therapeutics (£3.5M), Hobbs led the detailed characterisation and invented small molecules to target the C-Natriuretic Peptide (CNP) pathway (*J Clin Invest* 2014; *Circulation* 2014, 2018;) to treat coronary heart disease, hypertension and pulmonary hypertension.

Brown's discovery of the mutational architecture of adrenal adenomas led GSK and Apollo Therapeutics to fast track the evaluation of small molecules inhibiting Cav1.3, which reduces aldosterone secretion and may be an anti-hypertensive therapy (*NEJM* 2015). In 2019 Eaton, a leader in redox mechanisms of cardiovascular disease, joined WHRI, bringing a European Research Council Fellowship, MRC and BHF Programmes. Eaton, with Charles (BHF Intermediate Fellow and new Lecturer), generated mechanistic evidence for potential anti-oxidant therapies to treat cardiovascular disease (*Nature Comms* 2015, 2016 and *Hypertension* 2017). Thiemermann FMedSci is exploring repurposing opportunities (*Ann Surg* 2017x2) for hypertension, pulmonary hypertension and organ protection in trauma.

Following the British Hypertension Society Research Working Party, Brown with Caulfield, completed a suite of trials (the PATHWAY studies with BHF Programme and NIHR funding of £2.6M) to answer major questions in hypertension management. The PATHWAY-1 trial indicated

that starting with two medications reduced the time to blood pressure control and was preferable to a single agent. The PATHWAY-2 study demonstrated the superiority of spironolactone for resistant hypertension and led to changed NICE Guidance (2019) and European Society of Cardiology (ESC) 2018 Guidelines for Hypertension. These recommended spironolactone as a fourth medication (*Lancet* 2015). The PATHWAY 3 Trial showed that combining a thiazide with a potassium sparing diuretic reduced metabolic impacts (*Lancet Diabetes Endo* 2015). In 2018, a mechanistic sub-study of PATHWAY 2 showed that resistant hypertension is a salt retaining state, and that amiloride 10 mg was slightly superior to spironolactone for blood pressure control (*Lancet Diabetes Endo* 2018).

Cardiovascular devices and cellular therapies: We have explored stem-cell based therapies for coronary heart disease, applying bone-marrow derived progenitors to heart failure patients (EU award £6M Mathur; *Eur Heart J* 2015, 2020). With QM Institute of Bioengineering (UoA12), we identified novel methods for epicardial placement of biocompatible materials in myocardial infarction and are investigating the vital role of macrophages, and the potential of embryonic and inducible pluripotent stem cells (Suzuki; *J Clin Invest* 2016). This is funded by a BHF Programme and Japanese Promotion of Science.

From our NIHR BRC theme in devices, we established a multidisciplinary **Device Innovation Centre** with the QM Institute of Bioengineering, Yale University and the UK-CRC Barts Clinical Trials Unit. This led to Mathur and Caulfield securing substantial funding (€3M) from the European Research Development Fund, £0.75M from Charles Wolfson Charitable Trust, and £1.7M from Barts Charity. This builds on our strength in testing novel devices such as the NIHR Experimental Medicine Evaluation and BHF Funded trial of innovative radiofrequency ablation of left adrenal tumours (Brown) and drug eluting bio-degradable stents (Lansky, Baumbach *Eur Heart J* 2015, 2017; *Lancet* 2018). Our integration of bioengineering, basic science and clinical trials attracted a new partnership with Yale. Alongside we established the largest Cardiovascular Magnetic Resonance Imaging Centre in Europe (Petersen, *JACC* 2015) and have causally linked air pollution to cardiac ventricular remodelling that precedes heart failure development (*Circulation* 2018).

Major Grants. QM cardiovascular research played a key role in the successful MRC Strategic e-Med Lab award (multi-partner consortium; £9.4M to QM, UCL, KCL, the London School, Sanger, the Crick and the European Bioinformatics Institute) creating a multi-petabyte datacentre for cardiovascular genomics collaborative research enabling multiple Nature/Nature Genetics papers. We have held numerous BHF and MRC programme grants over this REF period including Suzuki (cardioprotection, £1.2M), Tinker (arrhythmia, £1.1M), Hobbs (vascular pharmacology, £1M), Deloukas (cardiovascular genomics, £1.1M), Warner (platelet bio-reactivity, £850K), Eaton (oxidative stress £760K), Ackland (cardiovascular function in critical care, £460K) and Kellsell (desmosomal cardiomyopathy, £1M). In addition, Marelli-Berg's work on cardiovascular immunology has led to the award of a BHF Chair (renewed in 2020, £1.3M) and three BHF Programme Grants.

D) Inflammation research and trauma

Since 2014 we have united our basic and translational inflammation research in a cross-Institute initiative, investing £1.5M in the Centre for inflammation and Therapeutic Innovation (CiTI). This focused four inter-disciplinary areas to identify and develop innovative therapeutic strategies: i) genomic and stratified medicine in inflammation; ii) vascular and cardiac inflammation, and cell trafficking (see cardiovascular research); iii) target identification and therapeutic exploitation and iv) reparative and regenerative therapeutics. CiTI has enabled strategic partnerships with

biopharmaceutical companies Union Chimique Belge (5 PhD studentships; 4 collaborative projects, more than £600K; Dell'Accio; Perretti) and ONO (£500K; Malaspina, Nissim, Perretti). We have also developed, with Oxford, the Versus Arthritis Centre of Excellence in the Pathogenesis of Osteo-Arthritis (£1M; Lead Dell'Accio).

With Versus Arthritis we created two CiTI chairs in Inflammation Sciences, attracting Rot (£1.2M Wellcome Investigator; *Nature Immunol* 2014, 2017) and Pitzalis in Experimental Medicine and Rheumatology. We also created a Chair in Inflammation and Therapeutic Innovation (0.2 FTE; Mantovani; *Nature* 2019; *Cell* 2019) in partnership with a top Italian medical school, Humanitas. This leveraged funding for two clinical lectureships (from Versus Arthritis and NIHR: £1.1M) and one non-clinical lectureship (Dufton; *Nature Comms* 2017, 2019).

Creation of this cross-disciplinary Centre has enabled new inward investment and partnerships in stratified arthritis care, liver disease, haematology, dermatology and trauma, leading to new external awards, faculty and partnerships.

Stratified Medicine in Arthritis. At the Barts Arthritis Centre, Pitzalis developed a Doppler based approach to guided biopsy. This has been used to understand synovial pathobiology and the role of precision biologics in rheumatoid arthritis (Humby, Pitzalis; *Lancet* 2014, *Ann Rheum Dis* 2016, *Arthritis Rheumatol* 2016). Building on the foundations of the MRC Pathobiology of Early Arthritis Consortium, we established a portfolio of trials to test the role of synovial pathotype in stratifying biologic selection (digital pathology and tissue expression). These include the MATURA project (MRC/Versus Arthritis; £5M joint with Manchester) and the NIHR RA4RA Study (£350K). This led to a €14M EU award (~€1.8M for QM) to extend the value of precision biologic use in rheumatoid arthritis.

This platform has created a large biobank of synovial tissue enabling multiple partnerships with pharma to refine drug development and the patients who will benefit from individualised treatments (see section 4). Based on this, we have invested in similar biobanks and multi-omics approaches for systemic lupus erythematosus and Sjogren's disease, with Lewis (*Cell Rep* 2019) and Bombardieri (*Arthritis Rheumatol* 2014, 2109; *J Exp Med* 2019), respectively.

Liver and Gastrointestinal Disease Research: In 2018, we invested £1.5M into hepatology research to create the Barts Liver Centre where Foster and Kennedy published major advances in hepatitis C and B (*NEJM* 2015, 2018, *J Clin Invest* 2018x2), and on non-alcoholic steatohepatitis (NASH) by Alazawi (*Ann Surg* 2016). This leveraged around £1M from commercial partners (Gilead and GSK), MRC funding (£0.7M; Alazawi), and a Wellcome Trust collaborative award with King Faisal University in Pakistan (£3M; Foster).

Our chronic bowel disease research focuses on inflammation (Lindsay; *JAMA* 2015, *Lancet Gastro Hepatol* 2017), visceral pain (Aziz, Knowles *Gut* 2015, 2018), and post-surgical bowel disorders. Funding from NIHR (Knowles: 5 awards £3.7M) enabled mechanistic and diagnostic work on disorders of defaecation (Knowles, Sanger; *Gut* 2016, 2019) and clinical trials (Knowles; *Ann Surg* 2014, *Lancet* 2015). We led the recent international diagnostic classification in this field, with major with EU H2020 funding (2020-2025, €9.6M of which €1.4M to QM).

Dermatology. With major BHF and CRUK programmes for research into monogenic dermatological disorders, Kelsell linked inflammation in the skin, heart, oesophagus (*Nature Comm* 2017, 2018; Blaydon, *Am J Hum Gen* 2016), X-linked ichthyosis (Action Medical Research; O'Toole) and atopic eczema (O'Shaughnessy, *J Clin Invest* 2019; O'Toole, Kelsell, *J Invest*

Dermatol 2019). We have established a Bangladeshi cohort to enable us to investigate the genetic basis of skin disease in our community.

A joint CRUK programme with Dundee (Harwood, £0.5M) identified an azathioprine-induced signature in squamous cell carcinoma (*Nature Comms 2018*). Using 3D models of skin and human samples, we identified targets for skin cancer signaling (O'Toole, *J Clin Invest 2020*; Philpott, *Cancer Res 2018*). Two Medtech Innovator entrepreneurship awards were awarded in 2018 and 2019 resulting in a spin-out company, Keratify, and BBSRC funding through both an Industrial Partnership Award (Bishop) and several BBSRC-CASE studentships (Philpott, Harwood, O'Toole, Bishop, Connelly).

With Animal Free Research UK funding (£1M), we established a Centre of Excellence in Animal Replacement Science which developed new models of skin diseases using organoids and 3D culture systems. 3D-modelling emerged as a cross-cutting technology (£0.55M investment from QM; Connolly) leading to a dedicated Centre for organ-on-a-chip technology (the Centre for Predictive In-Vitro modelling). This harnessed expertise in SMD with the Faculty of Science & Engineering (MRC Technologies Transforming Life network, £0.5M), with a partnership with the Harvard spin-off Emulate™ (2019).

Haematology. Our internationally leading haematology research, supported by Bloodwise (£1.4M, 2015) and MRC (£1.65M) to Dokal, Fitzgibbon and Vulliamy, established an international patient registry leading to the characterisation of disease genes in bone marrow failure, myelodysplasia and leukaemia (*Am J Hum Genet 2014, 2016; Blood 2015; J Clin Invest 2015; PNAS 2018*). Pasi led ground-breaking trials of novel gene therapies for haemophilia A, including targeting of anti-thrombin with RNAi (*NEJM 2017*), and viral delivery of factor VII (*NEJM 2018, 2020*). Warner studied platelet lifespan relevant to thrombotic and bleeding pathologies (BHF programme, £0.85M; *Blood 2014*).

Trauma and Critical Care. We established the Centre for Trauma Sciences in 2012, with initial support from Barts Charity (£3.6M). This has made a major clinical impact on trauma-associated coagulopathy (Brohi, *PLoS Med 2017*) and understanding of platelet function in trauma (*PNAS 2019*), which changed NICE guidelines on trauma (see Impact statement). Recently, we discovered immunological changes in the early response to trauma leading to MRC funding (£1M, Brohi, Pennington; 2019-2022). We are now testing an adenosine agonist to improve the early vascular response to trauma funded by the US Department of the Army (\$1.3M). To capitalise on this, we launched a new research theme in Critical Care & Perioperative Medicine and appointed Ackland (NIHR Advanced Fellowship £1.5M) to enhance our epidemiology and clinical trials research in this area. This should make a difference to the care of 300 million surgical patients worldwide per year (Pearse; *JAMA 2014; Lancet 2018, 2019*).

Major grants include CRYOSTAT-2 (NIHR HTA & Barts Charity, £2.4M, 2017-2021), MODET focusing on trauma in the elderly (Dunhill Medical Trust, £236K, 2016-2019), and the repurposing of artesunate (Brohi, Thiemermann; Wellcome Translational Award, £758K, 2015-2018).

Neuroscience. Our neuro-inflammation research has made advances in multiple sclerosis (Giovannoni, Baker, Schmierer), neurodegeneration (Malaspina, Sheer), and brain and spinal cord injury (Yip, Michael-Titus, Shah). Funding includes £1M from Nutricia Research (Michael-Titus; *J Neurosci 2015; Hum Mol Genetics 2019*) and the Motor Neurone Disease Association where Malaspina is a partner in the EU project MIROCLAS (£673K; Malaspina, *Lancet Neurol 2015*). In a major success, Schmierer and Giovannoni repurposed Cladribine to delay or arrest multiple

sclerosis progression (NIHR £2.5M; *NEJM* 2017). Nizetic (*Nat Comms* 2014, Wellcome Collaborative Award £577K) focuses on the genetics of Down's syndrome associated with neurological phenotypes.

Endocrinology. At QM, we have adult and paediatric endocrine centres linked to the Barts Endocrine Centre, offering a tremendous platform for life-course endocrine research linked to the UK's largest endocrine tumour programme. This has enabled discoveries of new genes for neuroendocrine tumour syndromes (Korbonits, *PNAS* 2018), delayed puberty (Dunkel, *Embo Mol Med* 2016; *Hum Mol Gen* 2019), short stature (Storr, NIHR Advanced Fellowship £1.8M), familial pituitary adenoma and adrenal deficiency (Metherell, *J Clin Invest* 2017). Our research into growth disorders resulted in us leading the development of the NICE guidelines on the management of adult growth hormone deficiency.

Therapeutic Innovation in Inflammation. We developed reparative programmes for the osteoarthritic joint (Dell'Accio, *Ann Rheum Dis* 2015, 2016, 2017; *Science Transl Med* 2020; Perretti, *Science Transl Med* 2015). We have led research into the mechanisms of vascular (Nourshargh, *J Exp Med* 2014, *Immunity* 2015, 2018, *Blood* 2016), cardiac (Marelli-Berg, Longhi, Hobbs, Ahluwalia, *Immunity* 2017, *Circulation* 2019, *J Clin Invest* 2017) gut and infection associated inflammation (Perretti, *PNAS* 2014; *Embo Mol Med* 2015; Dalli, *Nature Med* 2015; *J Exp Med* 2015; Norling, *J Clin Invest Insight* 2016; Montero-Melendez, *Nature Comms* 2020). Therapeutic strategies are now in phase I and phase II clinical trials (SynAct Pharma AS) and QM-owned IP of an annexin peptide is being developed with ResoTher Pharma for myocardial infarct, with Phase I studies planned for Q4 2021.

E) Population Health Research

Building on the international renown of the Wolfson Institute of Preventive Medicine (WIPM) we created the Institute for Population Health Sciences to harness strengths in preventive medicine, primary care, mental health, public and global health (in UoA2 return). Here we highlight our preventive medicine research, screening and public health relevant for the UoA1 return.

Cancer Prevention and Risk Reduction: Cuzick leads the International Breast Cancer Intervention study. In the IBIS1 Trial, he demonstrated that women treated with tamoxifen for five years had a 30% reduction in breast cancer risk for at least 10 years (*Lancet* 2015). Cuzick coordinated 25 international centres in the IBIS-II trial of breast cancer recurrence (Cuzick £10M, CRUK, Astra Zeneca and Sanofi) showing that anastrozole reduced risk (*Lancet* 2014). Subsequently he established the long-term effectiveness of tamoxifen in preventing recurrence in both pre- and post-menopausal women, as well as the superior efficacy and safety of anastrozole in post-menopausal women at increased risk (*Lancet* 2014). This changed NICE and international guidelines for clinical practice (Cuzick; *Lancet Oncol* 2015). Anastrozole was more effective than tamoxifen for preventing cancer recurrence in women with receptor-positive ductal carcinoma in situ (Sestak; *Lancet* 2016).

Cancer Screening and Risk Reduction: At QM Duffy coordinates the Policy Research Unit in Cancer Awareness, Screening and Early Diagnosis, with seven institutions (QM, UCL, KCL, LSHTM, Hull York Medical School and Durham) to inform policies for breast, bowel and cervical screening programmes (Duffy, NIHR £8M, renewed £5M to 2023). Work led by Duffy and funded by the Policy Research Unit has shown screening for ductal in situ breast cancer is clinically useful (*Lancet Oncol* 2016). We demonstrated that mammography in 40 year olds could reduce mortality from breast cancer (Cuzick, *Lancet Oncol* 2015). We played a key role in establishing Human Papilloma Virus (HPV) identification and vaccination as the most effective method for primary

prevention of cervical cancer and have demonstrated the greater efficacy of a 9-valent HPV vaccine (Cuzick; *NEJM* 2015).

In women's health, Thornton investigated the use of risk assessment, oxytocin antagonists and progesterone in preterm labour or preeclampsia (NIHR EME £1.7M; *Lancet* 2016). An assessment was undertaken (NIHR Health Technology Assessment £1.3M) to investigate the cost-effectiveness and impact of management for those who plan, provide or receive care from the NHS and social care services. Women's Health research brings together basic biology (Nadkarni, *PNAS* 2016) with translational work effected through experimental medicine (Ahluwalia, *J Clin Invest* 2017) and pragmatic trials (Iliodromiti [UoA2]).

To complement the excellence in cancer and cardiovascular (Cuzick, Duffy and Wald) disease prevention, we were awarded £1.5m from the Barts Charity to establish a unit focused on the prevention of chronic neurological diseases, including Parkinson's, multiple sclerosis and Dementia. This Centre is led by new recruits Noyce (*Lancet Neurol* 2019, *JAMA Neurol* 2019), Dobson (*Neurology* 2019) and Marshall (*Brain* 2019).

Over this REF period, we established a highly successful global health research portfolio with awards of more than £33M. This is outlined in UoA2 and not further discussed here, apart from the work of Bourke (Wellcome Dale Fellow; *Science Transl Med* 2019), who described the impact of malnutrition on the immune-activation status in pregnant mothers in Zimbabwe, and Kelly who investigated malnutrition and HIV in Zambia (Gates Foundation £2.25M, MRC Programme £3.6M; *EBiomedicine* 2017).

1B-2. Strategic investment into multi-disciplinary research and supporting infrastructure

Our major research themes were supported and expanded by establishing cross-cutting activities, namely: Genomic Medicine, Functional Genomics, and Post-Genomic Phenotyping. We have invested in posts and infrastructure to support these cross-disciplinary activities.

QM have invested in new facilities for a phospho-proteomic Unit (more than £1M; Cutillas, *Sci Cell* 2014; *Nature Biotech* 2020) and established a Lipid Mediator Unit (£1.2M). The investment in facilities and academics have enabled two QM spin-out companies Kinomica[™] and Resolomics[™]. Our investment in advanced multi-photon microscopy was used by Nourshargh to attract Rot a new Wellcome Investigator and renew her Wellcome Investigator Award. We also enhanced our imaging infrastructure at the Barts Heart Centre to create the largest cardiac imaging centre in Europe and are completing a new capital fit-out of the EU and Charles Wolfson funded Device innovation centre (£3.75M), stimulating new Small Medium Enterprise and MedTech industry investment in the UK.

We decided to strengthen our international leadership in genomic medicine by hosting Genomics England in prime medical school space, offering faculty positions to new scientists and seconding key staff to deliver on time and target the 100,000 Genomes Project (see above). This led to new faculty and investment in our Genome Centre (£300K). We also expanded our depth in functional genomics with epigenetics, chromatin biology and gene editing (Rakyan, *Science* 2016; Madapura, *Nature Genetics* 2016, 2018; Branco; *Dev Cell* 2016, *Nature Comms* 2018; Lin; Ficiz, *Nature Comms* 2017). As a result of our research asset base, the Beijing Genome Institute has invested £15M over 5 years in a UK Headquarters in the QM BioIncubator.

1B-3. Development of Impact Cases with acquisition of evidence

QM is one of the few universities to have a permanent impact team (see REF5a), which supports every stage of the research lifecycle, from planning to evidence gathering. Impact is critical to our future success to promote our research to expert and non-expert audiences. In 2017, QM appointed a Deputy Vice Principal for Research Impact (Datta), with strategic oversight of impact across the university. In Sept 2016, SMD appointed a Deputy Dean for Research Impact (Prof Steph Taylor) with strategic oversight who was supported by a Faculty Impact Officer and Institute academic impact leads who identify academics and projects for support and development. To maximise the acquisition of data and evidence for impact, we funded a post in our Health Economics Research Group (UoA2) who provides data on cost effectiveness and wealth generation.

Training in Impact for staff and Students. PhD students have a dedicated QM-wide 'Impact Day' in year 2 to facilitate sharing of best practice in impact generation, communication and evidence gathering. The Impact Academic Leads have been trained to assess impact opportunities and provide feedback and support to study authors, ensuring appropriate development in each case. This provides inter-disciplinary input and assessment across the whole SMD, with regular input and support from the larger QM Impact Team.

Below, we present three exemplars out of eleven impact cases returned to UoA1:

Primary human papillomavirus testing. Cytological cervical screening, introduced in Britain in 1988, led to a 60-70% reduction in cervical cancer mortality. In an extensive body of work published since 2003, Cuzick has driven the decision to replace cytological with the more effective primary HPV screening. As a result, programmes to convert to primary HPV cervical screening are recommended in the 2015 European Guidelines and are being introduced around the world (Turkey 2014, Netherlands and Australia 2017, across the UK 2020). Our analyses indicate that HPV primary screening in the NHS will prevent around 600 new cases of cervical cancer every year.

Better management of Chronic Hepatitis C. Pivotal trials led by or involving Foster identified effective hepatitis C virus (HCV) treatments which are now recommended in international guidelines. He demonstrated the aggressive nature of genotype 3 HCV and the poor therapeutic response in cirrhosis, leading him to establish bespoke, successful treatments. In England, with Foster as national lead, this led to an Expanded Access Programme followed by general access. The policy is the largest NHS investment in specialist services and involves 22 networks managing more than 50,000 patients. The Public Health England HCV annual report 2019 indicates a fall in deaths and transplants due to HCV of 16% and 53%, respectively. Foster's work is pivotal for the WHO target to eliminate HCV by 2030.

Trauma-Induced Coagulopathy and Major Trauma Haemorrhage. Brohi has led efforts to define the mechanisms of Trauma-Induced Coagulopathy and improved our understanding of why patients succumb to organ failure after severe injury. His team led the development of a damage control resuscitation strategy, including a massive haemorrhage protocol or 'Code Red', adopted by all 23 major-trauma centres in England. At Barts Health Trauma Centre, implementation reduced mortality rates from bleeding by 20.5% between 2014 and 2017.

1B-4 Public and patient engagement at Queen Mary

QM has a long history of commitment to public engagement having started life as the *People's Palace*, in 1887 to provide culture, entertainment and education in East London. As one of the

most diverse universities in the UK, we prize our engagement and involvement with our diverse community of 97 nations. We have strong relationships with local schools (St Pauls Way, the Drapers Academy in Harold Hill), inspiring the next generation of learners. The **Centre for Public Engagement** was founded as part of an RCUK Catalyst award in 2012 to embed and sustain public engagement at QM (more details in REF5a). Below are activities specific for clinical medicine.

The **Centre of the Cell** is an informal science learning centre and is the first in the world to be located within a working biomedical research laboratory. It aims to improve the educational, career and health choices of children, young people and families. The Founder and Director, Balkwill, is a leading cancer researcher and science communication expert. In 2018/19, the Centre of the Cell delivered 24,957 individual experiences to young people, their families and members of the public, representing a major portal for public engagement for the Life Sciences at QM, with activities including an immersive digital interactive cell biology experience, live science shows, workshops, debates, science talks, on-line and card games. All activities are developed in collaboration with researchers, providing unique and cutting-edge content. Since 2013, there have been over 155,000 participants in the Centre's activities and 207,000 since its opening in 2009. Our website had 100 million+ hits from over 160 countries and we have produced four free science Apps with 8810 downloads to date and four different Trumps card games (Cell, Virus, Bacteria and Gene) with thousands of sets sold or distributed free to young people. In 2016, the Centre received an **Excellence with Impact commendation from BBSRC** for having developed and delivered a vision for maximising impact, outstanding practice and institution-wide culture change.

In 2019, the Centre of the Cell expanded with the creation of Neuron-Pod (awarded a Commendation in the 2019 National Structural Steel Design Awards): a striking 10-metre high free-standing external structure providing over 80m² space, connected via a footbridge to the original Centre. With Neuron-Pod, we augment and diversify activities in public engagement and increase participant numbers. An example is the music meets science series. Since the pandemic lockdown, the Centre of the Cell has continued to engage via social media and monthly newsletters. The team introduced 'science at home' activity sheets and developed a new science show, The Neuron Show, with input from SMD neuroscientists. Support has continued for our Youth Members (128 active members at present) with online monthly newsletters and video content for Instagram TV. This provides advice for university applications and a personal statement feedback service.

Our medical and dental students interact with the local school children of East London through mentorships where they encourage and inspire children into higher education. Medical students also work part-time as Centre of the cell explainers, providing it with a flexible workforce, which improves the communication skills and disposable income of our medical and dental students (students can also access hardship funds from The Medical College of Saint Bartholomew's Hospital Trustees).

The Barts Pathology Museum. In 1879, the Prince of Wales, who later became Edward VII, opened the Grade-II listed museum which has offered training to generations of medical students for over 100 years. It contains over 5,000 medical specimens, representing a wide range of medical conditions through the ages. With support from the Medical College of Saint Bartholomew's Hospital Trustees, the Museum continues to exhibit specimens. An ongoing project is using smart phone technology to enhance engagement by bringing specimens to life through videos and graphics on visitors' phones.

School Work Experience Schemes. Marshall, Bishop, and Ahluwalia have hosted the Science Training for Aspiring Research Scientists (STARS) programme since 2013. Year 12 students spend one week in July doing cellular and molecular biology experiments and experiencing different biomedical careers. They have contact with patient volunteers from the TrialsConnect community who take part in trials and interact with national research initiatives (such as the 100,000 Genomes Project). With support from Barts City Lifesavers, everyone leaves with certified key life-saving skills. BCI and Centre of the Cell presented at the 2016 Royal Society Summer Exhibition, where around 14,000 people visited the stand on cancer cells and their environment.

Training and engagement in cancer medicine and research for the public is done with VOICE, a Patient Advocate training course (Marshall, Grose, Jones). This is a residential course and students (who are cancer patients, former patients or family members of patients with cancer) learn about cancer and clinical trials. The teaching and training is targeted to students who have no prior basic scientific knowledge and morning lectures are complemented by afternoons in the laboratory.

Pint of Science. Our students run the “*Pint of Science*”, an international science festival involving 40 UK universities. This is run in an informal social setting, bringing QM scientists and the public together to discuss research.

There are numerous smaller events for public and patient engagement. Examples are: (i) As part of our cardiovascular research outreach, we hosted a Myocarditis Day for patients; (ii) In 2017, the BHF Ambassador, the Duchess of York met our leading BHF-funded researchers; (iii) Marelli-Berg received the BHF Heart Hero award for science communication, demonstrating the effectiveness of our staff in engaging the public in complex science; (iv) The TrialsConnect Covid-19 [website](#) was used to improve understanding of Covid trials; (v) Through CiTI we organised ‘BBQ in the CiTI’ attended by patients and their families affected by musculoskeletal disease.

1C. Future strategic aims and goals for research and impact

1C-1 Research.

A) Queen Mary’s future strategic aims and plans for research and impact

The Queen Mary Strategy 2030 outlines our ambition to be the most inclusive university creating opportunity for all. We aim to attract and retain top class researchers and ensure their outputs are world leading and impactful on health, wealth and society. Research Impact is now embedded in everything we do at QM to ensure we maximise the value of our research at every opportunity (see assessing impact). In spite of the challenging economic climate, we will expand our contribution to the UK Life Sciences Strategy through clinical medicine research and training at our Whitechapel and Barts/Charterhouse Square Campus sites. We will focus on our strengths and continue our major upward trajectory in cardiovascular, cancer, genomics, inflammation and population sciences.

B) Barts Life Sciences

Post-Brexit and post-Covid, we are convinced that Life Sciences and the university ecosystem will continue to have a major role in stimulating international exchange, practising science without borders, stimulating inward investment and attracting talent. These will be vital to the UK’s global leadership in clinical medicine research. We are determined to rise to the challenge and with Barts Health we have created **Barts Life Sciences (BLS)** with clinical medicine research opportunities for an immediate population of 2.5 million people from 97 Nations.

The current status of Barts Life Sciences: We have partnered with the DHSC (investment £80M) and Tower Hamlets to develop a major inner London Life Sciences envelope of 1.5 million square feet, rejuvenating the land vacated by the old Royal London Hospital in Whitechapel. We will facilitate academic-industry-NHS, linking with our diverse local community who are typically under-represented in research. In tandem, we are master-planning the estates needs at the Barts/Charterhouse Square Campus where in 2023 we will celebrate the 900 years of clinical medicine and research for patient benefit at St Bartholomew's Hospital and will launch a major appeal in May 2021. Our BLS strategy focuses on a £600M expansion in multi-disciplinary biomedical life sciences faculty, research and training with embedded QM and Barts Health facilities around which we will attract cognate companies. To kick start this development, the DHSC are planning to invest £10M in a 25,000 square feet new Bio-incubator to add to the 40,000 square feet of space offered by QM Bio-innovation already full and on-site. As an early sign of success, the Beijing Genome Institute have made a £15M investment over 5 years to create their UK headquarters at the QM Bio-incubator based on our genomics strength and planned development in Life Sciences.

Focus on Precision Digital Healthcare: This major strategic initiative will open new vistas on biology by integrating digital precision healthcare into our diverse community. We will build on our recent successes in mobilising electronic health data for Covid in Barts Health and Primary Care through the DISCOVERY dataset which reaches across 2.5m people. We will form global academic, industry and healthcare partnerships to ensure that the UK remains at the leading edge of clinical medicine research. A major advantage of the Barts Life Sciences partnership will be that precision medicine healthcare can be rapidly undertaken with one of the largest Trusts in Europe to accelerate the pace of healthcare transformation.

Realising the BLS ambition: We will capitalise upon our extant research strengths in cardiovascular, cancer, genomics, inflammation and population health through research hubs built on inter-disciplinary excellence in digital health, data, precision-omics, advanced medical technologies and advanced analytics. These hubs fit with key areas identified by the UK Life Sciences Strategy and will catalyse further funding opportunities and produce outputs in areas that match our clinical medicine excellence.

Initial investment and expected impact: As an initial commitment to Barts Life Sciences QM has invested in a new cross-faculty Digital Environment Research Institute and refurbished 2500 square metres of space for artificial intelligence and advanced analytics. This links with our potential investment of up to £120M for a new building as part of the Digital Precision Health vision for Barts Life Sciences. This expansion in our clinical medicine research will be used to take a once in a lifetime opportunity to develop the latest digital precision healthcare, securing health gains and equity in life expectancy for a community set to expand by 29% in the next 15 years. Our goal is to build on our existing healthcare datasets and be in the vanguard of national plans to assemble well curated, linked datasets across the entire NHS for patient benefit.

Future opportunities: Recently, we have been approached by Canary Wharf Group, property developers who created the second largest financial centre in the world. They wish to partner Barts Life Sciences to develop up to 3 million square feet of estate on the Isle of Dogs (4 minutes from Whitechapel by Crossrail). With external market testing we are evaluating the potential of this partnership which with Barts Life Sciences existing footprint could propel the UK into the top three for Life Science estate in the world. External benchmarking suggests that the development will create 12,000 life science posts and the gross value added is £12 billion over the next 30 years.

QM's Post-REF 2021 Plans: We intend to expand our research to a population of 6m. We will routinely offer patients the opportunity to participate in longitudinal life course studies, combining routine tests, data from wearables, remote sensing, digital pathology, imaging, and multi-omic repositories. Barts Life Sciences will make these real-world precision datasets available to academia and industry for digital trials and will use the scale of our data assets to select niche populations for accelerated trials enrolment. We will expand our clinical trials research, building from our top decile position for commercial studies, our world number one position for the QM-UCLP Prime Site trials hub and our position as the top recruiter in the world for the Janssen Covid Vaccine trial. We will incorporate our regulatory and governance success in moving at speed and pace in Covid-19 trails to ensure that we can do the same for clinical studies post-Covid.

New multidisciplinary strengths Post-REF2021. We will embed new multi-disciplinary cross-cutting themes across all areas of strength outlined above. These are 'environment and health', 'life-long health and multimorbidity' and 'crisis prevention and management'.

Our work in Environment and Health and the future aims are provided in UoA2 and so are not described further here. We reason that research into multi-morbidity (Life-long Health) is crucial in view of the aging population and the complexity of chronic conditions. As such, an integrated approach is required, bringing together discovery science with translation, complementing new therapies with changes in lifestyle and nutrition. Our strategy dovetails with Barts NHS Trust's plan to open a new Hospital at Whipps Cross. It is anticipated that this will be a beacon hospital leading academic developments in multimorbidity, with a focus on ageing, diabetes, mental health and obesity will be investigated.

For Crisis Prevention and Management, our vision is to build on trauma and critical care by bringing together resilience, social health care and social sciences. A crisis is a time of intense difficulty or danger: but it also represents a moment of opportunity. Disasters can be environmental, medical, humanitarian, economic; they can relate to individuals, to specific communities, to populations, from local to global scale, and they can often be intersectional across these disciplines. Their effects can have catastrophic consequences for individuals, organisations, corporations and entire societies. While often experienced as unexpected, unprecedented events, these 'black swans' can be planned for, avoided, mitigated and effectively managed, often with positive outcomes. We will work closely with Barts NHS, East-London Foundation Trusts and the London Air Ambulance to create a multi-pronged research environment that can provide fresh inter-disciplinary solutions to the complex challenges of disaster and crisis management.

We intend to pursue centre status across our key areas of excellence, expanding emerging areas such as **cardiac inflammation** and **hepatology**. In cardiac inflammation, we will build on the BHF Accelerator Award to secure a BHF Centre of Excellence. We will develop new diagnostics and therapeutic tools to transform the treatment of heart conditions, from myocarditis to inflammatory-dilated cardiomyopathies. We have already established collaborations with leaders (J Hill, Dallas, and G Condorelli, Humanitas) in heart failure with preserved ejection fraction. We will continue to align with the Barts Heart Centre strategy to improve clinical care. We will investigate opportunities for the Barts Liver Centre, leveraging strategic funding for translational and clinical research in hepatitis B, C and HIV (Foster, Orkin, Kennedy), which will enable impact locally, nationally and internationally (with Kelly, in Zambia). We have commenced capacity building in this area following the recent award of a competitive bid for £1.5M from Barts Charity.

In population health, we plan to capitalise on our successful prevention work in cancer and cardiovascular disease to develop the Neurology Prevention Unit and the pharmacological prevention theme. We will build on our ongoing work, such as that on aspirin (led by Cuzick), to develop pharmaco-prevention trials to understand how aspirin prevents colorectal, oesophageal and gastric cancers. We will also expand our work on vitamin D in tuberculosis and respiratory medicine (Martineau [UoA2]) to ensure that prophylactic pharmacological interventions (e.g. Vitamin D, Aspirin, Omega-3) are applied to benefit patients affected by chronic diseases.

1C-2 Research Integrity.

To implement the highest standards, we appointed (2019) Professor Grigg as Deputy Dean for Research Integrity who provides mentorship for researchers and advice on general research integrity training including the use of the educational resources of UK's Research Integrity Office. The SMD's [research integrity website](#) links to relevant protocols and the UUK Concordat, a blog by the Deputy Dean for Research Integrity, and individual contact details for integrity enquiries. QM's clinical trial transparency is very good, with 94% of our European Union Clinical Trials Registered (EUCTR) studies reported in 2019 (EU Trials Tracker). We have developed the infrastructure for researchers to upload individual data supporting published studies to our publicly available Research Information Management System (Elements/QM PubLists). We are committed to developing an audit and reproducibility culture for both clinical and non-clinical research and to uphold the Hong Kong principals for assessing researchers fostering a culture of research integrity. Seminar series are delivered for PhD students (3 times per year from the Deputy Dean for Post-Graduate Research and Deputy Dean for Research Integrity) and there is a research integrity workshop for senior academics (twice per year, alternate on our two campuses).

2. People

2A. Academic Staff

Strategic staff recruitment and development.

Post-REF2014 we embarked on an ambitious recruitment process to accelerate capacity in clinical medicine funded by QM strategic and external funds (CRUK, BHF, UKRI, Versus Arthritis, Wellcome). Where possible, we support researchers from PhD through to Chair level. We increased the quality and critical mass in our targeted research themes and attracted 34 early-career (Lecturer/Senior Lecturer) and 18 senior academic (Reader/Chair) appointments with academic posts for our successful fellows expanding our return by 77 FTE.

Strategic success with Early Career Researchers: For REF2014, we undertook an early-career-researcher recruitment programme and 14 out of the 18 now have tenured academic posts funded mainly through external grants. Based on this success, we won an award from the Barts Charity (Perretti, Kelsell, Thornton; £6.2M, 2018) for our [Rising Stars Scheme](#) to recruit 15 Young Investigators. These were provided with a £350-400k package over 3 years to cover salary and a flexible funding allowance. Each fixed-term lectureship has a supervisor and a mentor (identified by their track record for nurturing emerging talent). Below we summarise some of the outputs of these achievements.

We recruited 2 Wellcome Trust Royal Society Henry Dale Fellows (Horejsi, *Cell Rep* 2014; Dalli, *J Exp Med* 2014) and an MRC Career Development Fellow (Mardakheh, *Dev Cell* 2015), augmenting our capability for post-genomic phenotyping. In genomic medicine, we appointed

Traylor (*BMJ* 2018; *Nature Genetics* 2019), Barbosa (UKRI Rutherford Fellow, *Nucleic Acid Res* 2014) and Gurdasani (UKRI Rutherford Fellow; *Nature* 2016; *Cell* 2019). In functional genomics, Madapura (Lecturer; *Nature Genetics* 2016, 2018), Cerase (Lecturer funded by the Rett Syndrome Trust funding; *Science* 2017) and Villar Lozano (BHF Fellowship; *J Clin Invest* 2017). Through our partnership with Genomics England, we recruited Smedley (promoted from Senior Lecturer to Professor, *Science Transl Med* 2015; *Nature Protocol* 2015; *Nature Genetics* 2017) and appointed Moutsianis to a senior lecturership (*Nature Genetics* 2015, 2017).

In inflammation, we recruited Henson (Lecturer promoted to Reader; *Nature Immunol* 2014; *J Clin Invest* 2014; *Cell Rep* 2016) and Dufton (Lecturer; *Nature Comms* 2018, 2019). Our strategy attracted Maillard (UKRI Future Leadership Fellow £1.5M; *Embo J* 2016), Rowe (ERC Starter Grant; *J Cell Biol* 2016; *Embo Report* 2018, *Nature Comms* 2020), Chambers (*J Allergy and Clinical Immunology* x2), Subramanian (*Cell* 2017; *Circ Res* 2015; *J Clin Invest* 2014) and Abdul-Salaam (*Circulation* 2014; *Circ Res* 2019) for work on cardiac inflammation.

In cancer with £10M from the Barts Charity, we recruited two lecturers (Stojic and Rouault-Pierre; *Nature Comms* 2015, 2017; *Leukaemia* 2017, 2019) and a senior lecturer (Finch; *PLoS Genetics* 2019) to enhance our research in cancer metabolism, tumour microenvironment and tumour targeting. Our Early Career Researcher (ECR) programme recruited cancer scientists with high impact papers; Ganuza (*Nature Cell Biol* 2017), Bellelli (*Cell* 2018), Ombrato (*Nature* 2019), Werner (*Nature Genet* 2016), Keklikoglou (*Nature Cell Biol* 2019) and Efremova (*Nature* 2018; *Nature Comms* 2018). We recruited a CRUK Clinician Scientist (Okosun; *Nature Genetics* 2016) and a Wellcome Clinician Scientist (Riches; *Blood* 2014).

We invested in preventive medicine and created the Neurology Prevention Unit with Noyce (Senior Lecturer; *Lancet Oncol* 2016; *Neurology* 2017) and Marshall (Senior Lecturer; *JAMA Neurol* 2019; *Brain* 2019). We attracted Rognoni (Embo Fellowship; *Nature Med* 2014; *Nature Cell Biol* 2017) and, in 2019, Raimondi (BHF Intermediate Fellowship; *J Exp Med* 2014).

Ackland enhanced our links with critical care (Reader to Professor; WHRI; NIHR Advanced Fellowship £1.5M and held the British Oxygen Chair of Anaesthesia for the Royal College of Anaesthetists; *Lancet Respir Med* 2015; *Nature Comms* 2017). In paediatric endocrinology, Storr increased capacity in growth paediatric endocrine disorders (NIHR Advanced Fellowship £1.8M). In 2018, McCormick (Senior Lecturer; *J Neurosci* 2014, 2015; *PLoS Biol* 2015) brought expertise in molecular pharmacology and cell biology.

New professorial appointments: We appointed several new cardiovascular chairs and groups attracting Brown (NIHR EME grant; *Lancet* 2015 x2, *NEJM* 2015; *Lancet Diabetes Endocrinol* 2016) from Cambridge in 2015. In 2017, we appointed Baumbach from Bristol, Lansky from Yale (joint papers; *Lancet* 2015, 2018; *Eur Heart J* 2015) to cement a new partnership with Yale in cardiovascular devices. We appointed Eaton, a European Research Council Fellow, an MRC and BHF programme Grant Holder a leader in cardiovascular redox research (*Nature Comms* 2015, 2016; *JCI* 2015; *Circulation* 2017). To create a new inflammation partnership with Humanitas University in Milan, we appointed Mantovani (*Nature* 2017; *Cell* 2019) and created a new Versus Arthritis Chair for Rot (Wellcome Investigator; *Nature Immunology* 2014, 2017). In cancer, we appointed Schmid (*Lancet Onc* 2016; *J Clin Onc* 2016; *NEJM* 2018). With £10m (Barts Charity) for new professorial appointments we recruited Sanz-Moreno (*Nature Comms* 2014, 2018; *Cell* 2019) and Kamil Kranc (*J Exp Med* 2015, 2017; *Blood* 2016). These chairs brought programme funding from CRUK, BHF, NIHR and MRC and a senior European Research Council (ERC) fellowship.

Mentorship.

For all QM recruits, and especially our ECR community, a supportive mentorship programme has been developed. This includes supervision from within and outside the host Institute. Grant peer-review processes are in place within each Institute and support is provided by the Doctoral College. White board events and group/institute seminars provide an opportunity to develop research projects and publications. We support early career researchers via grant-writing clinics, fellowship application mentoring and mock-interviews from experienced staff. The Barts Academy, created by MacDonald and Sheer in 2014 for the first intake of ECRs, acts a forum for mentorship, away-days, training events and enhances peer-to-peer interaction. Over 50 fellows, lecturers and ECRs contribute to the activities of the Academy.

Successful examples of our mentorship are Wellcome Royal Society Dale fellowships for Branco (*Dev Cell* 2016; *Nature Comms* 2018) and Bourke (*Science Transl Med* 2019) and an MRC Career Development Fellowship for McCarthy (*J Clin Invest* 2015). MRC New Investigator Research Grants (NIRG) have been awarded to Aksoy (*Cell* 2019), Godinho (*Nature* 2014; *PNAS* 2015) and Nightingale (*J Cell Sci* 2017). Guasti (*Embo Mol Med* 2016;) and O’Loughlen (*Cell Rep* 2017) won BBSRC New Investigator Research Grants. Godinho won the Lister Prize in 2016 and Ganuza an MRC Career Development fellowship (£1.5M).

We believe that mentoring and developing talent is key to future success. This has led to multiple PhD students winning funding, such as the Versus Arthritis Foundation Fellowship, BHF Intermediate fellowship, and the Sir Henry Wellcome Fellowships. The support of our mid-career fellowship staff is evidenced by the Versus Arthritis Career Development Fellowships for Norling (*JCI Insight* 2016), Voisin (*J Ex Med* 2014), and Corsiero (*Ann Rheum Dis* 2016). BHF Intermediate Fellowships have been awarded to Longhi (*PLoS Biol* 2014; *Cell Metabolism* 2017), Nadkarni (*PNAS* 2016), Lozano, and Raimondi. Cooper won a Versus Arthritis Career Progression Fellowship which we supported with a lectureship (now promoted to senior lecturer). In 2019, Norling obtained a Versus Arthritis Senior Fellowship. Pearce (*PNAS* 2014x2, 2015) obtained a CRUK Career Establishment Award. Aksentijivic secured a Wellcome Career Development Fellowship (*Nature Comms* 2020). Graham (ECR recruited in 2013, now promoted to Professor; *Nature Med* 2016; *Nature Genetics* 2016, 2018) won a Wellcome joint Investigator award. Senior academics have won major awards such as Balkwill (Advanced ERC) and Nourshargh (Wellcome Investigator; renewed in 2020). Storr and Ackland were awarded NIHR Advanced Fellowships and Pearse held an NIHR Professorship.

Career Development: Our mentoring, grant writing clinics and mock interviews with cross-Institute and Research Deanery input (outlined above) have led to major awards. We provide career development for all academics and encourage fellowship applications and research council grant submissions.

QM adopted the principles of the *Researcher Development Concordat* to create a research environment and culture that nurtures and promotes our researchers, improving employment opportunities and supporting career development. Our support systems have led to an increase in successful grant applications which have grown year on year since 2016.

QM run an annual academic promotion round where applicants are considered on merit based on their contribution to research, the institute and faculty. Recognising that there are communities within our Faculty who may face additional barriers to progression, we offer promotion workshops to aid preparation, and some are specifically for women such as the SMD Women’s Promotions

workshops. All provide staff with the information required for promotion. In this UoA, there were 20 researchers (9 women and 11 men), promoted to senior lecturer, reader or professor in 2020.

For details on promotion rates and equality please see Section 2C.

2B. Post-Graduate Students.

Training future non-clinical and clinician scientists is one of our major goals. At the census date of December 2020, there were 545 registered research degree students enrolled in our faculty, of which 418 are in UoA1, an overall increase of 53%. There are 17 full time MRes students, 7 part-time MRes students, 370 full time PhD students and 48 part-time PhD students. Recruitment increased by 34% in 2017/18 and 27% in 2018/19 mainly due to Research Council and other doctoral training programmes. Approximately 36% of our PGR students are on clinical programmes. Increasing PGR numbers has been achieved through matched funding opportunities, competing for Doctoral Training Programmes (including Europe) and increasing charity funded PhD studentships.

PhD Programmes: QM co-led an MRC doctoral training programme with Southampton (2015-2019; 4 PhD's per annum in QM of which 2 are faculty funded, plus 2 iCASE places). We have a tailored MRes in translational immunology as part of the programme. Our BHF 4-year doctoral training programme on cardiac and vascular research was renewed (£6M; 2013-2021) and enrolls 4 students per year (plus a matched student from QM). This has recently been renewed for 2021-2025 with 3 studentships and one matched. Through CiTI and a collaboration with UCB Pharma, we established a PhD training programme with UCL Partners to support 4-8 PhD's over 4 years. This scheme provides students with experience of therapeutic drug and antibody development. It also provides industry insight by having a UCB supervisor. For clinical PhD's, Yaqoob/Thiemermann (WHRI) created (September 2014) a Barts-HCA Healthcare Clinical Fellowship Programme to improve translational research and foster the next generation of clinician-scientists. To date, 18 Clinical fellows have entered the programme and studied for a MD/PhD, MSc or to enhance their clinical research. This generated income of approximately £3.4M for QM. Prendergast (UoA2) is a partner in a Wellcome doctoral training programme on Global Health (lead LSHTM), which supported 3 clinical PhDs at QM.

Clinical training fellows: We attract highly motivated clinicians through MRes and PhD degrees. These contribute to the translation of our basic science to improved clinical care. The NIHR Integrated Clinical Academic Training Programme (IAT; leads Marino until January 2019 and then Korbonits with Alazawi) in partnership with Barts Health NHS Trust currently hosts 59 fellows (43 Academic Clinical Fellows [ACF] and 16 Clinical Lecturers [CL]). Of the ACFs appointed between 2006 and 2013, 62% obtained competitive personal fellowships (from MRC, Wellcome, CRUK and others) to undertake a higher degree. This is an indication of our strong research and training environment. Of the CLs, 86% were research active after completion of training, and 61% are currently employed on a substantive clinical academic post or fellowship, thus highlighting the high retention rate in academic careers. In addition, the recently awarded BHF Accelerator Award provides 1-year seed funding for young clinicians working towards Intermediate Fellowships focused on inflammation of the heart.

Clinical and non-clinical PhD studentships are funded by the Medical College of St Bartholomew's Hospital Trustees and the Barts Charity. For clinical studentships, funding is used to produce preliminary data to apply for training fellowships; non-clinical studentships are supported through research projects.

Training of PGR Students and The Research Environment. We aim to promote academic excellence among our Postgraduate Research Students. Student progression is monitored at 6, 9 and 30 months, with transfer to write up at 36 months and submission within 48 months. Our 48-month SMD submission rate is 88%, above that required by UKRI and the Vitae Concordat. All students must complete 70 hours per year of transferable skills training, provided by the QM Doctoral College. Students have access to welfare counsellors, careers advice and support for wellbeing/mental health issues. They benefit from courses on emotional resilience, survive and thrive programmes and our professional pastoral service. All new academics attend a full-day Supervisory Training course as part of their formal induction. Experienced supervisors attend a refresher course every two years to maintain their knowledge of PhD degree management and support services for students and supervisors. Supervisors must meet their students at least 10 times per year, as per the *SMD Code of Practice for PGR Programmes 2019-20*, although in practice it is much more frequent.

SMD provides an inclusive environment where diversity is valued and celebrated. 63% of our PGR students are women. QM is committed to creating an environment where all students and staff are treated with dignity and respect. We have a policy of zero tolerance to bullying to ensure all are free from prejudice, discrimination and harassment. Our students are treated fairly and are not treated any differently due to age, marital/civil partnership status, gender, gender identity, disability, race, ethnic or national origin, sexual orientation, family circumstances, religious or political beliefs. The only consideration must be that the individual is able to satisfy the requirements of the programme.

SMD encourages cross faculty co-operation and supervision. It is estimated that of the full-time students submitted under UoA1, 11% will be co-submitted to UoAs 2, 3, 5, 11 and 15. Areas such as biomaterials and 3D bio-printing with synthetic organoids offer joint studentships with the Faculty of Science and Engineering. Academics working on devices and microfluidics can access our BHF studentship programme.

2C. Equality and diversity

QM aims to be the most inclusive university of its kind anywhere. As evidence that Equality, Diversity and Inclusion (EDI) are central to our values, we introduced new structures and reporting lines in 2018. In 2019 a Vice Principal for People, Culture and Inclusion (Sheila Gupta) was appointed (see REF5a for EDI activities at the Institutional level) and at faculty-level an EDI group (led by **Eldridge**) takes oversight. This work is supported by a dedicated Athena Swan Co-ordinator and data officer.

Awareness of EDI. Unconscious bias and Active Bystander training are mandatory for all QM staff and were reviewed and updated in 2020. We are developing training packages on allyship, black history, and terminology, with the aim of providing a range of resources in different media to enable staff to progress their knowledge and understanding of EDI. Queen Mary has been a partner of the 'B-Mentor' scheme since its inception (2012). This is run across four London Institutions and is a scheme where senior academics mentor black and ethnic minority academic staff.

Race, equality and protected characteristics. The Faculty EDI group led the following initiatives: an action plan following the killing of George Floyd; significant contribution to the inclusion of citizenship as a promotion criteria; developing an external speaker series to raise the profile of EDI and individuals with protected characteristics within the university community;

establishing a well-read monthly newsletter containing links to further reading and resources; a research project on attainment gap between Black and ethnic minority and non-BAME students; contribution to a QM group focusing on gaining a Race Equality Charter and, linked to this, signing the BMA Charter for medical schools to prevent and address racial harassment; and recommendations for greater transparency in the membership and terms of boards and committees.

Flexible working at QM. We have well-signposted resources around support for flexible working. We have offered (Pre-Covid) support such as funding to support childcare costs for returners to attend out of town conferences. Examples are the *SMD Travel Grant for PhD students and Postdocs* and the *Financial Assistance Fund (FAF)* which provides a non-repayable grant to cover childcare costs. A Welfare Advisor is available to provide tailored information. A parents and carers network has been established in response to lockdown to provide support and a sense of community.

LGBTQ+ at QM. We funded staff to attend Stonewall training who act as diversity champions including highlighting the 'QMOut' LGBTQ+ network. Our Athena SWAN Chair (Orkin) is a nationally recognised LGBTQ+ role model (Visible Lesbian 100 award 2020, RCP 'this doctor can' LGBTQ+ profile) and President Elect of the Medical Women's Federation.

Championing women: At QM, we have a successful Athena SWAN programme and achieved Silver status in 2014 and 2017. We made major progress towards addressing the gender pay gap through promotion, allowances for leadership roles and supporting Clinical Excellence Award applications. **Orkin** has led two workshops in 2020 and mentored 8 women who applied in this round (vs 1 application in 2018 and 2 in 2019).

Gender balance in UoA1. Since 2014, our targeted interventions achieved an impressive record of gender balance for UoA1 staff, and around 45% of our research-intensive professors are women compared with 23% across the entire Russell Group. In UoA1, over 50% of research-intensive staff at senior lecturer and lecturer level are women. QM offers a range of schemes to support and encourage female staff to progress their careers (recruitment and retention initiatives, leadership and mentoring).

Promotion for women in UoA1. For the 2014-2020 period, the promotion scheme (all academic levels) saw 106 men and 108 women being promoted, with 31 applications from men and 43 from women rejected. Of the successful ones, the split for academic posts is as follows: senior lecturer, 31 and 46; reader, 37 and 33; professors, 40 and 19, for males and females, respectively. Our faculty (Ahluwalia) has led annual reviews of the attainment gap in promotion across the university for the past 2 years and initiatives including targeted pathways to promotion workshops for staff and more recently the inclusion of Citizenship as criteria for promotion. With leadership from Sandra Eldridge (EDI), Chloe Orkin (Athena Swan) and Amrita Ahluwalia (Promotion) we are resolving residual discrepancies between junior and senior academic appointments through support and mentoring of those with protected characteristics presently underrepresented in our faculty.

QM Women in Leadership. We are committed to recognising successful senior female staff in leadership and four of our seven institutes had/have women as director or deputy director 2014-2020.

3. Income, infrastructure and facilities

3A. Income

Total grant expenditure in this Unit for the period August 2013-July 2020 was £379M resulting in an average research spend of £54.1M per year. The average income per FTE in UoA1 was £1.7M for the 7-year period. This represents more than a four-fold increase compared to the REF2014 submission (£405k/FTE). The corresponding average annual figures are £243k/FTE/year and £81k/FTE/year for REF2021 and REF2014, respectively.

Of the £379M total research income, £64.6M was from UKRI funding (17% of total), £16.8M from NIHR (4.4%), £14.7M from the EU (3.8%), and £69.4M (18.3%) from commercial sources. Of the latter, 68% was from UK-based companies (£47.1M), reflecting our knowledge exchange activities and therapeutic innovation.

The awards (rather than spend) was £412M over the REF2021 period.

3B. Infrastructure Investment

Since REF2014, over £25M has been invested in research buildings and facilities. The University provided around £11.7M for a wide range of projects to improve our facilities. A further £14.4M was secured through competitive proposals to external funders, including MRC, the Wellcome Trust, HEFCE Catalyst Fund, Barts Charity, the European Regional Development Fund, the Charles Wolfson Charitable Trust and a number of other Trusts and foundations. Major programmes of refurbishment have been undertaken in Whitechapel to create new space for East London Genes and Health and our Catalyst Centre (£1.2M internal, plus £4.8M external). The Neuron Pod (an extension to the Centre of the Cell, our public engagement flagship) received £30K internal and £2M external funding.

At our Barts/Charterhouse Square campus, circa £3.4M was invested in the John Vane Science Centre; £2M in the biological services unit, plus £1.4M in new cryo-store facilities offering safe long-term storage of biological samples. In 2017, we leased a further 5000 square feet of space for expansion at the Charterhouse Square Campus.

We capitalised on two £10M awards in cancer and cardiovascular research to provide the equipment and capital fit out for new appointments to succeed. In Clinical Research, the new Cardiac Devices Hub will be completed shortly with €3M investment secured from the European Regional Development Fund. In addition, a programme funded by £6.2M from Barts Charity will deliver significant improvements and additional space for new research groups at Charterhouse Square. This funding has pump primed the platform for 3 CRUK Centres and an NIHR Biomedical Research Centre.

We have Invested more than £4M in cross-Institute equipment since 2015 (funded by QM and Barts Charity). Access to state-of-the-art equipment has enabled cutting-edge research in a number of areas. Relevant to UoA1 has been: 1) the Advanced Microscopy Imaging Unit, which brings together 81 items of supporting equipment with more than 20 imaging modalities (£3.5M between 2016 and 2019) and the CREATE lab, a 3D tissue bio-printing facility (£0.75M QM plus 0.35M from Barts Charity). Established in 2017, this laboratory brings together bioengineering scientists, biomaterial scientists and chemists with SMD researchers to enable research in cancer stroma and dermatology, orthopaedics, rheumatology, cardiovascular disease, dentistry and trauma.

To support our wet laboratory-based scientists, we invested more than £2M into the newly refurbished Biological Service Units. We augmented our phenotyping capabilities in preclinical settings, by investing a further £200K into a new echo for rodents, more than £300K into metabolic phenotyping facilities (Phenomaster and Fat Echo-MRI; QM and William Harvey Foundation Award) and a two-photon microscope. The microscope was funded by Wellcome and BHF although we provided a technical manager and other instruments for animal imaging. Our goal is to compare and contrast animal with human phenotypes leading to advances in understanding clinical issues.

In order to support cross-cutting activities we have upgraded the infrastructure for the our Genome Centre (more than £300K investment including the purchase of a single cell analyser). We have invested around £1M into a proteomics and phosphor-proteomic Unit for cell and molecular biology, including the analysis of drug pharmacokinetics and pharmacodynamics, protein composition and structure, post-translational protein modifications and enzymatic activity. In 2018, a metabolic flux machine was purchased for £0.5M to support phenotyping and metabolism which emerged as a cross cutting research theme. In 2015, we established a cross-cutting Lipid Mediator Unit equipped with state-of-the-art liquid chromatography tandem mass spectrometry to identify and quantify bioactive lipid mediators, their precursors and pathway markers in biological systems. QM invested £0.75M, Barts Charity £0.5M and additional equipment was funded by an ERC Starting Award.

These examples illustrate our strategic support for existing areas of strength and how we have developed cross-institute facilities to promote collaboration and efficiency.

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

4A. Academic Partnerships.

QM has a clear strategic approach to collaborative academic and healthcare partnerships at international, national, regional and local level. In the post Brexit era, we hold the view that to enhance the UK's position in global medical research and retain the outstanding international faculty we have attracted, we must form international alliances and partnerships that allow QM and UK Universities to continue to conduct science without borders. Our partnerships are all designed to deliver important biological insights that change healthcare, society, the economy and benefit the partners (better together). Though EU-funded consortia, Marie Curie Fellowships and Marie Curie Innovative Training Networks (involving over 40 academics in UoA1) we have established productive links with several HEIs in Europe and we have a medical school in Malta. Below we describe partnerships that are new or extant over the REF period and for each illustrate the benefits

4B. International, National and Regional Partnerships

At QM, we have a Vice Principal (VP) for International and Global Partnerships (Grant) and at the Faculty level we have a Dean for International (Leigh [UoA3]) and an Executive Board that oversees and examines all strategic partnerships.

QM leadership in the Global Alliance for Genomic Health (GA4GH): Building on Caulfield's work, co-leading international consortia, he co-chairs the multi-national Global Health Implementation Forum of GA4GH of over 20 national or international initiatives. This is focused on advancing genomics across the world working towards translation into clinical care by adopting

GA4GH standards for data sharing. **The benefits:** QM faculty have shared innovative analytical approaches such as Exomiser that increases diagnostic yield in rare disease. We created a Genomics England/QM Panel App, a globally crowdsourced tool based on evidence-based gene panels for identification of variants (*Nature Genetics* 2019). This has been accessed by 20,000 users/ month running 4 million gene queries and was adopted by the Australian Genome Health Alliance via GA4GH in December 2019.

QM-Yale cardiovascular Devices Partnership: We established a multidisciplinary Device Innovation Centre between the William Harvey, QM Institute of Bioengineering, Yale University and the new UK-CRC accredited Barts Clinical Trials Unit. **The benefits:** We attracted Lanksy (0.5FTE) from Yale and Baumbach (QM) as joint appointments to maximise the QM-Yale bridge and they published in the *Lancet* and *European Heart Journal*. This led Mathur, Baumbach, Lanksy and Caulfield to secure substantial funding for the new EU Devices Centre (see above). This has developed multiple commercial relationships which are attracting new studies for patient benefit and could only have been facilitated through this Centre.

The first Sino-British (QM) Molecular Oncology Centre: In 2006, Lemoine and Wang established the first Sino-British Research Centre for molecular oncology at Zhengzhou University (ZZU) in central China's Henan Province. Since then, the partnership has grown to become the Chinese Academy of Medical Sciences (ZZU-AMS), focused on the treatment and prevention of cancer. **The benefits:** This has led to major grants from the National Natural Science Fund in China and major research exchange. In recognition of the work conducted in the ZZU-AMS, Lemoine was elected as a Foreign Academician of the Chinese Academy of Engineers (2017) and awarded the National Friendship Prize by the Chinese Government.

The QM-Humanitas Partnership: In 2017, this partnership was developed by our cross-faculty initiative, CiTI, with the premier Italian University Humanitas. **The benefits:** This attracted a world-leader in Inflammation research to the UK and QM (Mantovani) which led to joint publications and professorships for Mantovani and Pitzalis; (*Nature Immunol* 2019) and projects with dual principal investigators (e.g. Marelli-Berg with Condorelli, Balkwill with Allavena). QM and Humanitas have agreed to award joint PhD degrees maintaining crucial scientific links to Europe.

QM-Pakistan Research and Training Partnerships: In 2017 QM entered a partnership with the National University of Medical Sciences (Islamabad, Pakistan). We hosted 6 clinical academics for 8-months training supported by the British Council. Joint research projects were supervised by QM academics (Aziz, Cutillas, Kelsell, Martineau, Baker, Prendergast). In 2020, the Faculty signed an MoU with Punjab University. **The benefits:** This led to project applications to the Global Challenge Research Fund, the British Council, Newton and Fleming funds. A new cohort of National University of Medical Sciences Fellows has been funded by the Higher Education Commission of Pakistan and a doctoral training programme is being established. With Punjab University, we are establishing joint projects in women's health research and in malnutrition due to its impact on the development of chronic disease later in life.

QM- Singapore A*STAR Programme: QM have established a joint PhD programme with A*Star with 2 PhD students per year since 2019.

QM-Fundacao Osvaldo Cruz (FioCruz): In 2019, QM signed an agreement with FioCruz for joint work in infectious diseases, **The benefits:** Access to patient samples and disease models for Dengue fever, Tuberculosis, Yellow fever and Zika, though pump-priming and a programme of exchange. Progress has been impeded by the pandemic.

QM-Brazil and Royal Melbourne Institute of Technology (RMIT, AUS): in 2020, we built on our partnership with FioCriz to create a consortium devoted to study Covid. The Federal University of Minas Gerais, the Fundacao Getulio Vargas and RMIT in Australia have now joined the consortium. **The benefits:** projects are underway, and are focused on the epidemiology and genetics of Covid to explain the incidence and severity. Immunological studies identify predictive markers for mild, moderate and severe disease.

QM-Global Health Research in Africa: QM has long history of high-quality research in sub-Saharan Africa, with research in many areas such as mother/child HIV and mental health. These are detailed in our UoA2 submission. We will continue these studies and explore additional opportunities for discovery and clinical research

4C. Industry Partnerships

In accordance with the UK Life Sciences Strategy, QM has placed academic-industry partnership at the heart of our research programme and will continue to do so through our Barts Life Sciences development. In the period between 2014 and 2021 we partnered with over 100 different companies. These included international pharmaceutical and biotechnology companies (eg GSK, AstraZeneca, Pfizer and Takeda); biotechnology SMEs and manufacturers of diagnostics, research tools, medical equipment, and consumer products. Our industry research expenditure increased from £5.0M per annum at the start of this REF cycle to around £8.0M per annum thereafter. Total commercial research spend for the REF2021 period was £69.4M.

We highlight some of our key strategic partnerships:

QM hosts Genomics England in prime medical school space and provides academic support to this Department of Health Company, seconding more than 20 scientists per year to deliver the 100,000 Genomes Project, leading to the creation of the NHS Genomic Medicine Service. **The benefits:** In 2018, Caulfield led negotiations with Illumina achieving a 27-42% reduction in cost and improved turnaround for 500,000 whole genome sequencing for the NHS and research over the life of the contract. This offers the UK most favoured customer status, the latest technology and the lowest price worldwide. As a result, since 2014, Illumina have invested £100M in the UK creating a new European HQ and 100 science jobs. In 2019 Caulfield persuaded Illumina to fund 5000 total RNA sequences to provide UK and international researchers with transcriptomes to aid the diagnosis of rare disease. In 2020, he successfully engaged Illumina to partner our Covid whole genome sequencing programme with £9.89M of discounted matched whole genomes to elucidate the genomic architecture of Covid-19 leading to the identification of new therapies.

QM partnered IQVIA (formerly Quintiles) to create the world's first Prime Site. This is a concentrated trials hub which has now been extended from its origins in 2008 in QM across UCL Partners (UCLP) reaching 16 NHS Trusts in North and East London. **The benefits:** This model has been extended to three UK locations and 24 other locations across the world. In 2020 QM's UCLP's Prime Site was the world's number one enroller to clinical trials as a result of global leadership in the Janssen Covid vaccine Trial. In 2016, a health economic analysis showed that the health economy of north and east London received £16M per year of inward investment.

QM in the top decile for patients in industry clinical trials: Since 2014 we have partnered with industry in 429 studies and in one year enrolled 16,000 patients in commercial trials. For example, in breast cancer prevention, Cuzick was supported by AstraZeneca and Sanofi Aventis (£9.3m).

QM-Industry Partnerships in Stratified Arthritis Care: Pitzalis and Bombardieri harnessed our MRC funded Stratified Healthcare programmes in rheumatoid arthritis and Sjogrens syndrome to partner Medimmune, Pfizer and Genetech raising over £12m of commercial funds for stratified medicine studies enabling targeted biologics in inflammatory arthritis.

UCL Partners Academic Health Sciences Centre (AHSC) and Network and London Life Sciences: QM and Barts Health made major contributions to the redesignation of the most successful AHSC (Thornton deputy director) and this partnership enabled us to create the Barts Heart Centre. We are part of London Life Sciences and play a key role in MedCity (Thornton Trustee).

QM Gastrointestinal Partnerships: In early 2015, a partnership with Takeda (more than £1.6M) focused on the discovery and translation of new therapeutic interventions in gastro-intestinal motility disorders was created (Sanger, Blackshaw, Stagg).

QM Cardiovascular Devices: Our £1.7M UK CRC Cardiovascular Clinical Trials Unit paved the way for cardiovascular device trials with new valve technology (Hechingen, Germany) for patients without alternatives. With Echopoint, we undertook first in human studies of a novel physiology catheter for intracoronary measurement of pressure and flow velocity (Optical Ultrasound device; £3M).

Others: QM is part of **Pfizer's Global Medical Excellence Cluster (GMEC) Rare Diseases Consortium** focused on drug discovery and development, through which Pfizer recently funded a collaboration (£0.5M, Lin). Pfizer, Ipsen, Novartis, Sandoz and Ono have partnered with us in pituitary disease (Korbonits, Storr). GSK funded 15 early translational research projects and they are our most frequently-cited industry collaborator on publications since 2014 (SciVal),

Technology transfer and commercialisation. Between August 2014 and July 2020, staff in UoA1 submitted 198 patent applications, concluded 62 commercial agreements, generated over £3M of commercial IP income, and created three spin-off companies.

4D. Marks of Esteem

Awards, Chairs and Investigatorships.

Ahluwalia received WISE Award for her research for on dietary nitrate.

Brohi was awarded the American Heart Association's Lifetime Achievement Award for Trauma Resuscitation Research (2016), the first non-US awardee ever.

Brown, Caulfield, Duffy were awarded NIHR Senior Investigator Awards.

Pearse has an NIHR Professorship.

Marelli-Berg was awarded a BHF Chair (2015, renewed 2020);

Brown received the International Society of Hypertension Tigerstedt Lifetime Achievement Award for his work in hypertension (2018).

Caulfield, Cuzick, and Munroe were ranked in the top 1% by citations for field and publication year in the Web of Science (2015-2019).

Deloukas was in the top 0.1% in genomic medicine (2019).

Caulfield was awarded a knighthood in 2019 for services to the 100,000 Genomes Project. He received the European Society of Hypertension Bjorn Folkow Award 2016 and the International Society of Hypertension Franz Volhard prize for outstanding hypertension research in 2018. Caulfield co-chairs the Global Health Implementation Forum of the Global Alliance for Genomic Health driving standardisation of genomics in healthcare across the world.

Cuzick received the Commander of the Order of the British Empire (CBE) in the 2017 New Year honours, for services to cancer prevention. He won the American Cancer Society medal (2015) and became a Fellow of the Royal Society (2016); won the CRUK Lifetime Achievement Award (2017), and the Robert Sutherland Award for Excellence in Translational Research in 2015,

Korbonits delivered the inaugural Lady Estelle Wolfson Lecture at the Royal College of Physicians (2018).

Lemoine has Chaired of the NIHR's Urgent Public Health Group for Covid 19 and is the Medical Director of the NIHR Clinical Research Network. He was elected as a Foreign Academician of the Chinese Academy of Engineers (2017).

Nourshargh FMedSci has held two Wellcome Investigator-ships.

Perretti delivered the Rocha e Silva lecture (Brazilian Society of Pharmacology and Toxicology, 2014) and was inducted into the Brazilian Academy of Sciences (2015).

Pitzalis delivered the British Society for Rheumatology's most prestigious scientific lecture, the Heberden Oration (2020).

Pitzalis and **Rot** were awarded Versus Arthritis UK Chairs (2017). Rot holds a Wellcome Investigator Award.

Thiemermann has received the Albert Nelson Marquis Lifetime Achievement Award for his work on shock (2018).

Thornton was awarded an honorary Fellowship of the Royal College of Physicians

The William Harvey Research Institute was recognised as a Pharmacological Centre of Excellence in 2015 by the British Pharmacological Society.

Fellows of the Royal Society.

Cuzick was elected to the Fellowship of the Royal Society in 2016.

Fellowships of the Academy of Medical Sciences.

Hodivala-Dilke and **Deloukas** were elected Fellows of The Academy of Medical Sciences, bringing our total to 23: Balkwill, Brown, Caulfield, Cuzick, Deloukas, Dezateux, Dokal, Flower, Gribben, Hart, Hodivala-Dilke, Leigh, Lemoine, Lister, MacDonald, Nourshargh, Tansey, Thiemermann, Tinker, Wald, Williams, Sir Nick Wright, Young.

Officers of Learned Societies.

Kelsell is President of the European Society for Dermatological Research.

Ahluwalia is Editor in Chief of the British Journal of Pharmacology.

O'Toole has chaired BADGEM (Dermatology and Genetic Medicine) national clinical network (2017).

Marino is the president of the British Neuro-Oncology Society.

Grant Panel Membership.

Harwood is the Chair of National Cancer Research Institute non-melanoma skin cancer group.

Lemoine chairs the NIHR i4i Challenge Awards Panel, the NIHR Real-World Evaluation Panel and the Diabetes UK grant panel (2011-2018). Staff are widely encouraged to take up board and panel positions, with **Korbonits**, **Lemoine**, **MacDonald**, **Van Heel**, **Balkwill** and **Hodivala-Dilke** serving on MRC panels; **Thornton** on the EME (MRC/NIHR), HDR-UK and MRC Multi-morbidity panels; **Chapple** and **Henson** served or serve on the BBSRC panel; **Kermorgant** and **Grose** on the Irish Cancer Society fellowship Panel; **Perretti** on the Versus Arthritis Fellowship Panel; **Balkwill**, **Hodivala-Dilke** and **Sestak** on CRUK panels; **Marshall**, **Grose** and **Jones** on Breast Cancer UK committees; **Fitzgibbon** on Blood Cancer UK; and **Thiemermann** acted as deputy chair and chair of NIHR Fellowships Committee.

In public/patient engagement, **Marelli-Berg** was named as one of the top 10 inspirational women in science by the BHF (October 2019). In societal impact, three of our academics have been identified as top influential Londoners in the 2019 Evening Standard progression list: **Lemoine** for work on biomarkers for pancreatic cancer, **Lindsay** for work on Crohn's Disease, and **Brohi** for work on trauma care. The latter's work on knife crime in London has had national media profile with BBC and BBC news (see Impact Case Study).

QM's healthcare and societal contribution to the Covid-19 pandemic has seen over 160 members of staff volunteering to work in the NHS or at the PHE laboratories in Milton Keynes. **Lemoine** chaired the DHSC's Urgent Public Health Group, **Caulfield** led training of more than 120 volunteers for the Covid Research Delivery at the Nightingale and across Barts NHS Trust Hospitals enrolling 10,000 people in trials, **Orkin** led Covid-19 clinical research. She has obtained funding for a vaccine trial in pregnant women. **Marelli-Berg**, **Caulfield** and **Deloukas** are on the joint BHF-NIHR panel, to coordinate national and international studies on Covid-19. Since July 2020, over 600 patients have been enrolled into NIHR priority trials. Investment (more than £50K) into Category-3 laboratories has enabled Covid-related research to take place including the Health Care Worker programme (**McKnight; Science Immunol 2020**). In December 2020, we began a £3.6M partnership with DHSC offering 3,000 Covid tests per day (**Nedjai**).