Institution: University College London (UCL)
Unit of Assessment: 1 (Clinical Medicine)
1. Unit context and structure, research and impact strategy

1.1 Overview: Context and Structure

The overarching aim of UCL's research in Clinical Medicine is to address major challenges to human health and thereby increase global well-being and prosperity. The 393 staff (344.18FTE) in this unit of assessment (UoA) engage in basic, clinical and translational research, lead large-scale multi-centre clinical trials, and lead or participate in interdisciplinary national and international collaborative networks with external partners in academia, the NHS, and industry, in four major areas: (1) Cancer, (2) Infection, Immunity & Inflammation; (3) Child Health; and (4) Experimental Medicine, encompassing organ-specific disciplines and cross-cutting themes. Staff are located in UCL's Faculty of Medical Sciences (FMS) and Faculty of Population and Health Sciences (FPHS), two of four faculties comprising UCL's School of Life and Medical Sciences (SLMS).

Strong links between UoA1 and our partner NHS Trusts are catalysed by two NIHR Biomedical Research Centres (BRC), an Academic Health Sciences Centre (AHSC), and by a larger federated health science network, UCL Partners (UCLP). The wider context for this submission is the co-location and close collaboration or integration of participating units with a major concentration of world-leading biomedical research, including: a major Cancer Research UK (CRUK) Centre; the Institute of Clinical Trials and Methodology (ICTM) incorporating the UCL MRC Clinical Trials Unit and CRUK and UCL Clinical Trials Centre; the Wellcome/EPSRC Centre for Interventional and Surgical Sciences (WEISS); the Institute of Orthopaedic and Musculoskeletal Science (IOMS); the Institute of Immunity and Transplantation (IIT); the Wolfson Drug Discovery Unit; the London Centre for Nanotechnology; the Francis Crick (Crick), Farr and Alan Turing institutes; the Institute of Sport Exercise and Health (ISEH); as well as a new £1BN Google headquarters development, where we are the key translational research partner in clinical medicine.

The vitality, future sustainability and strength in depth of the world-leading research in this submission are enabled by an environment which allows the full realisation of our researchers' potential. This is achieved by creating and sustaining a physical environment and research culture which foster and actively promote interdisciplinarity, collaboration, enterprise, impact for society and the economy, the development of early scientific careers, and equality, diversity and inclusion in everything we do, exemplified by:

- **A vibrant, positive Open Science research culture** embedding the principles of equality, diversity and inclusion, indicated by 2 gold, 5 silver, and 1 bronze Athena SWAN (AS) awards to UoA1 Divisions and Institutes.
- **Outstanding new facilities and infrastructure**, supported by ambitious new institutional and external investment for buildings and refurbishments greater than £217M, including the PEARS Building for the IIT, and the Zayed Centre for Research into Rare Disease in Children.
- **Growth in quality and impact of research**: Since 2014, >14,700 peer-reviewed publications were authored by UoA1 staff, receiving >409,700 citations, including 901 highly cited articles (in the top 1% for citations in their field), and an overall Category Normalized Citation Impact of 2.72 (i.e. almost 3x the world average). Papers published by UoA1 staff ranked No.1 overall in the NIHR/RAND analysis (2015) of highly cited publications in clinical science for UK, and all of our research themes ranked in the top 3, closely aligned with areas of clinical excellence in our partner NHS trusts. UCL ranked in the top 4 of world-leading universities in preclinical/clinical/health sciences (2015). Ten staff in this UoA (**Attard, Yellon, Swanton, Zumla, Herrero, McGranahan, Cross, Peggs, Quezada, Moon**) are Clarivate Highly Cited Researchers producing multiple highly-cited papers that rank in the top 1% by citations for field and year.
- **Research income** with >£850M research funding awarded in grants, and £777M research expenditure, equating to £322,521 spent per FTE per annum.

- **World-leading researchers**: In this submission, since 2014, staff have been awarded 72 prestigious fellowships and personal awards, there were 93 newly promoted Chairs and 49 new recruits at Senior Lecturer level or above.
- **Major external collaborations**: >60% of UoA1 research outputs involved international collaborations, and staff in this UoA lead or participate in many major national and international collaborative networks and consortia.
- **Investment in research training**: Vibrant doctoral training programmes producing the next generation of biomedical research leaders, awarding 144 Doctoral Degrees annually, including a Wellcome Clinical Research PhD programme and the largest NIHR Academic Clinical Fellowship and Clinical Lectureship programme in England and Wales.
- **Research with Impact**: UoA1 is submitting 13 Impact case studies demonstrating major improvements in the diagnosis, management and treatment of human diseases, and significant benefits for society and the economy, reflecting major UCL investment in clinical trials, translational research, enterprise and interdisciplinarity. Since 2014, UoA1 researchers have attracted external private sector investment in spin-out companies of > £900M that collectively employ more than 1000 people. Since March 2020, UoA1 staff have made leading contributions in the fight against COVID-19 (described in **4.2.2**).

UoA1 comprises seven units (Divisions & Institutes): the **Cancer Institute** (CI, Director **Enver**); the **Division of Infection and Immunity** (I&I; Director **Morris**); the **UCL Great Ormond Street Institute of Child Health** (GOS ICH; Director **Smyth**); the **Division of Medicine** (DoM; Director **Kleta**); the **Division of Surgery and Interventional Sciences (**DSIS**;** Director **Mudera);** the **Institute of Cardiovascular Science** (ICS; Director **Hingorani**); and The **UCL EGA Institute for Women's Health** (IfWH; Director **David**).

Research in these units is closely integrated and aligned with our partner NHS Trusts: University College London Hospitals NHS Foundation Trust (UCLH); the Royal Free London NHS Foundation Trust (RFL); Great Ormond Street Hospital for Children NHS Foundation Trust (GOSH); Royal National Orthopaedic Hospital NHS Trust (RNOH); and Whittington Hospital NHS Trust. These partnerships are underpinned by two Biomedical Research Centre (BRC) awards, representing the largest single investment in biomedical research by the NIHR: the UCL/UCLH BRC, (£111M, >10% greater than 2008-13), and the BRC in Child Health to GOS ICH (£37M, increased 5.7% compared with 2008-13).

1.2 Research and Impact Strategy

Our mission is to advance understanding of human disease from the molecule to the patient, and through the rapid translation of this knowledge, to achieve maximum benefit for patients, society and the economy. Our strategy for achieving this is based on the following core principles:

- Investment in people and infrastructure
- Promoting diversity
- Fostering interdisciplinarity and partnership
- Supporting translational research
- Creating a pro-enterprise culture

The key mechanisms for realising our strategic research and impact goals are:

Establishing Major Research Centres supported by new infrastructure and large-scale funding, led by world-leading researchers. In this REF period, UoA1 units have established the Zayed Centre for Research into Rare Disease in Children (illustrated in Figure 1), created the WEISS Centre for Interventional and Surgical Sciences, renewed the CRUK major centre in Cancer Research, completed construction of the PEARS building for the Institute of Immunity and Transplantation (Figure 1), and delivered the Africa Health Research Institute (AHRI) (see **3.2**).

Figure 1. Major Infrastructural Investment in UoA1. Left: The Zayed Centre for Research into Rare Disease in Children adjacent to GOS ICH (Photograph credit to Stanton Williams|Photography: Hufton + Crow). Right: the PEARS Building (opening 2021) for the IIT – the façade opposite Royal Free Hospital (top), and the main atrium (bottom).

Creating High-quality Translational Research Enabling Platforms: The potential of higher-throughput technologies linked to patient data and informatics for transforming drug/therapy discovery is being realized through public, private, and social enterprise partnerships to de-risk early-stage drug candidates. Essential to this is our creation of cross-cutting platforms, with embedded research-led disruptive innovation to stay ahead of the curve and drive clinical translation. These include: extensive genomics, proteomics and metabolomics facilities; a Therapeutic Innovation Network with world-leading expertise in translational cell and gene therapies, small molecules and biologics; a Healthcare Engineering & Imaging theme advancing clinical applications of engineering, nanotechnology, advanced imaging and computation, and repurposing existing therapies; all in strategic partnership with industry (see **1.3**).

Interdisciplinarity: This REF period has seen a sustained drive to increase our interdisciplinarity by planned co-location of diverse disciplines as an integral component of major infrastructural investment, e.g. engineering, imaging, bioinformatics, computational medicine and biomedical research in facilities with a common purpose, including the WEISS Centre, the Zayed Centre and the PEARS building. Organisational change has also fostered interdisciplinarity: the restructuring of GOS ICH focused on priority areas critically dependent on interdisciplinarity (see **1.4.3**); in Surgery and Interventional Sciences, 3 of the 4 prioritised themes are inherently cross-disciplinary, Energy and Tissue (UoA1) and two are in UoA12, (Materials and Tissue, and Nanotechnology). Interdisciplinarity has been further facilitated through engagement with Academic Health Partnerships and with UCL Research Domains by seeding pilot projects, fostering and enhancing awareness of opportunities for interdisciplinary working.

Conditions of UCL's capital investment funding for equipment are inter-faculty involvement and multi-user capacity to promote interdisciplinarity; >£2M has been disbursed to such initiatives

in UoA1, including multi-user two-photon imaging, Biobank support, and pre-clinical PET-MRI. The BRCs have invested in facilities specifically for interdisciplinary working, including clinical PET-MRI (£1.1M), a research 3T MRI system (£1.1M), and a radiopharmaceutical GMP laboratory (£2.52M).

In a survey of UoA1 staff, 68% of respondents conducted interdisciplinary research, and 33% (283 of 860) of our submitted outputs comprised interdisciplinary research. In REF2021, 53 staff in UoA1 Divisions and Institutes were returned in other UoAs (Biosciences, Engineering, Chemistry, Population and Health Sciences). UoA1 hosts or its staff participate in 15 interdisciplinary PhD programmes (see **2.B.3**), and students in UoA1 units undertaking PhDs outside traditional biomedical disciplines increased from 19.5% of entrants in 2013 to 28.7% of 2019 entrants.

The investment in interdisciplinarity in UoA1 underpins the excellence and impact of our research exemplified in several of our impact case studies: world-leading immunologists collaborating with innovators in manufacture of advanced therapies ("Next-generation programmed T cell therapies for cancer treatment…" and "Development of novel therapies for inborn errors of immunity in children and adults…"), surgeons and clinicians working with medical physicists ("Transforming the diagnostic pathway for men at risk of prostate cancer by the introduction of magnetic resonance imaging" and "Transforming the diagnosis and treatment of ATTR amyloidosis…"). Interdisciplinarity also greatly enhances our agility, an outstanding example of which is the extraordinary partnership between intensive care clinician scientists and engineers resulting in development of a breathing aid for COVID-19 patients from concept to manufacture of a clinical device within a few days, forming another of our impact case studies ("UCL-Ventura CPAP breathing aids for COVID-19 patients…").

Career Development and investment in people: To build capacity, resilience and sustainability in our environment, we established the BRC Experimental Medicine Academy to create the next generation of translational researchers equipped with the knowledge and skill set to realise impact for patients. Our submission hosts a Wellcome Clinical PhD programme and the largest NIHR Academic Clinical Fellowship and Clinical Lectureship programme in England and Wales, supported by investment in an Academic Careers Office (ACO) delivering nationally recognised innovation in training. Joint studentships supported by our interdisciplinary PhD programmes, in areas outside the biomedical sciences (e.g. engineering, physics, mathematics, computer and data sciences), and partnered with the local Crick, Farr and Turing institutes, enhance the potential to transform medicine; specific funding streams also target investment in early career researchers, such as the UCL Excellence Fellowships and the Wellcome Institutional Strategic Support Fund (WISSF) (see **2.A** and **2.B**).

Advancing Equality, Diversity and Inclusion: The 7 units in this submission hold 2 Gold, 5 Silver and 1 Bronze Athena SWAN awards. We encourage career development and leadership opportunities for women in science: 3 of the 7 UoA1 units are led by women, whereas only one was in REF2014; 4 out of 10 of our BRC research theme Directors are women; 5 years ago, none were led by women (see **2.C** for our EDI activity).

Collaboration and Extending Our Global reach: UCL has International Strategic Academic Partnerships in biomedicine with Yale, Utrecht Medical Centre, Peking University, a Drug Discovery/ Pharmaceutical sciences alliance with University of North Carolina, the AHRI with the Malawian and South African Health Services and Governments, and is founding partner in the International Precision Child Health Partners (IPCHiP) with Melbourne, Boston and Toronto. UoA1 staff lead many international collaborations, including the CRUK-funded International Alliance for Cancer Early Detection, major international multi-centre Clinical Trials (e.g. PROMIS, Re-IMAGINE, STAMPEDE) and EU collaborative programmes through our success in the EU Horizon 2020 grants: UCL is the top University in Europe for Horizon 2020 projects, with 115 health projects valued at £55M, 55 of which are led or partnered by UoA1 researchers (see **4.1**).

Empowering Translational Research, Enterprise, and Innovation: Our research's impact on society and the economy has been maximized through investment in facilitation of translational research and enterprise, central to which are UCL's Translational Research Office (TRO), the BRCs and AHSC, and UCL Business (UCLB). This structure has energized translational research

and fostered a vibrant enterprise culture within this submission that empowers collaboration between academics and private capital.

Engagement of UoA1 staff with the TRO has, since 2014, resulted in 16 MRC Developmental Pathway Funding Scheme (DPFS) awards worth £23.3M, and 41 smaller proof-of-concept translational awards, including MRC Confidence-in-Concept, BRC and Therapeutic Acceleration Support grants, worth >£4.5M to UoA1 staff. The TRO also facilitates large-scale clinical studies in collaboration with industrial or biotech partners such as the £56M SUMMIT trial with Grail Inc (led by **Janes**). Overall, from 2013 to 2019, 48% (41 of 85) of large translational projects managed by the TRO were led by UoA1 staff, supported by >£63.3M translational funding (of £129.6M total). The success of our translational pipeline is instanced by development of a Novel Liver Dialysis Device to extend the life of patients with acute-on-chronic liver failure (led by **Jalan**), which was highlighted as an exemplar of successful translational research in the 2019 evaluation report of MRC-funded translational research; the dialysis device has been commercialised through UCLB, with the formation of the spin-out company Yaqrit and a €6.4M European Union Horizon 2020 award to run a Phase IIb clinical trial from 2017.

The BRC has galvanized major cultural change in the UCLH/UCL partnership towards celebrating and rewarding enterprise and innovation. The AHSC has created a Translational Research and Enterprise Accelerator with expertise in each step of the translational process, marshalling milestone-driven early phase projects via coordinated project-specific teams, with early phase regulatory and industry partnership, trial design, technology transfer and investment expertise – demystifying the process for discovery scientists and increasing their engagement in clinical translation.

Enterprise in UoA1 has been catalyzed by two UCLB-led UCL technology funds, the Apollo and UCL Technology Fund (£100M) which pump prime and de-risk new start-ups. Partnership with UCLB generated 6 spin-out companies based on UCL-led research in UoA1 which have raised >£900M in private investment, including Orchard Therapeutics (gene therapy for childhood diseases), Autolus (cancer T-cell immunotherapeutics), Achilles Therapeutics (therapies targeted at tumour neo-antigens), Freeline Therapeutics (therapies for haemophilias), and Quell Therapeutics (engineered T-cells), several underpinning our impact case studies (see **4.2.2**).

Our graduate start-up companies supported through UCL BaseKX have attracted more external investment than ever before (£60M in 2018/19). Several of these are supporting disadvantaged people: for example, 'In2ScienceUK' gives low-income young people a chance at science careers and Kalgera helps safeguard the finances of vulnerable adults.

UoA1 researchers have also established major strategic partnerships with industry, including leadership of the £16M MRC/GSK EMINENT programme and a recent GSK commitment to establish a new Respiratory Innovation Hub at UCLH/UCL (£2M p.a.), a new BMS cancer immunotherapy hub, and partnerships with UK Cell and Gene Therapy Catapult, Stevenage Bioscience Catalyst and with General Electric, Philips and Siemens in advanced imaging.

NHS Engagement: Key to realising the health and societal impacts of our research is engagement with our NHS partners to rapidly translate research into patient benefit through major clinical trials, leveraging NIHR BRC funding to deliver value for money and amplify the scale of this activity. This engagement is central to several Impact Case Studies in UoA1, including "Development and Implementation of the first treatments for Duchenne muscular dystrophy and Spinal Muscular Atrophy", "Advancing availability of curative surgery to children with refractory focal epilepsy", "Transforming breast cancer patient care with a novel single-dose intraoperative radiotherapy (TARGIT-IORT)…", "Transforming national and international clinical practice in the treatment of resistant hypertension", and "Improving the identification and treatment of patients with familial hypercholesterolaemia (FH) through the establishment of a DNA diagnostic service…". The two BRCs in this submission use proof-of-concept funding to de-risk early innovation and increase the confidence of commercial partners and major funders. The success of this strategy was evidenced in 2016 by: a dramatic increase in patients in phase-I/II trials (+300%) since 2012; a doubling in our managed translational research portfolio, attracting £72M external investment in 2016 versus £18M in 2012, with a portfolio containing 10 times more projects in or on the cusp of clinical translation than in 2012; securing 25% of MRC DPFS awards nationally for translation of UCL research, often in partnership with industry; UCL top European University for health research awards in first 2 years of European Horizon 2020 grants. The UCL/UCLH BRC is set to leverage over £600M

during the current BRC term (2017-2022), equivalent to £8 research income for every £1 of BRC investment.

Conduct of large-scale, complex clinical trials has been accelerated through co-working of our investigators with the UCL Institute for Clinical Trials and Methodology (ICTM). The ICTM is a centre of excellence for clinical trials, meta-analysis and epidemiological studies, with a focus on methodological innovation to add clinical and research value to trials such as adaptive trial designs, and multi-arm-multi-stage platform trials led by UoA1 staff (e.g. **Attard, Emberton**) (see **4.2.2**).

Engagement with UCL's infrastructure for Maximising Societal and Economic Impact: Our research's societal and economic impacts are amplified through strategies for enterprise, public engagement, patient involvement in research, and extending the global reach of our research especially in low and middle income countries, all enabled via engagement of our researchers with the REF Impact Team, UCL's Social Policy Unit, UCL Innovation and UCL Enterprise, UCL Grand Challenges, UCL Consultants (UCLC), UCLB, the Academic Health Partnerships (AHPs), AHSCs, UCL Global Engagement Fund, UCL Public Engagement, and UCL Culture. Our impact case studies have been developed in close partnership with the REF Impact Team, and facilitated by AHPs, and, as mentioned above, in partnership with UCLB, UCLC and UCL Innovation and Enterprise. Innovation and impact were additionally accelerated through grants to UoA1 researchers totalling £1.39M for 51 projects from Higher Education Innovation Fund and BBSRC and EPSRC Impact Acceleration Awards.

Public and Community Engagement: To realise research impact and ensure its relevance for the public and our communities, UoA1 researchers work closely with the three Public Engagement (PE) Managers assigned to SLMS in the UCL Engagement & UCLH/UCL Joint Research Office (JRO) Public and Patient Involvement (PPI) Team. The UCLH/UCL BRC, and the GOSH/GOS ICH BRC, employ a Head of PPI & Communications and a PPI Manager who work closely with their counterparts in the UCLH/UCL JRO. The SLMS PE Manager supports PPI through funding rounds, networking opportunities, expert advice, training and reward and recognition. We have created a SLMS Community of Engagers, a network to share skills, experiences, resources and knowledge in PPI and PE. The network hosts termly events for peer support and sharing case studies, and a monthly newsletter to ~100 people in UCL who lead on PPI/PE activity is shared with their networks. During the REF2021 period, the JRO PPI team has trained 156 people (projected ~350 by end 2020), funded 15 projects through grant schemes of £10,500 (projected ~£22,500 by end 2020), and supported 42 individual researchers/projects in their PPI/PE activities (projected ~100 by end 2020). Since August 2013, co-working between UoA1 staff and the UCLH/UCL JRO PPI Team has resulted in nominations for 26 PE awards, receipt of 3 PE awards, support and advice to 95 staff and students, and funding for 12 projects through grant schemes offered by UCL Engagement and UCLH/UCL's JRO PPI Team. This includes: Beacon Bursaries awards for "a focus for family participation: CAR T cell games that start a conversation" and "Engaging young people with chronic rheumatic conditions in research development and communicating their ideas through digital media"; a Focus on the Positive award for "Knowledge is power: increasing understanding of science in the over-65s"; as well as Train and Engage, Step Out, Innovation Seed Funding, and Fellowship awards. UoA1 units won three UCL Provost's Awards for PE in 2015-17 (an Early Career award, a Professional Services award and a Student award). Training was also provided to 6 UoA1 staff by the UCL Centre for Co-production, and 31 UoA1 staff attended bespoke training workshops delivered by the Engagement team in 2016-19.

Open Science, Research reproducibility and Integrity: UCL's commitment to research transparency and integrity are underpinned by its policies described in REF5a. All research In UoA1 is conducted in accordance with UCL's Statement on Research Integrity (encompassing the principles of the UK Concordat to Support Research Integrity), UCL's Code of Conduct for Research, and its Statement on Transparency in Research, including the responsible use of metrics for Open Research, aligned with UCL's commitment to the San Francisco Declaration on Research Assessment (DORA). UCL is a founding member of the UK Reproducibility Network. This framework informed preparation of all aspects of this submission.

An open research environment in UoA1 has been advanced by creating resources and procedures for implementation of open access compliance in all participating units, including allocation of administrative staff time and staff training in open access to make all publications available in UCL Discovery (described in REF5a). Overall compliance with open access policy of all publications in UoA1 units is >85%, and >97.5% of the 860 publications submitted in UoA1 are compliant. Our commitment to open research is exemplified by the launch in 2018 of a new platform, UCL Child Health Open Research, through collaboration between GOS ICH with F1000, enabling rapid, author-led publication and open peer review of any research focusing on child health. Data sharing initiatives have extended open access in other areas, e.g. GOS ICH's collaboration with GOSH's Digital Research, Informatics and Virtual Environment (DRIVE), using EPIC software, to make patient data available, and DECOVID, a repository (with UCLH, University Hospitals Birmingham, and University of Birmingham) of electronic health records for COVID-19 hospitalised patients.

Our staff have substantially contributed to research reproducibility, integrity and transparency: 125 staff in UoA1 (33%) published papers that reproduce key findings in their field; 87 (23%) published articles or promoted research reproducibility by defining guidelines or setting standards for research procedures or analyses; 141 staff (37%) made research data, software, or code available using open source sharing platforms; and 67 staff (17.5%) contributed to best reporting practices e.g. pre-registration, full design and analysis reporting (such as STAR methods).

1.3 Development of our Research Environment since REF2014

Since REF2014, major growth and development in UoA1 has occurred within all research themes: Cancer (Major CRUK Centre Award, Proton Beam Therapy Centre opening 2021); Infection, Immunity & Inflammation (PEARS building, establishment of the Africa Health Research Institute); Child Health (new 5 year academic strategy, and opening of the Zayed Centre); and Experimental Medicine (newly refurbished Charles Bell House, facilities for rehabilitation science at the RNOH, laboratories for Respiratory Medicine, and a phenotyping suite for Cardiovascular Science). Specific major investments are described in section **3**.

Reorganisation has been driven by a focus on major areas of research strength, and enhancing opportunities for interdisciplinary synergy between researchers: in GOS ICH, a major review resulted in a new strategy and research organisation aligned with future strategic research priorities; in Experimental Medicine, clinical and pre-clinical imaging groups were combined in a single Research Department, and the Institute for Cardiovascular Science was reconfigured in 2017 into four research departments (see **1.4**).

Recognising that investment in early career staff is essential for the sustainability and vitality of our research, since REF2014 there has been a more strategic emphasis on developing a positive research environment, particularly for early career researchers, and a culture that fully and proactively promotes the principles of equality, diversity and inclusion (EDI), exemplified by our success in Athena SWAN awards, and by initiatives to embed awareness of and training in the full range of issues relevant to EDI (described in **2.C**).

Increased emphasis in REF2021 on maximising the impact of our research on society and the economy is exemplified by the award in 2016 of the NIHR BRCs to UCL/UCLH and GOSH/GOS ICH. Renewal and uplift of our BRC funding reflects our world-leading excellence in Cancer, in Infection, Immunity and Inflammation, and in Child Health, and also funded 2 new BRC themes within UoA1 in NIHR "highlighted areas", where the UCLH/UCL partnership is internationally leading, recognizing our developing strengths in these disciplines: **Cardiovascular Diseases** in which we are developing novel imaging and biomarkers for improved detection of cardiovascular disease and treatment stratification, a genetics-based drug target validation database, and new prosthetic heart valve and vascular grafts; and **Obesity**, linking one of the UK's largest adolescent and adult specialist obesity centres, to UCL physiological and behavioural sciences to understand and better stratify novel treatments for obesity.

Integral to our research strategy and the renewal of BRCs has been creation of 6 cross-cutting themes, comprising coordinated research enabling platforms, and providing multiple points of synergistic interaction with our major research themes:

Therapeutic Innovation Network (TIN): This research platform, coordinating world class strengths in Gene, Cell and Regenerative therapies, with the Drug Discovery Institute, UCL School of Pharmacy (in UoA3) and the Stevenage Bioscience Catalyst, enables development of innovative therapeutics and drug/therapy repurposing across the research themes.
Healthcare Engineering & Imaging: This aligns the UCL Institute of Health Care Engineering, UCLH Clinical Imaging, UCL Centre for Medical Imaging Computation and Centre for Advanced Biomedical (preclinical) Imaging – all internationally leading - within a single coordinated theme.
Healthcare Informatics, Genomics/omics, Data Science (HiGODS): This platform brings together UCL strengths in health informatics and the UCL Farr Institute, UCL Computer Science, Institute for Digital Health and genomics and -omics resources, linked to our extensive patient and population cohorts. Most researchers associated with this platform are in UoA2.
Translational Research & Enterprise Accelerator (TREACC): A platform which coordinates our expertise in experimental medicine project management, governance, regulatory support, technology transfer and commercialization, to steer and accelerate therapeutic innovation and translation.
Education and training: The BRC Experimental Medicine Academy, realizing a strategic goal from REF2014, aims to build capacity and resilience in experimental medicine, fostering collaborations beyond traditional medicine and life sciences boundaries and with national institutes and industry, and developing future leaders.
Patient & Public Involvement and Engagement: A dedicated unit to ensure our research is relevant, and public/patient facing.

1.4 Research Objectives in the current assessment period

Below in **1.4.1** to **1.4.4** are described the research strategies for each of the major research themes in this submission.

1.4.1 Cancer

The mission of the UCL Cancer Institute (CI) together with cancer research groups in the Divisions of Medicine and Surgery, and in the Institute for Women's Health, is to improve patient outcome in cancer, and to educate and generate the next generation of world leaders in cancer research. To fulfil these ambitious goals, UCL cancer research spans discovery biology and proof of concept work to preclinical development, integrated with early and late phase clinical trial capacity, harnessing the multidisciplinary opportunities provided within the multi-faculty structure of UCL, and the close integration between researchers and front-line clinicians. More than half the teams in UCL's Cancer Institute are clinician-led.

Cancer is a prioritised research theme within UCL's SLMS, and operates within a network of partner organisations including UCLP, the UCL/UCLH and GOSH/GOS ICH BRCs, and our partner NHS Foundation Trusts. The **Cancer** theme in the UCL/UCLH BRC focuses on precision medicine, closely aligned with strategic focuses in UCL's cancer research programme, specifically: proton beam therapy and precision guided surgery; understanding tumour heterogeneity to develop better targeted therapies; and developing and delivering a pipeline of novel cellular cancer immunotherapies.

Major Research Groupings

Developments in the current REF period have made UCL a powerhouse of cancer research, recognised nationally and internationally for the excellence, impact and innovation of its research. Areas of strength are **cancer cell biology** (inflammation, mechanism of cell cycle control, stem cell biology, metastasis, genome regulation and stability), **translational oncology (**world leading expertise in development of advanced therapies involving engineered T cells and antibody based medicines, radiation oncology), **molecular pathology** (cancer genomics and evolution, and advanced cancer imaging, particularly in lung, sarcoma, thoracic, gastrointestinal and haematological cancers), and **cancer clinical trials**, working closely with ICTM to innovate and increase the international impact of our cancer trial activity, and pivotal in enabling UCL's strategy of bench to bedside translation of science discoveries.

Key recruits and appointments

Major new recruitments in Cancer since REF2014 include **Vanhaesebroeck** to develop our expertise in cancer signalling and translational drug development, **Parrinello** (Neuro-Oncology) aligned with our efforts to develop new understanding of brain cancer, **Attard** (Medical Oncology), **Ng** (Imaging lead NCITA). **Fisher** was appointed to build capacity in cancer computational biology. **Sharma** (now Honorary) was appointed to build critical mass in radiation oncology, and **Maria Hawkins** (Engineering, returned in UoA12) was recruited to a Chair in Radiation Oncology in 2019, with close links with the CI (visitor status and lab space), specifically to support expansion of our research programme for radio-oncology ahead of the Proton Beam Therapy Centre opening in 2021. Several earlier career staff have established their research independence, including appointments for **McGranahan, Vladimirou** (Senior Research Associates), **Tape** and **Barber** (Principal Research Fellows), **Jansen** and **Pillay** (Clinical Professorial Research Fellows), **Herrero** (Professorial Research Associate), **Jamal-Hanjani** and **Hiley** (Senior clinical lecturer / clinical consultants).

1.4.2 Infection, Immunity, Inflammation

Research in this theme is undertaken in UCL's Division of Infection and Immunity (I&I), comprising the IIT, the Research Department of Infection, and the AHRI, and in the Division of Medicine. Its mission is to understand the molecular basis of immunity and infection, to identify the causes of infectious and immunological diseases at population level, and to rapidly translate this knowledge into benefit for patients and populations in the UK and globally.

The UCL/UCLH BRC **Inflammation, Immunity and Immunotherapeutics** theme (BRC Theme Director, **Morris**) is also a prioritised research theme within UCL, focusing on improving outcomes for patients with serious progressive diseases associated with dysregulated immunity, inflammation and fibrosis; identifying therapeutic targets; developing novel serum/tissue and imaging biomarkers; and delivering novel anti-fibrotics and immunomodulatory agents. BRC funding has provided infrastructure and personnel support for the development of the Pathogen Genomics Unit (Directed by **Breuer**), recently relocated to the Zayed Centre (see **1.4.3** below). In addition, the BRC supports Bioaid, an experimental medicine initiative to archive host and pathogen material from patients presenting with fever, which has led to a major collaboration with the Wellcome Sanger Institute. The BRC has invested in infrastructure and personnel to support the development of gene therapy approaches to treating immunodeficiencies and haematological cancers. The future vitality, growth and sustainability of this research theme has been secured with completion of the £60M PEARS building to house an expanded IIT (started 2018, led by **Stauss**) opening in Q2 2021, realising a major strategic goal of REF2014 (Figure 1).

Major Research Groupings

Major research groups and areas of excellence in this theme are: **Immunobiology**, including basic research on T cell and B cell function, novel B & T cell subsets, and mechanism of T cell senescence in ageing humans; **Translational immunology and immunotherapeutics**, Including preclinical T cell engineering research for landmark gene therapy trials, and a major area of synergy between immunology, **cancer** and **child health; Immunodeficiency**, embracing genetic screening of families using single nucleotide polymorphisms to reveal susceptibility genes for fungal infection, hyper IgE syndrome, early onset inflammatory bowel disease and certain autoimmune conditions; **Epidemiology of infection**, including next generation pathogen sequencing as a powerful tool to reveal the mechanisms of drug resistance, and tracking the origin and epidemiology of virus outbreaks; **Host-pathogen interactions** focusing on mechanistic cell biology and genetic approaches to identify new molecular targets to prevent HIV entry and infection; **Rheumatology**, hosting the largest Rheumatology groups in the UK, with particular expertise in SLE, Rheumatoid Arthritis, Anti-Phospholipid Antibody Syndrome and Scleroderma. Rheumatology at UCL has established a worldwide reputation for pioneering B cell depletion to treat patients with rheumatoid arthritis (Rituximab), systemic lupus erythematosis (including childhood onset SLE), myositis and vasculitis; **The Centre for Amyloidosis & Acute Phase Proteins** (incorporating the UCL Wolfson Drug Discovery Unit and NHS National Amyloidosis Centre) is world leading in translational amyloidosis research; **Innate immunity** research, spanning the innate responses to infection and tissue injury.

Key recruits and appointments
Strategically important recruits to this theme since August 2013 include **Reeves** (Associate Professor), to strengthen our critical mass in Virology, **Seddon** (Professor of Immune Cell Homeostasis) appointed to develop our expertise in immune cell homeostasis, and **Heyderman** (Professor of Infectious Diseases and International Health) and **N'dungu** (Professor of Infectious Diseases) who have jointly developed our strengths in analysis and treatment of global infectious diseases. **Jolly** (Associate Professor) and **McCoy** (MRC Research Fellow) have enhanced our excellence in understanding fundamental mechanisms underlying HIV function, while **Leslie** (Wellcome Senior Research Fellow) increases our capacity to investigate the pathogenesis of tuberculosis.

1.4.3 Child Health

UCL's GOS ICH (so renamed in 2016 to reflect its close partnership with GOSH) is the largest children's research institute in Europe, and undertakes fundamental, translational and clinical research across the whole spectrum of childhood health and disease. On publication metrics, it is consistently in the top three Child Health research institutes in the world. The mission of GOS ICH is to improve the health and wellbeing of children and the adults they will become, through world-class research, education and public engagement. In 2014, GOS ICH launched a five-year academic strategy, a key aim of REF2014, underpinned by the principles of:

- Interdisciplinarity
- Developing Academic Leaders
- Accelerating Translation
- National and international partnership and leadership

This strategy was refreshed in 2019 to strengthen the partnership with GOSH, and include new strategic initiatives in stem cell biology, data science (UoA2) and global health (UoA2).

GOS ICH Departments align closely with GOSH BRC vertical themes of Gene, Stem and Cellular Therapies (led by **Thrasher**), Genomics and Systems Medicine (led by **Chitty**), Novel Therapies and their Translation into Childhood Diseases (led by **Muntoni**) and Advanced Treatments for Structural Malformation and Tissue Damage (led by **Sowden**). Ahead of the anticipated GOSH BRC renewal application in 2021, the BRC leadership is working with GOS ICH to ensure that its refreshed strategy enhances BRC renewal. With **Goldblatt**, GOSH Director of Research and Innovation, **Smyth** and colleagues have developed a strategy for GOSH to become a "Research Hospital", in which "research" is a key strategic pillar of the hospital, all children treated by GOSH have the opportunity to become research participants, and delivery of high-quality research is a fundamental priority for those responsible for delivery of clinical care. Opening of the Zayed Centre for Research into Rare Disease in Children in 2019 is a striking affirmation of this research-driven vision for GOS ICH and GOSH, and greatly enhances the capacity of research at GOS ICH to stay at the forefront internationally, and progress its innovative treatments for childhood diseases.

Major Research Groupings
The new strategy created five research and teaching departments, four in UoA1: **Developmental Biology and Cancer** focussed on Developmental Biology, Stem Cells and Cancer, Birth Defects Research, Childhood Cancer, and Stem Cells and Regenerative Medicine**;** **Developmental Neurosciences,** which investigates cell and molecular mechanisms underlying processes in neurological diseases, rapidly translates research to diagnose and adopt individualised therapies for childhood neurological disease, and progresses biomarker development for monitoring of response to interventions; **Infection, Immunity and Inflammation** with research programmes in the molecular basis of immunological and inflammatory disease, microbial genetics and host response to challenge, development of disease prevention strategies through diagnosis in early childhood and vaccination strategies, world-leading translational research in immunological and inflammatory diseases using novel biologic agents, and cell and gene therapies**;** and **Genetics and Genomic Medicine** with emphases on the Molecular Basis of

Rare Diseases, ciliopathies, Inherited Disorders of Metabolism, and Genome Biology and Personalised Medicine; co-location in the Zayed Centre of UCL Pathogen Genomics (led by **Breuer**) and UCL Genomics (led by **Castellano**) strategically enhanced our research capability in genomic sequencing, and facilitated UCL's leadership in the COVID-19 pandemic through its role in mapping spread of SARS-CoV-2 variants (see **4.2.2**). **Population, Policy and Practice** is returned in UoA2.

Key recruits and appointments

Since 2014, GOS ICH has appointed 30 new academic staff in UoA1 (11 lecturers, 11 Associate Professors and 8 Professors), including **Voit**, recruited from Sorbonne, Paris as GOSH/GOS ICH BRC Director, **Hargrave,** Clinical Professor of Paediatric Neuro-oncology, **Livesey**, Wellcome Senior Investigator and Professor of Stem Cell Biology, and **Elvassore**, Professorial Research Associate in Stem Cell and Regenerative Medicine, the latter two appointments aligned with our new strategic Initiative in stem cell biology.

1.4.3 Experimental Medicine

Experimental Medicine incorporates research from the Divisions of Medicine and Surgery and Interventional Sciences, the Institute of Cardiovascular Science and the Institute for Women's Health, which focuses on specific organ systems, together with major cross-disciplinary research themes including biomedical imaging, novel surgical approaches to the treatment of human disease, and large-scale clinical trials.

Research described in this section is closely aligned and integrated with the NIHR-UCL/UCLH BRC. **Williams** led the successful UCL/UCLH BRC re-bid of £111.5M and is its Director. The **Cardiovascular Diseases Theme** component of the bid doubled from £5M to £10M compared with the previous BRC and **Hingorani** (UoA2) leads this theme with **Elliott, Rakhit, Hughes, Muthurangu, Williams** and **Manisty** theme board members. **Batterham** is the Director of the new **Obesity Theme** in the current UCL/UCLH BRC, and her research has strong research links with the **Cardiovascular Diseases Theme**. The Research Departments of Liver & Digestive Health, Respiratory Medicine, and Renal Medicine are all major stakeholders and beneficiaries of the **Inflammation, Immunity and Immunotherapeutics BRC Theme**, through support for clinical academics and competitive BRC research funding awarded to their staff.

The **Healthcare Engineering and Imaging Theme** is a "horizontal" theme within the UCL/UCLH BRC, interacting extensively with UoA1 researchers in Cancer, Infection, Immunity, and Inflammation, Respiratory, Liver and Digestive Health, and Surgery and Interventional Sciences; to facilitate these interactions, **Punwani** is BRC Director of Clinical Imaging, co-funded by the **Healthcare Engineering and Imaging** and **Cancer** BRC themes.

Major research groupings

The Institute for Liver and Digestive Health performs basic, clinical and translational research on liver disease, particularly viral hepatitis, liver fibrosis, portal hypertension, liver failure and liver transplantation.

Renal Medicine is one of the largest centres for kidney disease research in the UK, closely integrated with the clinical department providing renal services to North and Central London; it is one of the most active clinical trial units with high rates of trial recruitment.

Respiratory Medicine spans clinical and laboratory research with a focus on lung fibrosis/ injury, Infection, Chronic obstructive pulmonary disorder (COPD) and its genetic causes (alpha-1 antitrypsin deficiency), and lung cancer (within the **Cancer** theme).

Intensive Care Medicine located in the Bloomsbury Institute for Intensive Care Medicine (Directed by **Singer**) undertakes basic and translational research, informatics studies and clinical trials in critical illness, internationally leading expertise that underpinned **Singer**'s co-development of new breathing aids for COVID-19 patients.

Obesity Research investigates the pathophysiology of obesity and type 2 diabetes in order to identify new prevention and therapeutic strategies, particularly gut hormones as tractable therapeutic strategies for obesity and type 2 diabetes, and improving the health outcomes of bariatric surgery.

Cardiovascular Science is conducted by staff in the Institute of Cardiovascular Science, and the Divisions of Medicine and Surgery, with major focuses on: basic research into cardiovascular development, function and pathologies; population science and experimental medicine, studying factors leading to human cardiometabolic disease and ageing (some staff returned in UoA2), and housing major cohorts including the Southall and Brent revisited study and the MRC 1946 birth cohort as part of the MRC Unit of Lifelong Health and Ageing, clinical research into heart muscle disease and arrhythmias, novel approaches to cardiac imaging based on MRI, and machine learning; and Children's Cardiovascular Disease, forming one of the largest paediatric cardiovascular groups in the world, collaborating and co-located with staff in GOS ICH.
Biomedical Imaging. The Department of Imaging comprises The Centre for Advanced Biomedical Imaging (Director, **Lythgoe**); the Institute of Nuclear Medicine (Director, **Groves**); and the Centre for Medical Imaging (Director, **Halligan**). The Department performs medical and pre-clinical imaging research across multiple scales and technologies, and its researchers collaborate closely with staff across UoA1, and in Physics, Engineering and Computing in the WEISS centre and elsewhere.
Surgery and Interventional Sciences based on the Bloomsbury, Royal Free and Stanmore/RNOH campuses, embraces a comprehensive approach to surgery and perioperative medicine with a strong emphasis on technological innovation and multidisciplinary working, with strengths in urology, perioperative medicine, tissue engineering, nanomedicine and surgical theranostics, biomaterials for surgical reconstruction and regeneration, and orthopaedic and musculoskeletal science, centred on new approaches and platforms for post-surgical rehabilitation and implant science. It also hosts the Institute of Sport Exercise and Health, a partnership with the British Olympic Association, the English Institute of Sport, the WEISS Centre and IOMS.
Women's Health: Research in this area is conducted by researchers in the UCL EGA Institute for Women's Health (**IfWH**). Major research focuses are: the impact of hypoxia and inflammation on brain development in utero and in the early neonatal period, leading to a pipeline of neuroprotective agents for early phase trials; and development of gene therapy for a variety of pregnancy conditions, including the potential for in utero cure of congenital disorders.

Key recruits and appointments

Respiratory Medicine has been strengthened by appointment of 4 new professorial staff through promotion (**Porter, Hurst, Lipman**) and external recruitment of **Sattelle** (from Oxford), and 2 new intermediate-level clinician scientists (**Jacob & Navani** from Cambridge). **Beale** is a joint Crick/UCL appointment in renal science. In **Cardiovascular Science, McGregor** was appointed Professorial Research Associate, **Manisty** Clinical Senior Lecturer in Cardiac MRI and Heart Failure, **Patel** and **Treibel** won BHF Intermediate Clinical Research Fellowships, **Captur** was promoted to Senior Clinical Lecturer. In **IfWH, Guillot,** and **Siassakos** were recruited to strengthen Maternal and Fetal medicine, **Teschendorff** was jointly appointed to IfWH and CI in Women's Cancer, **Hall** and **Gurtin** joined research groups in Reproductive Health; and **Clark** and **Madsen** have strengthened Neonatology.

1.5 Research objectives for next 5 years

1.5.1 Achievement of REF2014 goals

Much of what was planned in REF2014 has been delivered and is presented in **1.1** to **1.4** above, and summarized here. The aspiration for an electronic health record system with research capability for patient stratification in trials and data-mining facilities linked to UCL e-health initiatives is embodied in the Healthcare Informatics, Genomics/omics, Data Science (HiGODS) cross-cutting theme in our UCL/UCLH NIHR-BRC renewal. This is a collaboration between UCLP (including the Farr Institute), the Crick, the Wellcome Sanger Institute and the European Bioinformatics Institute, with the aim to develop an eMedLab integrating genomic, imaging and clinical data for population health research, and to stratify patients for clinical trials. Another key cross-cutting platform in the UCL/UCLH NIHR-BRC is the BRC Experimental Medicine Academy, fulfilling our plan in REF2014 for a Research Training Academy.

In **cancer**, there have been major developments in cancer biology and genomics resulting in landmark discoveries in cancer heterogeneity and genomics. These are the subject of one of the highest profile collaborations between UCL and the Crick Institute (**Swanton, Quezada,**

McGranahan) and have created a major new spin-out company (Achilles Therapeutics). There has been a step change in development of gene therapy, immunotherapy and stem cell transplantation approaches to cancer with world-leading progress in chimeric antigen receptor (CAR)-engineered lymphocytes and vector design (**Pule, Peggs**), and development of CAR-T gene transfer attracting large-scale private investment (Autolus). The KCL/UCL Comprehensive Cancer Imaging Centre, funded by CRUK and the EPSRC, was established to develop imaging, combined with clinicopathological assessment, genomics and in-house optical proteomics, for elucidation of the molecular and physiological processes of cancer, and has led to the new National Cancer Imaging Translational Accelerator (see **3.1.4**). The high energy Proton Beam Therapy Centre, opening in 2021 (£125M; 8000m^2), will vitalise radio-oncology research and personalized medicine in this area. Plans in REF2014 for development of **Infection, Immunity and Inflammation** have crystallised with the PEARS Building (opening in 2021), and delivery of the AHRI. In **Child Health**, a new academic strategy has been implemented in GOS ICH. The Zayed Centre for Research into Rare Disease in Children opened in 2019, greatly expanding research space and facilities for its programmes. The Versus Arthritis Adolescent Rheumatology Centre funding was renewed with opening of new laboratories. In **Experimental Medicine**, the new GMP radiopharmaceutical laboratory opened in 2015, funded by BRC and UCL; a fully refurbished Charles Bell House opened in 2016 housing the WEISS Centre, and a hub and major expansion of facilities tailored for interdisciplinary working. New facilities for rehabilitation science have been established in Stanmore RNOH, and a floor of new laboratory and office space has invigorated development of Respiratory Medicine.

1.5.2 Research Plans for next 5 years

A central strategic goal in the next 5 years will be renewal of our UCLH/UCL and GOSH/GOS ICH BRC funding, building on the achievements presented above and developing new, strategically important, areas of translational research as outlined below.

In **cancer**, the aim is to understand, detect and treat cancer by coordinating strategic priorities across the BRCs, Academic Health Science Centres and Networks, promoting cross-disciplinarity, and progressively expanding partnerships and delivering our comprehensive networks. Early detection of cancer (particularly lung) will be accelerated by the International Alliance for Cancer Early Detection (ACED) of which UCL is a leading member. This is a unique, researcher-led, collaboration supporting early detection research and enabling early detection leaders to accelerate progress in this area. Acceleration of new cancer therapies, particularly immunotherapeutics, will be greatly enhanced by building a new centre integrating immunotherapy translational research with state-of-the-art bioincubator facilities, co-located with the Cancer Institute (CI) on the Bloomsbury Campus. A site for this development with a suitable footprint has been identified in Mortimer Market and provisionally approved by UCLH, contiguous with the Macmillan Cancer Hospital and 2 minutes' walk from the CI.

Opening of the Proton Beam Therapy Centre in 2021 together with strategic recruitment in radio-oncology will provide a major clinical resource to invigorate research into radiotherapy, and improve outcomes in and personalise radiotherapy for tumours of major unmet clinical need, including lung cancer and glioblastoma. Work on paediatric cancer will be expanded with the strategic aim of developing precision medicine approaches by defining unique disease-linked susceptibilities through partnership with GOSH and UCLH's Paediatric Cancer Centre of Excellence, building on clinical opportunities provided by the new Proton Beam Therapy Centre. Key to achieving these goals will be development of leaders in cancer research detection and treatment through a multidisciplinary collaborative training programme. Strategic recruitment will develop our critical mass in basic cancer research, including a new Associate Professor in Haematology focused on fundamental stem cell science, and a new post in molecular mechanisms of T-Cell immunosuppression.

In **Infection, Immunity and Inflammation**, planned major new recruitment to the expanded IIT in the PEARS Building from 2021 will develop critical mass in basic and translational immunological research, and accelerate translation of stem cell transplantation and gene therapies for diseases of immunodeficiency. The PEARS building will catalyse synergies and collaborations between UCL researchers in immunology, through co-location of researchers currently on geographically disparate sites (Bloomsbury and the Royal Free), and by providing outstanding

research facilities. Existing UCL research groups will occupy 75% of the new space, and 25% is dedicated to recruitment of established and future world leaders, key to establishing the IIT as an international centre of excellence. Renewal of Wellcome funding for AHRI in 2021 will drive new treatments for infectious diseases in developing and low-income countries. An Infection Research Institute (IRI) will be established by co-locating infection and microbiology research to newly refurbished space, provisionally identified within the Cruciform Building (Bloomsbury campus), concomitant with the move of the DRI Interim Hub to its new home in Gray's Inn Road (estimated 2023). This plan has been approved by UCL and underwritten by a firm UCL institutional commitment.

In **Child Health**, the new Zayed Centre provides major new research capacity and facilities, including a good manufacturing practice (GMP) suite that, together with new recruitment, will underpin basic research to drive understanding of mechanisms underlying rare childhood disease and accelerate translation of our research in novel gene-based and cell-based therapies for childhood diseases. Researchers in the Zayed Centre will use the unique GOSH DRIVE platform to integrate rich health data with data science and digital innovation, to develop scalable solutions to enhance child health care across the NHS and globally. DRIVE integrates closely with the Health Data Research UK London Hub (hosted in UCL), which will provide linkage of genetic and clinical data with routine health and education records (currently data from 9 million children in the UK). Collaboration with other world-leading children's centres through the IPCHiP partnership on phenotypic and genomic data from children with rare diseases will enable gene discovery and understanding of mechanisms of disease.

A strategic goal of **Experimental Medicine** is to expand capacity in cross-cutting translational imaging platforms and clinical trial activity through: development of the UCL/UCLH Imaging Trials Unit (led by **Punwani**), including appointment of a leading medical statistician to the Department of Imaging in late 2019 (**Mallett**), to develop statistical methods applied to diagnostic test accuracy and prognosis in imaging studies; building our capacity in hyperpolarised MRI for renal, breast, brain, and pancreatic cancers; and installation of an experimental clinical MRI (led by **Lythgoe, Punwani**) to fast-track clinical translation of novel imaging techniques, further supported by new senior academic recruitment in preclinical imaging. Capacity building in artificial Intelligence will also be a key strategic priority for imaging research. The Royal Free Masterplan is an ambitious scheme jointly between UCL and the Royal Free NHS Trust, which aims to transform this site into a research-oriented hospital and UCL biomedical research institute complex. The PEARS building is the first phase in realisation of this ambition, with future prioritised projects including reorganisation of research in Surgery and Interventional Sciences, part of which is establishment of the Charles Wolfson Centre for Reconstructive Surgery, a £1.4M project to bring together innovative surgical techniques and recent research to accelerate research translation for patient benefit and train future generations of surgeons and research leaders. Planned relocations to the Royal Free Campus of biomaterials and microbiology research from the Eastman Dental Institute and biomaterials research from the RNOH in Stanmore will boost critical mass in these areas, and will be supported by creation of a new >100m^2 imaging suite. Cardiovascular Science will further consolidate its estate and co-locate staff at a Cardiovascular Hub in Bloomsbury, and use its BHF accelerator award in Cardiovascular Science Data, renewal of the BHF 4-year PhD Programme (successful late 2020) and the UCL-wide Cardiovascular Network to develop Cardiovascular Science throughout UCL.

2. People

2.A Staffing strategy and staff development

All UoA1 units are committed to securing the vitality and future sustainability of our research environment through staff development and recruitment. Our environment encourages and supports the development of an international research profile characterized by research excellence and contributions to research impact, through mentoring and staff training and development, and an emphasis on nurturing these characteristics through procedures for staff appraisal, promotions, and appointments.

2.A1.1 Support for staff development

As described below, units in UoA1 actively implement the "Concordat to Support the Career Development of Researchers" (https://bit.ly/3mixAze) at all career stages through appraisal, probation and promotion schemes, mentoring, networking, training, succession planning, and by developing leadership that reinforces our commitment to the Concordat.

Appraisal and promotion: All staff are appraised annually within the UCL Appraisal, Review and Development scheme, by their Head of Department or manager, in order to set research and training goals, and plan for progression and promotion. Annual appraisal rates in UoA1 averaged 78% in 2018-19.

UoA1 staff eligible for senior promotions (academic and research) are annually reviewed by committees prior to the promotions round and 'promotion mentors' within UoA1 provide support and advice for staff nominated for promotion. Since 1st August 2013, the numbers of staff being promoted to Senior Lecturer, Reader (Associate Professor since 2018), and Professor across this submission were, respectively, 11, 40, and 93 during this REF period. In addition, 19 UoA1 staff were promoted to Principal Research Associate or Fellow, and 8 to Professorial Research Associate or Fellow.

Mentoring: All UoA1 units have established mentoring and staff development schemes within this REF period, particularly for junior staff. Such schemes for PhD students, post-doctoral and early career staff are integral to Athena SWAN (AS) programmes established within all our units. To develop staff and facilitate the transition to research independence, or other career paths, all units run bespoke schemes at local level to identify staff with potential for securing fellowships or other research grants, particularly early career staff, and to support them from pre-application to post-application and interview stage. This provides oversight of applications by committees with suitable expertise, pre-submission application review, and mock interviews. During the current REF period, >200 staff in UoA1 units have received bespoke mentorship in these schemes, contributing to success in 72 fellowship applications.

Networking: SLMS-wide Research Domains and Early Career Networks organise many talks about diverse career paths and provide opportunities for junior researchers to interact with senior ones. Units in UoA1 offer further opportunities for networking from visits of international speakers, international meetings and symposia held in UCL, and dedicated career workshops. Many units have also established bespoke networking groups. The ICS Research and Academic Networking Group (RANG) brings together junior staff to support early career researchers to collaborate across UCL, and acquire the skills, knowledge and experience needed to further their careers within UCL and beyond. The UCL Cancer Domain supports an Early Careers Network, and the CI created a postdoctoral association to encourage visibility, leadership and networking, with monthly social events and a postdoc retreat. The Division of Medicine's early career researcher group organises lectures and workshops, with talks by representatives from industry and inspirational role models on career development.

Training: All staff have protected time to complete 10 days per year of skills training, and are mandated to participate in diverse training schemes, which play important roles in skills enhancement and preparing them for future careers as independent researchers or alternative career paths (eg scientific publishing, industry). Courses in fair recruitment and PhD supervisor training are compulsory for staff involved in recruitment or PhD supervision. In addition to UCL-run courses, all units in this submission have local initiatives. For example, the CI engages its staff in external courses such as EMBO Laboratory Leadership.

UoA1 staff (**Sharma** & **Montgomery**) advise UCL's Academic Careers Office (ACO), which supports academic and clinical academic researchers in SLMS. Funding for training schemes

obtained through the ACO provide skills training for clinically trained and non-clinical academics, including MRC Skills Development Fellowships, the Wellcome Clinical PhD Programme, the NIHR Integrated Academic Training Programme (largest in the UK), and the UCLH BRC Education Academy. The ACO trained 2,417 UoA1 researchers during this REF period, increasing from 132 in 2014-15 to 1,085 in 2019-20, and generated £4.5M in research training grants for UoA1 researchers in 2017-20 alone.

Leadership: An important part of staff development is preparation for leadership roles. The Divisions and Institutes in this submission annually review the needs of staff at all academic grades for leadership training, and nominate staff for UCL's Leadership enhancement programmes. During the current REF period, 81 staff in this submission have been on leadership programmes, including the Future Leaders Programme (50% female participation), a nine-month training programme to train potential Heads of Department, and UCL's Women and Senior Women in Leadership Programmes.

Succession planning: Appraisal and promotion plays a key role in succession planning. All UoA1 Division and Institute Directors lead on succession planning for leadership roles, while Faculty Deans lead on appointment of Division and Institute Directors. In both cases, new appointments are made following open advertisement and extensive staff consultation, and for more senior appointments this has involved extended searches for suitable internal and external candidates. Examples of succession planning in UoA1 include appointment of the new Heads of Haematology in the CI (**Peggs** appointed 2019), of Infection and Immunity (**Morris**, 2019), Medicine (**Kleta**, 2018), IfWH (**David**, 2017). Staff in protected groups are actively encouraged to apply for leadership positions. In several units (e.g. DoM, GOS ICH), a policy of appointing Deputy Heads of Research Department has been instituted both to provide leadership development opportunities and to facilitate succession planning.

Support for Early Career Researchers (ECR): All UoA1 units have ECR development programmes embedded in their AS schemes, aligned with the professional development programme for ECR staff run by UCL's HR Organisational Development team (https://bit.ly/3a879dc). Central UCL funding provides hypothecated support for ECRs. During the REF period, researcher-led initiative awards were obtained by 2 ECRs in UoA1 for attendance of professional career development meetings, and UCL's Grand Challenges Doctoral Small Grants with a combined value of £55,187 were awarded to 18 UoA1 ECRs. 42 ECRs are returned in this submission.

Key to diversifying the skills portfolio of ECRs are opportunities for training in teaching. The UCL Arena fellowship scheme (accredited by the Higher Education Academy (HEA)) provides education training at different levels. Since 2014, 102 staff in UoA1 units have been awarded Associate Fellowships, and 90 staff obtained Fellowships, Senior Fellowships or Principal Fellowships of the HEA. Many workshops and talks raise awareness of alternative career paths. For example, UoA1 AS schemes run regular half-day workshops on diverse career paths for researchers, including transitioning to independent academic and non-academic career pathways, teaching, scientific publishing, careers in industry, or with research funding agencies, and hosting events as part of UCL's 'Careers in Research Week'.

2.A1.2 Recruitment and retention

Our recruitment strategy comprises two main components. First, new UCL-funded positions, aligned with strategic research or educational initiatives, enable recruitment of outstanding staff in open competition. Secondly, we retain as many of our ECRs as possible via fellowships, to enhance their development and the vitality of larger research groupings. This strategy resulted in recruitment of 70 new researchers in this submission, including 49 at senior lecturer level or above. Supporting fair recruitment based on EDI principles is central to our recruitment processes, and is described in section **2.C**.

Institutional resources, including generous start-up funds, have supported fellowship recipients and recruitment as an integral part of investing in the people underpinning both the excellence of our research environment, and our research strategy. Since 2014, UoA1 units have supported several new posts with recruitment packages, examples of which include: 7 professorial posts, including Chairs in Medical Oncology, Neuro-oncology and Computational Biology, and 6 senior research posts in the CI; a Chair of Stem Cell Biology, with a large group in the Zayed Centre; a senior clinical research-track appointment in the Division of Medicine including 2 post-

docs and an MBPhD student; a Chair in immunology in the Division of Infection and Immunity with a studentship and research expenses; a new Lecturer in Maternal and Foetal Medicine in IfWH; and 7 academic recruits to DSIS with fully-funded PhD studentships. Particularly for new ECRs, care is taken to limit teaching and tutorial loads during probation. ECR staff in UoA1 also received £153,023 from the Wellcome Institutional Strategic Support funding (WISSF) for Fellowship Extensions and other support at crucial career transition points. The ablest of our researchers move on to more senior fellowships and UCL-funded posts, with proleptic appointments supporting retention. For example, 3 prestigious UKRI Future Leaders Fellowships were awarded to UoA1 staff since their launch in 2018, with substantial UoA support including tapered salary, commitment to an open-ended position at the end of the fellowship, and appropriate research infrastructure.

Our environment also promotes job security for research staff. Since 2014, 25 UoA1 staff have moved from time-limited research contracts to tenured academic posts. Substantial sums were spent on retention packages for UoA1 staff in the REF period as salary uplifts or funds for equipment or infrastructure. For example, since 2014, UCL has committed >£2.24M to secure retention of key staff in this submission, including packages allowing 4 staff to progress to tenured associate professor or professorial positions, and to make proleptic appointments with tapered salary contributions for others. The Faculties comprising this submission have harmonised annual rewards processes (https://bit.ly/3nmjGxI) to recognise exceptional performance for staff at all grades in the form of honoraria or bonuses. In all UoA1 units, rewards committees are widely advertised and all eligible staff reviewed by Divisional and Institute leaderships and encouraged to apply. As mentioned above, staff eligible for senior promotion are reviewed annually and 'promotion mentors' provide them with support and advice.

2.A1.3 Integration between clinical and basic scientists

UoA1 staff comprise a close to 50:50 mix of clinicians and basic scientists (47/53% in REF2014). Employment contracts and annual monitoring schemes ensure that clinically active staff have sufficient time to devote to research, and that their different activities and duties are appropriately balanced. Integration of clinical and non-clinical scientists is enabled by their working alongside each other in shared lab space, close collaboration in consortia and other grants, and frequent opportunities for interaction through research away days, seminar programmes, lab meetings, and networking events. In addition, during the REF period, 1165 clinicians had Honorary appointments in UoA1 Divisions and Institutes, they collaborated extensively with UoA1 staff, and made major contributions to grant funding, published research, and staff training.

2.B Research Students

2.B.1 Research students

1010 doctoral degrees were awarded in UoA1 in the current REF period, a significant increase from the 688 awarded in REF2014, and 1287 PhD students enrolled in this submission between 2013 and 2019. The PhD completion rate for students supervised by UoA1 staff is 78.6% for 2013 entrants.

2.B.2 Recruitment

Recruitment to PhD training in UoA1 has been strong, due to the excellent reputation of UCL coupled with the active engagement of staff with other HEIs, third sector organisations and industry. 41 MSc/MRes courses, with 983 enrolled students in 2019/2020, provide a vibrant programme of postgraduate research training and strong recruitment to PhD programmes. Students on MSc/MRes courses spend at least four out of 12 months exclusively on a research project, and graduate well prepared for PhD or research posts. Our success is also attributable to our support schemes for prospective fellowship candidates, which has been essential in increasing the number of MRC Clinical Training Fellowships, a scheme in which this UoA has maintained a high success rate. Our studentships and clinical training fellowships have been funded through MRC, BBSRC, BHF, Wellcome, CRUK and Versus Arthritis. In addition, units in this submission have been awarded studentships through UCL's Impact Studentship scheme, which involve collaborations with industry or third sector organisations, with UCL providing 50% of the funding,

and £60,987 was awarded through the UCL SLMS Grand Challenges scheme for UoA1 studentships co-funded by UCL and the BRC. We have been successful in obtaining 23 CASE awards in collaboration with industry. Our approach to recruitment takes full account of those with protected characteristics. All interviewers undertake UCL's Fair Recruitment training, and we monitor recruitment of students with protected characteristics. In 2019/2020, student postgraduate research student recruitment in UoA1 included 60.9% women, 43.5% identifying as 'non-white', and 7.6% with a disability, compared with 53.9%, 41.2%, and 3.2%, respectively, in 2013/2014. These data show that our recruitment policies are encouraging more students with protected characteristics to undertake their research degrees in UoA1 units.

2.B.3 PhD Programmes

Central to improving the quality of doctoral training is increased student enrolment in well-resourced 4 year PhD programmes, supported by the Academic Careers Office (see **2.A1.1**), all incorporating mentorship schemes, cohort-building activities, and specifically addressing equality and diversity, and mental health issues. Programmes hosted by our submission include:

- A Wellcome Clinical PhD programme (Directors **Lomas** (UoA1), **Rees** (UoA4); £6.5M) that has enrolled 33 students since 2014 (18 supervised in UoA1).
- The largest NIHR Academic Clinical Fellowship and Clinical Lectureship programme in England and Wales.
- Funding from CRUK Centre and Network awards and the BRC Cancer Theme supports a four-year PhD programme (clinical and nonclinical) which has enrolled 26 PhD students since 2014.
- The UCL MBPhD Programme**,** run by the Division of Medicine, is one of only two such programmes in the UK, enrolling 21 students in the REF period. The programme provides future clinical academics with training in clinical medicine and biomedical research by integrating a PhD within their basic clinical MB course. MBPhDs are undertaken at UCL or the Crick Institute, and are funded through the Programme itself or by the Crick, supported by scholarships via the UCL MRC Doctoral Training Programme, UCL/UCLH BRC, the Rosetrees Trust, The Astor Foundation and the International Journal for Experimental Pathology, and through Charitable MBPhD schemes (e.g. BHF).
- The UCL EPSRC-funded Centre for Doctoral Training (CDT) Programme in Medical and Biomedical Imaging (renewed in 2013; £5.6M) is co-hosted by Centres for Advanced Biomedical Imaging (co-director **Lythgoe** 2013-19)**,** and Medical Imaging (**Plumb** cancer theme lead). This CDT provides a comprehensive and integrative four-year PhD programme in imaging science, preparing students for successful careers in academia, industry and healthcare, with expertise in imaging science, computation, mathematics and their application and translation to clinical solutions and market impact.
- The Wellcome PhD Programme in Stem Cell and Developmental Biology (co-led by **Copp**) is in its fifth year, with the first year's students all graduated.
- The Oliver Bird four-year PhD Programme has funded PhD students in two cohorts and nine have graduated, six of whom are in post-doctoral positions (including a winner of the prestigious 2013 Garrod Prize from the British Society For Rheumatology), one is in industry, and one works for the European Medicines Agency.
- The BHF four-year PhD programme, first awarded in 2009 and renewed in 2016 and again in 2020, is run by ICS (Director **Muthurangu**, theme leads **Pineda-Torra, Schievano**) and has provided 4 PhD places each year across units in this submission (ICS, DoM), as well as UoA2 and UoA4.
- The Bench to Bedside PhD Programme in Infection, a four-year MRC-funded PhD programme, has been developed to combine research training in cutting edge biomedical science with an opportunity to experience the clinical context of the research.
- UCL-ADLQ PhD programme co-led by DoM, is a non-residential programme with the Anti-doping Lab in Doha Qatar (ALDQ).

Staff in this submission play leadership roles in other PhD Programmes: **Stuckey** is UCL representative on the BBSRC LIDo Doctoral Training Programme's Students and Research Committee; **Punwani** is PI for the National Cancer Imaging Translational Accelerator and under

this aegis is developing a training and network infrastructure across its partner institutions . UoA1 staff are also supervisors in cross-faculty UCL PhD programmes including:

- The UKRI-funded UCL Centre for Doctoral Training in AI-enabled Healthcare Systems (led by **Rees**, UoA4), which involves the UCL/UCLH and GOSH/ICH NIHR BRCs.
- The EPSRC CDT in Advanced Therapeutics and Nanomedicines**,** a collaboration between the University of Nottingham's School of Pharmacy and UCL's School of Pharmacy and industry partners including Alliance Boots, AstraZeneca, Pfizer, and GlaxoSmithKline.
- the 4-year Wellcome PhD programme in Optical Biology at UCL (**Alexandre, Fassatti, Ferretti, Grove, MacRobert, Parrinello, Sowden**).

2.B.4 Sustainable doctoral training

Our processes ensure that our doctoral training is effective and sustainable, supporting students throughout their training. All UoA1 Divisions/Institutes have a team of Graduate Tutors responsible for ensuring fair and equitable student recruitment, appropriate supervision and progress from MPhil to PhD registration and thesis submission. Graduate Tutors advise students on access to additional resources necessary for their work and provide support when they are in difficulties. All students are allocated to an experienced principal supervisor with a named secondary supervisor. PhD supervision courses are mandatory for all supervisors, and prior experience as a subsidiary supervisor is an additional requirement for primary supervisors. In 2014-2019, 377 staff in UoA1 units completed introductory courses on research supervision, and 98 staff returned in this submission undertook advanced courses. To support part-time PhD students, graduate tutors ensure that student work plans allow time and facilities for their doctoral studies, ensuring they are not disadvantaged by competing responsibilities.

Training, mentoring, and pastoral support are integral to all PhD programmes. PhD students in this submission are assigned personal tutors and mentors, and meetings with the personal tutor and mentor, together with regular faculty and Division or Institute communications, promotes involvement of students in UCL training and support, e.g. Doctoral Skills Development Programme, UCL Volunteering Services Unit, UCL Student Support and Wellbeing, and UCL Student Mediators. Directors, administrators and supervisors of PhDs and PhD programmes monitor mental health issues identified early in PhDs through regular progress and pastoral supervisor meetings. A SLMS working group on the PGR experience recommended institution of PhD Thesis Committees to oversee the progress of PhD students, which were implemented for all UoA1 PhD students from 2019.

Student progress is monitored through UCL's on-line Research Student Log. Students submit six-monthly reports (plus one at month three) for discussion and approval by the supervisory team, documenting academic progression and skills development training. The Log records review meetings, important milestones such as the MPhil to PhD upgrade, and discussions on research and training. Thesis upgrade seminars and examinations are organized by local graduate administrators within the first 12-18 months of PhDs, and are used by Graduate Tutors to evaluate progress of the cohort. Statistics for MPhil to PhD upgrade and submission rates within four years (six for part time students) are reported annually to the Research Degrees Committee and reviewed by Departments for action where appropriate.

Our students are strongly encouraged to participate in the UCL Doctoral School's Skills Development Programme, and the Doctoral School annual Research Poster Competition. Courses deliver the full range of skills defined by the Researcher Development Framework, and in UoA1, during the REF period, 89 PGR students received public engagement training (in 2018-20 alone), 92 completed Entrepreneurship training for doctoral students (2019-20 alone), 403 completed gateway Arena training leading (optionally) to an application to become an Associate Fellow of the HEA. In 2017-19 alone, 8 received Grand Challenges Doctoral Students' Small Grants totalling £60,987. Rapid growth in the role of UCL's Academic Careers Office in PhD student training is described in **2.A1.1** above.

The COVID-19 pandemic and the temporary closure of non-COVID-related research laboratories created major challenges for doctoral researchers. To support all PhD students, UCL rapidly implemented measures to ensure continuity of supervision, support, training, and funding throughout the period of lab closure and beyond, including: (i) Provision of 200 free places for SysMic online bespoke training for Biomedical PhD students in Computing and Statistical methods,

including artificial intelligence; (ii) the UCL Stipend Extension Scheme (SES) supported final-year funded students in submitting their doctoral thesis on time, by underwriting funding at the minimum London UKRI stipend rate for up to 3 months and allowing Departments and Supervisors to top-up stipend extensions from their own sources.

2.B.5 Integration into research culture

Doctoral students are integral to our research culture and environment. Most are involved in collaborative, often interdisciplinary, projects, and all are affiliated with research groups in UoA1, attending research planning meetings, research group meetings, contributing to research articles, presenting their work and attending conferences. Specific mechanisms further ensure integration of students into the research culture and to prepare them for future careers, including PhD seminar programmes, and participation in research retreats.

A PhD cohort culture is created in UoA1 by establishing regular PhD student-centred events combining research presentations with social and networking opportunities. PhD programmes (see **2.B.3**) hold social activities throughout the year including welcome events for new students in September, an MBPhD symposium in January and regular journal clubs (with breakfast). Pizza events are organised as are joint meetings with the French and other European MBPhD students. The Division of Medicine revamped its seminar programme to create a monthly event for PhD students combining several talks followed by a social event. Larger annual PhD days are opportunities to showcase PhD research by oral or poster presentations. Keynote speakers are invited, and prizes awarded for the best student presentations. UoA1 Division and Institute annual research retreats include sessions dedicated to PhD presentations. FMS and FPHS run annual Dean's Prize Events for research students and 3 minute-Thesis competitions, and students are encouraged to give presentations at national and international research conferences. Typically, students present at one or two national and one overseas conference during their training, supported by funds from the Doctoral School, PhD Programmes, and individual research groups.

2.B.6 Future careers of research students

The employment prospects and next destinations for our PhD students are enhanced in several ways. UCL's careers service offers specialised services including employer-led programmes; organises employers' forums with PhD recruiters, an internship scheme for research students, one-on-one advice sessions particularly for ECRs by dedicated staff with research experience; and facilitates secondments of research students and ECRs to external organisations. PhD programmes in UoA1 (see **2.B.3**) have career-oriented training and events embedded in their programmes, and all UoA1 units and their AS schemes run programmes of events and workshops on future careers. Appraisals also focus on future career aspirations and training required. A Graduate Outcomes Survey of PhD students in UoA1 (those completing in 2017/2018) to determine next destinations produced a 63.8% response rate, and showed that 88.7% of respondents obtained highly-skilled graduate-level employment after their doctoral research, with a median salary of ~£40,000 per annum 15 months after obtaining their PhDs. Of the remainder, 7.2% went on to further study (this may include medical students completing their basic training), and only 1% of respondents were unemployed after completing their PhDs. These data indicate that our post-graduate training produces PhD students in UoA1 with a high level of skilled employability.

2.C Equality & Diversity

Creation of an equal, inclusive and diverse environment, and raising awareness of these issues, are key priorities for UoA1 units, and significant progress in this area since REF2014 is presented below.

Supporting fair recruitment is central to our mission of increasing diversity, and a centrally supported programme provides Fair Recruitment Specialists to assist with this. In the current REF period, 51% of all applicants for positions in UoA1 at grade 7 and above (post-doctoral and higher) were female, 54% of shortlisted applicants and 56% of appointments were female. Black, Asian

and Minority Ethnic (BAME) individuals were 45%, 34%, and 28% of applicants, shortlisted and appointments, respectively, and disabled applicants, 2%, 3%, and 3%. These data indicate that while our recruitment processes do not disadvantage women and disabled applicants, a concerted future effort is needed to remove any existing barriers to increasing our diversity in recruiting from BAME groups.

Athena SWAN (AS) Self-Assessment Teams have been established in all units of this submission and are the main advocates for EDI. Since 2014, UoA1 units have obtained 2 gold awards (IfWH and GOS ICH), 4 silver awards to the Cancer Institute (CI), Medicine (awarded 2013, renewed 2018), Infection & Immunity (first awarded 2013, renewed 2017), and ICS (first awarded 2015, renewed 2018), and 1 bronze award (DSIS). Recognising the importance of EDI, all AS teams are represented on the senior leadership and Executive bodies of participating units, and leaders within units play active roles in AS teams. AS teams, awards and activities in this UoA have driven increased diversity since 2013. The proportion of female staff returned in UoA1 (HESA2 plus HESA3) increased from 46.6 in 2013 to 49% in 2020, and the percentage of female HESA3 staff increased from 28.4 to 35% in the same period, whereas female HESA2 (research only) staff decreased from 56.5 to 54.75%. Evidence that UoA1 AS programmes are effecting real change in the advancement of women at senior levels is provided by promotions data and the increasing representation of women in higher grades and in leadership roles: the percentage of UoA1 women successful in senior promotions (Senior Lecturer and above) increased from 34.5% in 2013/14 to 61.9% in 2019/20; 3 of 7 Heads of Division and Institute in this submission are women (**Smyth, David, Morris**). Since 2014, six NIHR Research Professorships awarded in UoA1 included three women and three from BAME groups. At faculty level in this submission, in both FMS and FPHS 4 of 8 Vice Deans are women, 3 in this submission (**Tran, Mauri, Chambers**). New local initiatives such as appointment of Deputy Heads of Research departments (in DoM & GOS ICH) have provided opportunities to develop greater gender balance in senior roles.

The GOS ICH Gold AS Award led by **Mills** and **Copp**, recognised a concerted focus over several years to achieve 50:50 gender balance at senior levels with visible role models and a culture of flexible working enjoyed by students and staff at all levels. The IfWH Gold AS award (co-led **Buckley**) recognised “the supportive culture of the institute, in which equality is embedded in everyday practices” with “many examples of sustained impact and innovative beacon activities, and strong leadership in equality and diversity” together with promotion of “flexibility and job-sharing at senior leadership positions” (from the AS panel feedback, 2017). The DoM’s AS Parental Support scheme recognised in its Silver Award (led by **Pineda-Torra, Rohn**) has disbursed >£124,000 to 24 staff since 2014 enabling replacement work cover, retraining, and stipends to complete PhDs, with significant positive impacts, including publication of papers, grant submissions and conference attendance; one recipient reflected that without the award she would not have been able to complete her PhD. The scheme was highlighted as best practice by a UCL institutional SWAN team subcommittee, and other UCL units run similar schemes as a result.

Women are encouraged to undertake leadership and training: Since 2014, 53 UoA1 female staff attended UCL's bespoke Women and Senior Women in Leadership programmes, and 50% of UoA1 staff participating in the Future Leaders Programme were female. Recognition of the importance of EDI has resulted in the appointment of Vice-Deans for EDI (from 2019) in FMS (**Tran**) and FPHS (**Buckley**), who will provide faculty level coordination of EDI activity across UoA1.

BAME HESA3 staff increased from 18.4% in 2013 to 19.5% in 2020, and 18.24% of successful UoA1 senior promotions over the REF period were BAME staff. Additionally, overall staff proportions increased from 23 to 23.8% for religion, from 1.8 to 2.6% for disability, and from 1.7 to 2% for sexual orientation (LGBTQ+). Building on the achievements of AS teams and initiatives, a major future challenge will be to grow awareness and take action on EDI in relation to protected characteristics other than gender, for example, in recruitment from BAME groups. IfWH has an EDI Team that meets monthly to discuss issues affecting all staff with the intention of promoting good practice across the Institute to benefit all staff and students for all protected characteristics. The new GOS ICH EDI Initiative, launched July 2018, aims to be ‘A Voice for All’ recognizing that access and treatment are not always equal for everyone and the need to redress the balance for under-represented groups, alongside addressing barriers to the progression of women’s careers. The initiative comprises a Steering Committee and Focus groups, responsible for preparing and submitting the GOS ICH’s successful Gold award application in 2020 and

implementing its action plan. Other AS schemes in this submission also prioritized underrepresentation of other protected groups in their efforts to improve equality and diversity, through promoting UCL's online training on Diversity and Unconscious Bias. Engagement in UoA1 with the new UCL Inclusive Advocacy initiative, designed to address differences in career progression and BAME staff attainment, is indicated by 20 of our academics becoming advocates for BAME staff.

Key to promoting a positive research culture has been training to combat harassment, bullying and bias. Since 2017, Unconscious Bias training has been mandatory for all staff; additionally, 25 of UCL's" Where Do You Draw The Line" workshops were organized specifically for UoA1 staff , and many UoA1 staff received Racialised Implicit Bias training. AS teams have led initiatives to combat harassment and bullying, and disseminate a culture of flexible working practises, including job sharing at senior levels, organisation of meetings in core working hours, and respect for child caring duties for parents.

Preparing this submission

Guidance and communications relating to identification of UoA1 staff and output selection emphasised the importance of EDI principles at every stage. Assessment teams comprising 89 UoA1 staff were convened in each participating unit to oversee staff inclusion, output review and selection, and chosen to reflect diversity across UoA1 with respect to all protected characteristics. Equality Impact Assessment (EIA) of our submission made us re-examine inclusion of HESA2 staff and output selection in the context of EDI considerations. Female and, particularly, BAME HESA2 staff were somewhat underrepresented in UoA1, but after rigorous scrutiny of our processes, this did not appear to be due to inequity in HESA2 staff inclusion, and likely reflects structural over-representation of white males in senior HESA2 grades or with fellowships. Disabled staff were 50% more likely to be represented in UoA1 HESA2 staff than non-disabled staff, although only 4 of 95 HESA2 declared as disabled. Clearly, future work is needed in UoA1 to ensure that research staff development fully reflects diversity in all aspects, and particularly with respect to BAME research staff.

HESA3 female staff were somewhat less likely than males to have outputs attributed to them, while HESA2 female staff were just as likely as male to have outputs attributed. BAME staff in this submission were more likely to have outputs attributed, though not markedly so, than white staff for both HESA3 and HESA2 categories, and were also more likely to have 5 or 4 outputs attributed per staff member. These data indicate that our processes for output review and assessment applied EDI principles rigorously and resulted in an output distribution profile that fairly reflected the diversity of staff in this submission.

3. Income, infrastructure and facilities

3.1 Income

UoA1 staff obtained over £850M in competitively awarded research funding, and spent £777M research income (excluding investment in spin-off companies), equating to £322,521 spent per FTE per annum, a 73.7% increase on annual research expenditure reported in REF2014 of £185,714 per FTE. Research income came principally from RCUK (15.5%), UK and EU government (27.8%), UK, EU and non-EU charities (44.8%) and industry (10.3%). Large-scale funding awards spanning units in UoA1 since 2014 are renewals of NIHR BRCs in UCL/UCLH and GOSH/GOS ICH representing the single biggest investment by the NIHR in UK research (£148M in total). Staff in this UoA have also been awarded 9 MRC Programme Grants, 6 Wellcome Collaborative Awards, 16 MRC DPFS awards, and lead or coordinate 18 EU FP7 and Horizon 2020 awards, and are partners in another 37. UCL also received more funding for COVID-19 research than any other University (UKRI, 22 June 2020).

Since 2014, UoA1 staff have been successful in obtaining personal fellowships, major awards, promotions or appointments, including 6 NIHR Research Professorships (only 5 awarded per year in the UK), 7 MRC Clinician Research Fellowships, 7 Wellcome investigator awards, 7 Wellcome Senior Research Fellowships, 2 CRUK Senior Research Fellowships, 2 Sir Jules Thorn Awards for Biomedical research (only 1 awarded per year), 3 Wellcome Clinical Research Career Development Fellowships, 13 HEFCE Clinical Senior Lectureships, 10 ERC awards (Advanced, Consolidator and Starter), 7 Wellcome Intermediate Investigator Awards in Science, 3 UKRI Future Leaders Fellowships, 6 Wellcome/Royal Society Sir Henry Dale Fellowships, 4 BHF Intermediate Clinical Fellowships, 93 newly promoted Chairs, 12 newly recruited Lecturers, and 49 new senior recruits at Senior Lecturer and above.

UCL has made major contributions to research in UoA1 through funding at scale for the entire translational research pipeline through the Translational Research Office (TRO) and UCL Business (UCLB). Since 2014, 41 large translational projects managed by the TRO were led by UoA1 staff, supported by >£63.3M external funding; the TRO also provided proof-of-concept grants each <£100K, totalling £2.65M, for 34 projects led by UoA1 researchers. Since 2014, UCLB has supported enterprise activity led by UoA1 researchers: £430,107 for 5 Proof-of-concept awards, £8.7M for 7 UCL Technology Awards, and £7.2M for the initial stages of spin-out companies, (see **4.2.2** for examples).

Strategically important funding awards underpinning research excellence and impact in this UoA are described below for each of the 4 major themes.

3.1.1 Cancer

UCL's cancer research has undergone major development since 2013, delivering key goals of REF2014, driven by its leadership of several Centre awards and multi-Centre collaborative networks. The CRUK UCL Centre (renewed 2017, £7.9M, plus £4.5M training grant for non-clinical and clinical postgraduate training), is part of a national network of 13 CRUK research centres delivering world-leading cancer research; UCL CI also houses the CRUK UCL Cancer Trials Centre (£15M, renewed 2017). In 2018 CI established the CRUK City of London Centre (£14M total, £2.8M UCL) focused on Cancer Biotherapeutics in partnership with Barts/QMUL, King's Health Partners and the Crick Institute. UCL (**Emberton, Punwani**) is a major partner in the CRUK-led International Alliance for Cancer Early Detection (ACED), a £55M investment bringing together UCL, Canary Centre at Stanford University, the University of Cambridge, the Oregon Health and Science University Knight Cancer Institute, and the University of Manchester. This will host 24 co-investigators across UCL and partner NHS trusts, with access to over 200,000 patients for clinical trials. **Janes** leads the £56M SUMMIT study of lung cancer screening for 25,000 people, the largest ever UK lung cancer screening study, providing training, and validation of a novel test for early lung cancer diagnosis. UCL hosts CRUK Centres of Excellence in Lung Cancer (awarded 2019, with University of Manchester; £1.5M to UCL), and in Brain Cancer (awarded 2018, with GOSH ICH and University of Edinburgh; £1.5M), and leads the CRUK RadNet (£1.5M total, with UCLH, Crick, KCL and Barts), combining multidisciplinary science and engineering for advanced radiotherapy and building training capacity in radiation oncology. CI is the UCL partner for the cancer theme in the UCLH-UCL BRC, supporting recruitment and infrastructure (£20M for cancer). Examples of other major funding include: MRC singe cell genomics award for state-of-the-art

equipment to study circulating tumour cells as surrogates of tumour tissue (£3.6M, 2014); a Brain Tumour Award, a CRUK-backed international consortium including UCL, Edinburgh, The Institute of Cancer Research (ICR), University of California San Francisco, and sick Kids/ University of Toronto, to advance research and treatment in brain cancer (£5.8M total, £1.8M UCL component, 2019); an Experimental Cancer Medicine Award to support early phase, experimental cancer research funded through a unique UK wide initiative jointly funded by CRUK linked to 18 Centres (£2.5M, renewed 2017); the UCL-led Cancer Immuno-Therapy Accelerator (CITA) (with UCLH, KCL, The Crick Institute, Bart's, The Royal Marsden Hospital, ICR), to generate state-of-the-art immune-monitoring and discovery research, with Immuno-Oncology clinical trial training (£5M, 2015); the Posthumous tissuE donAtion in CancEr (PEACE), led by UCL, a multi-centre national study collecting tissue and blood samples from patients with metastatic cancer after death (£4M, 2016); the International Glioma Cellular Genetics Resource (GCGR)**,** jointly led by Edinburgh and UCL, aiming to accelerate research into the biology and treatment of brain cancer (£3.7M, 2016). UoA1 researchers are also key participants in awards for multimodal clinical testing of prostate cancer patient plasma, (£5M, 2018), the Innovative CAR Therapy Platform (INCAR), to build understanding of mechanisms responsible for biological efficacy and toxicity of CAR T cell therapy (£4.5M, 2018), the CRUK Mesothelioma Accelerator Award (**Janes**) with Glasgow (£4.9M, 2019), the Hepatocellular Carcinoma Expediter Network (HUNTER) (£5M, 2018), and the Advanced radiotherapy Technologies Network (ART-NET) to generate innovative national radiotherapy treatment protocols (£4.3M, 2016). 17 Individual Cancer Researchers at UCL have received other major research grants as PI (each >£1M)**, (Emberton, Vanhaesebroeck, Quezada, Parrinello, Salomoni** (now Honorary), **Hartley, Nathwani, Pule, Fielding, Walczak, Peggs, Hochhauser, Jenner, Bennett, Davidson, Janes**). Senior fellowships have been awarded to **Quezada** (CRUK Senior Research fellowship)**, Hadjur** (Wellcome Senior Research fellowship)**, Payne** (CRUK Career development Research Fellowship)**, Mansour** (CRUK Senior Research Fellowship)**, Swanton** (Royal Society Research Professorship), **Janes** (Wellcome senior fellowship renewal), and **Jacob** (Wellcome Trust Clinical Research Career Development Fellowship).

3.1.2 Infection, Immunity, Inflammation

The Africa Health Research Institute (AHRI) was established from a £35M Wellcome award (Director, Pillay). I&I is the UCL partner for the UCLH-UCL BRC **Inflammation, Immunity and Immunotherapeutics** theme, supporting recruitment and infrastructure. **Breuer** (now in GOS ICH**)**, Director of UCL Pathogen Genomics Unit, is one of the leaders of the COVID-19 Genomics UK Consortium mapping pandemic spread, comprising the NHS, Public Health Agencies, Wellcome Sanger Institute, and UK universities including UCL, backed by £20M government funding. **Breuer** was also awarded £3.3M by NIHR for research combatting anti-microbial resistance and a £2.6M Wellcome Collaborative Grant to understand why Norovirus pandemics occur and how to control them; **Towers** obtained a £2.1M Wellcome Collaborative Grant on innate immune DNA sensing and viral evasion strategies, and **Griffiths** a £2.6M Wellcome Collaborative Grant for analysis of cytomegalovirus pathogenesis in a human challenge system. Collaborative awards were led by **Heyderman** to establish a Global Health Research Unit (£5.4M from NIHR), and **McHugh** who received a total of £2.4M from the Global Alliance to reduce the burden of tuberculosis in developing countries; **Akbar** was awarded a £2.1M MRC grant to enhance antigen-specific immunity in older humans using p38MAPK inhibitors and vitamin D3. **Heyderman** received £1.9M from the Bill & Melinda Gates Foundation to accelerate reduction in vaccine serotype population carriage in Malawi and other high disease burden countries. **Ehrenstein** was a key participant in a £5M MRC Stratified Medicine grant to improve therapy for SLE by application of novel and stratified approaches (MASTERPLANS).

UCL researchers in this theme received major individual grants: an £1.8M ERC Advanced Investigator Award to **Towers** for HIV innate characterisation and manipulation of primate lentiviral interactions with innate immunity; two MRC programme grants to **Seddon** (£1M) and **Walker** (£1.1M), for Regulation of T cell development and function by TNF signalling; four Wellcome Investigator Awards, £1.3M to **Maini** on immunopathogenesis and immunotherapy of viral hepatitis, £1.3M to **Jolly** for Virus-host interactions regulating HIV-1 replication in T Cells, £1.65M to **Sansom** to unravel the CTLA-4 immune checkpoint, and £1.6M to **Noursadeghi** for investigations of the Human Immune Response Variation in TB. **Leslie** was awarded a Wellcome

Senior Fellowship to investigate the role of lung tissue resident memory T-cells in the immunopathology of tuberculosis. **Stauss** obtained £1.5M (Apollo Therapeutics) to develop a new therapy for multiple sclerosis, and £2.2M (Wellcome) for characterisation of innate immune DNA sensing and viral evasion strategies. **McCoy** obtained an ERC grant (£959,000) to understand HIV-specific B cell function and viral Immunogenicity, **Pillay** received £900,000 from the Bill & Melinda Gates Foundation to investigate the transmission of HIV through understanding phylogenetic networks. **Giles & Rahman** obtained a £3.53M MRC DPFS award to develop PEGylated Domain I of beta-2-glycoprotein I as a new therapeutic agent for the antiphospholipid syndrome. Other major grants led by UoA1 scientists include: an £926,636 Versus Arthritis Programme grant to **Mauri & Isenberg** investigating the role of regulating B-cells in health and in rheumatic diseases; **Pepys** and **Rossor** were awarded a £2.75M UCLH/UCL BRC Strategic Award, for depletion of serum amyloid P component in Alzheimer's disease: DESPIAD. Major funding for clinical trials included: £1M from Versus Arthritis to **Isenberg** to evaluate Rivaroxaban versus Warfarin for stroke patients with antiphospholipid syndrome with or without SLE; £1.5M from Alnylam Pharmaceutical Inc to **Gillmore & Hawkins** for trials of novel treatments for amyloidosis; £1.2M from Eidos, for a phase 3 trial & Cardiac MRI sub-study to **Gillmore & Fontana**; £1.2M to **Ehrenstein** from GSK for safety and efficacy of Belimumab after B cell depletion (BEAT-LUPUS).

Senior and Career Development Fellowships have been awarded to **Rowe, Male, Grove, Kloverpris** (all Sir Henry Dale Fellows), **Maillard** (UKRI Future Leaders Fellow), **McCoy** (MRC Research Fellow), **Leslie** (Wellcome Senior Research Fellow), **Fontana** (BHF Intermediate Clinical Fellowship), **Pesenacker** (Versus Arthritis)

3.1.3 Child Health

The GOSH BRC, the only NIHR BRC focused on Child Health, was renewed in 2017 (£37.5M over five years, a 7% increase on 2012, directed by **Voit**). Through the BRC, GOSH and GOS ICH work closely together to deliver world class research; GOS ICH has also contributed substantially to GOSH Charity's Research Strategy (2016-22). The Charity committed a total of £50M to research over five years in new posts, infrastructure, and pump-priming grants to leverage additional external support, focused on clinical priority areas of Cancer, Infection and Immunity, Neuroscience, Regenerative and Developmental Science, Endocrine and Metabolic, and Cardiovascular.

In this REF period, five GOS ICH researchers were awarded NIHR Research Professorships, **Amrolia** (2013), **de Coppi** (2014), **Qasim** (2015), **Kurian** (2017) and **Kinsler** (2020); **Achermann** renewed his Wellcome Senior Fellowship for the second time in 2017; **Thrasher** was awarded a Wellcome Principal Research Fellowship in 2013, renewed in 2019; and **Kurian** was the sole recipient of the 2017 Sir Jules Thorne Award for Biomedical Research (£1.5M). In 2015, GOS ICH scientists were awarded three EU Horizon 2020 Health Grants (**de Coppi, Gaspar** and **Mole**).

Led by **Copp**, the Human Developmental Biology Resource (HDBR), a collaborative award with Newcastle University, funded in 2018, by Wellcome and MRC (£2.1M), provides an embryonic and fetal tissue bank for functional genetics and cell-based research. In 2019, **Livesey** led The Human Developmental Biology Initiative, a collaborative award by Wellcome for £9.58M (£3.22M to UCL), which will work closely with HDBR to develop the required technologies, creating two research hubs in proximity to the HDBR sites in London and Newcastle to advance understanding of developmental cell lineage as the basis for comparative studies of development between species, and understanding the developmental origins of disease.

Wedderburn with **Isenberg** renewed Versus Arthritis funding to establish a National Adolescent Rheumatology Unit at UCL/GOS ICH (£2M, a major uplift from the original award in 2012). **Wedderburn** also led a successful collaborative bid to the MRC Stratified Medicines call for the CLUSTER Consortium, "Childhood arthritis and its associated uveitis: stratification through endotypes and mechanism to deliver benefit".

Major funding for development of novel cell therapies includes a £1.65M MRC DPFS award to **Gissen** (2016) to develop AAV-mediated gene therapy for a severe metabolic liver disease, ornithine transcarbamylase deficiency, and a £1.4M MRC DPFS grant to **Qasim** to translate CRISPR/Cas gene-edited cell therapy products to the clinic.

Other major funding awards are £1.7M from Wellcome to **Jenkins** for investigation of ciliopathies, renewal of **Scambler's** British Heart Foundation Programme Grant (£1.43M) to investigate morphogenetic signalling pathways in Di George and Charge syndromes, and £1.53M to **Martinez-Barbera** by CRUK to characterise pro-tumourigenic activities of cellular senescence in adamantinomatous craniopharyngioma.

3.1.4 Experimental Medicine

Since REF2014, there has been major growth in experimental medicine particularly in imaging, respiratory research, cardiovascular research, surgery and interventional sciences, and obesity research.

Surgery

The newly refurbished Charles Bell House, opened 2016, houses the interdisciplinary WEISS Centre, established through a £13.1M Wellcome/EPSRC award to **Emberton, Punwani, and Lovat**, which enabled co-location of scientists in engineering, imaging, surgery, and biomaterials, bringing together multiple imaging modalities, robotics, sensing, nanoengineering, surgical navigation and simulation, to accelerate innovation, and concept-to-product research for maximum impact. A £1.8M refurbishment of IOMS on the Stanmore campus (completed 2019) has enabled co-location of IOMS staff and facilities for surgical rehabilitation research in a single building. **Moonesinghe** is one of three chief investigators in a global clinical trial supported by $9M in philanthropic support from the 'COVID-19 Therapeutics Accelerator' to establish whether chloroquine, a widely prescribed anti-malaria drug, could also prevent people from getting COVID-19.

Imaging

Punwani is lead and coordinator for the National Cancer Imaging Translational Accelerator with 8 UK Universities (CRUK £10M, 2019 – 2024), which superseded the CRUK/EPSRC Comprehensive Cancer Imaging Centre between UCL and KCL; **Punwani** is also lead for novel microstructural and metabolic MRI for prostate cancer (CRUK, £2.3M, 2018-23), and is co-investigator (Co-I) on multiple collaborations with **Emberton** in prostate cancer, including the world's largest developmental programme of metabolic hyperpolarised MRI for prostate cancer (INNOVATE, PCUK, £534,000 2015-19; Re-IMAGINE, MRC, £6.3M, 2018-23). **Lythgoe** was co-I on the UCL Centre for Doctoral Training in Medical Imaging (EPSRC, £6 million) and on the UK Regenerative Medicine Platform (MRC/EPSRC/BBSRC, £4.3 million). **Kalber** is co-I on the Regenerative Medicine Platform Safety and Efficacy Hub (MRC/EPSRC/BBSRC, UCL component £1.3M). **Stuckey, Lythgoe** were awarded £350,000 EPSRC funding for non-invasive imaging of glymphatic clearance to **Lythgoe, Wells**. **Stuckey** was co-I on a Regenerative Medicine Centre award (BHF, £2.5M). **Plumb, Taylor** are co-leads for NIHR HTA programme grants in Crohn's disease (£358,583, 2017-21), and for an NIHR EME programme in Crohn's (£895,292, 2016-20)

Fellowships were awarded to **Stuckey** (BHF Intermediate Fellowship £401,000), **Kalber** (EPSRC Fellowship £1.2M), **Harrison** (Alzheimers Research UK Fellowship £300,000), **Wells** (Wellcome/Royal Society Fellowship £759,037), **Walsh** (MRC Skills Development Fellowship £150,000), **Witney** (Wellcome Sir Henry Dale Fellowship £1.14M), **Plumb** (NIHR Postdoctoral Research Fellowship, £581,643, and NIHR Senior Fellowship).

Respiratory

New state-of-the-art laboratories for UCL Respiratory Medicine underpins major development in this area. **Lomas** obtained MRC Programme Grant funding for work on mechanisms and therapies for Alpha-1-antitrypsin deficiency (>£2M); **Hurst** obtained £1.3M from the MRC/GACD for his global COPD research; **Brown** was awarded £1.2M MRC Antimicrobial Resistance Target Discovery and Validation funding to develop adjunct antibody therapy for severe antibiotic-resistant *Acinetobacter baumanii* infections, and a £0.9M MRC Project Grant for Identification of effective protein antigens for novel *S. pneumoniae* vaccines. **Brown** was also co-I with **Breuer** on a £3M NIHR Antimicrobial resistance infrastructure award. **Porter** was awarded £2M to lead two clinical trials as part of a £10M fund launched to support research and testing of

therapeutics that could be rapidly deployed to help address COVID-19. **Jacob** was awarded a £400,000 NIHR BRC Capital Call Grant for Hyperpolarised Xenon lung imaging.

ILDH

Jalan leads two EU Horizon 2020 Consortia (€5.9M for Carbalive and €6.4M for Aliver) to develop and clinically translate innovative treatments for severe chronic liver disease. **O'Brien** was awarded £1.32M from Wellcome and the Department of Health for a nationwide clinical trial of albumin to treat infection in liver disease, the largest trial ever performed in this group of patients (ATTIRE), and £1.85M from the NIHR HTA, to reduce spontaneous bacterial peritonitis in liver cirrhosis (ASEPTIC trial). **Selden** received a £2M Wellcome Technology transfer grant for a bioartificial liver device for treatment of liver failure, and £1.45M for a Technology Strategy Board grant to development a GMP cryogenic cold chain for clinical delivery of regenerative medicine therapeutics.

Obesity Research

Batterham was awarded a £2.1M NIHR Professorship in 2016 for maximising the benefits of bariatric surgery**,** and was sole recipient of the 2016 Sir Jules Thorn Biomedical Research Award (£1.5M).

Intensive Care Medicine

Singer leads the Critical Care Theme of the NIHR Health Informatics Collaborative overseeing deposition of >120 million datapoints on >50,000 intensive care patients from 12 intensive care units within the 5 original BRCs in the UCL Safe Haven. **Singer** leads on first-in-patient clinical studies including the bladder tissue oxygenation monitor (£1.2M award from Wellcome & Department of Health), a novel sepsis biomarker panel (with Mologic, funded by a £1.3M Innovate UK Biomedical Catalyst Award), and is co-applicant on two multicentre clinical studies funded by the NIHR EME Programme, one a Wellcome Translation Fund Award, and one the EU COMBACTE antimicrobial resistance consortium.

Renal

Rohn obtained a £2M philanthropic donation to advance her work developing novel approaches to treatment of urinary tract infections. **Salama** obtained £567,350 MRC funding for targeting glycans in ischaemia reperfusion, and £274,554 from Kidney Research UK, to investigate and target sodium in autoimmunity and inflammatory kidney disease. **Gale** received £244,273 from Kidney Research UK to define functional genomics of congenital anomalies of the kidney and urinary tract.

Cardiovascular

UoA1 staff participated in a successful bid (lead **Hingorani**, UoA2) for a £1M BHF Accelerator Award supporting research in the BHF-NIHR Bloomsbury Centre for Clinical Phenotyping. **Hausenloy** received £1.5M for a BHF-sponsored multi-centre randomised controlled clinical trial on the effect of remote ischaemic conditioning on clinical outcomes in myocardial infarction patients undergoing primary percutaneous coronary intervention (Eric-Ppci); **McGregor** won a £1M MRC DFPS grant for development of a calcification resistant porcine pericardial heart valve; **Williams** was a major contributor to a £1.5M MRC DPFS award, and **Treibel** was a partner in a EU H2020 consortium award for Microvascular dysfunction in vascular cognitive impairment and heart failure (£759,000).

Other major grants include a £1M EPSRC HealthCare Challenge Award to **Schievano** for a hub for device personalisation in the treatment of congenital diseases, and a €1M ERC Starting Grant for computational modelling for personalised treatment of congenital craniofacial abnormalities. Major personal grants and/or fellowships were awarded to: **Deanfield** (BHF Chair extension); **Patel** £794,000 (BHF Clinical Intermediate Fellowship); **Treibel** (BHF Clinical Intermediate Fellowship £903,000); **Steeden** (Royal Society-EPSRC Dorothy Hodgkin Fellow, £414,000; UKRI Future Leaders Fellowship, £970,000); and 5 NIHR Senior Investigator awards (**Deanfield x2; Williams; Yellon, Elliot**).

IfWH

David was awarded a €2.6M FP7 grant (from 2013) to develop an innovative gene therapeutic treatment for foetal growth restriction, is co-applicant with UCL Healthcare Engineering on the GIFT Surg Wellcome/EPSRC funded £9.9M project to develop flexible fetoscopes that will lead to the evaluation and implementation of minimally-invasive techniques to repair spina bifida in utero, and is the UCL partner for an Horizon 2020 £4.8M grant, funding a first clinical trial of in utero stem cell transplantation for osteogenesis imperfecta (brittle bone disease). **Widschwendter** won a Horizon 2020 grant of £2.9M and a further £1.1M in charitable funding for research on women's cancers, and was also awarded an ERC Advanced grant of £1.8M. **Marlow** received £1.3M MRC funding for a clinical trial. **Waddington** received two MRC DPFS awards, to develop gene therapies for the early onset inherited genetic diseases, Dravet Syndrome, and Dopamine Transporter Deficiency Syndrome.

3.2 Core Infrastructure and Facilities

UCL has spent >£38M in this submission through its Capital Investment Fund (CIF) and Provost's Strategic Development Fund (PSDF) for major new research buildings, laboratory refurbishments, and to facilitate relocation of groups resulting from major infrastructure developments. In addition, UCL has awarded UoA1 groups £3.33M through its Capital Equipment Fund (CEF) and matched equipment fund, exclusively for shared equipment and facilities that are cross-faculty and multidisciplinary. UoA1 staff also received UKRI research income (in kind) of £1.13M for protein structural analyses using the Diamond Light Source Synchrotron, and the European Synchrotron Radiation Facility in Grenoble. Major infrastructural investment in individual UoA1 research themes is described below.

3.2.1 Cancer

In **Cancer**, there has been major investment in and expansion of existing core facilities, funded by the CITA CRUK accelerator, the CRUK UCL Centre, Cancer BRC Theme, MRC single cell genomics, and CRUK City of London Centre awards, and additional philanthropic donations, including: investment of £1.2M to upgrade our proteomics capability; substantial expansion of core flow cytometry, with investment of £1.4M, with key capital spending for high-speed cell flow-sorting, multidimensional flow-cytometry and CyTOFF cytometry; expansion of core genomics (£0.8M), including Fluidigm C1 microfluidic single cell sequencing technology, platforms for focussed (MiSeg) and high throughput (HiSeq) next generation sequencing and nCounter RNA multiplex profiler technology enabling analysis of RNA samples of poor quality; £0.9M for expansion of microscopy and cell imaging, including single cell time resolved analysis capacity (Nikon Biostation CT), confocal microscopy and high content imaging; and a new state of the art pre-clinical radiation research facility, including a Xstrahl SARRP small animal radiation research platform funded by £0.3M investment, further leveraged by UCL's investment in the Proton Beam Therapy Centre.

3.2.2 Infection, Immunity and Inflammation

The new PEARS building (led by **Stauss**) opening 2021, is a £60M investment including £24.2M from UCL's CIF, which will provide cutting-edge facilities for the IIT to develop world-leading basic, preclinical and translational research of the human immune system closely linked to clinical services and a clinical trial facility to translate research findings into patient benefit. The Pathogen Genomics Unit (PGU) has received major funding from the MRC, BRC, and UCL's CEF to **Breuer** (>£4M) to develop capacity in pathogen and other sequencing, transcriptomics and epigenetics; the facility has a turnover of ~£500,000 per annum and supports over £12M in grant income. The Centre for Amyloidoisis opened a new multiparametric cardiac MRI facility (£3M investment; led by **Hawkins, Gillmore, Fontana**) in 2016 for patient-centred research and clinical trials including a new gamma camera facility for diagnosis, quantification and monitoring of amyloid disease.

3.2.3 Child Health

Partnership between GOSH and GOS ICH created the Zayed Centre for Research into Rare Disease in Children, opened 2019 beside the existing GOS ICH building, and representing a major strategic investment in **Child Health** (£110M). The Zayed Centre provides state-of-the-art facilities for research into genetic and genomic medicine, regenerative medicine and cell and gene therapy, and is the new home for UCL Genomics, a collaborative research facility providing expertise in the latest genomics technologies including state-of-the art DNA and RNA sequencing and hybridization technologies, targeted sequencing, genotyping and methylation profiling. This will enable UCL Genomics to support a growing portfolio of projects at UCL as well as national and global collaborators. Equipment and laboratory fit-outs for the Zayed Centre are also supported by £2.75M from UCL's CIF.

The Human Developmental Biology Resource (**Copp**), described in **3.1.3**, has provided a new embryonic and fetal tissue bank to support research in this area. Other investment in child and adolescent health includes new laboratories for the Centre for Adolescent Rheumatology, a collaboration between GOS ICH and DoM, supported by £2M Versus Arthritis funding to **Wedderburn** and **Isenberg**.

3.2.4 Experimental Medicine

The refurbished Charles Bell House on the Bloomsbury campus (opened 2016) was a £35M investment providing state-of-the-art laboratories, offices and equipment for **Surgery & Interventional Sciences** (DSIS), for Imaging and the Institute of Healthcare Engineering (UoA15), and hosting the WEISS centre, including: facilities for image-guided surgery, metabolic hyperpolarised MRI in prostate cancer, including installation of a general electric hyperpolariser funded by a £5.3M MRC award to **Punwani** and **Emberton**, 3T MRI research, flexible wet labs, tissue culture, sequencing, laser work, histology, imaging and engineering workshops. This investment underpins UCL's leadership of the world's largest developmental programme for metabolic hyperpolarised MR in prostate cancer, and is powering innovative interdisciplinary research programmes in robotics, and surgical simulation and training. A £1.8M refurbishment of IOMS completed in 2019 on the Stanmore/RNOH campus has enabled co-location of all IOMS staff and has provided new purpose-made facilities for surgical rehabilitation research and the ASPIRE centre. A new medical imaging suite for DSIS was equipped with a £1M investment, offering unique platforms to researchers.

UCL **Respiratory Medicine** had a major refurbishment in 2014 (£4.2M from UCL's CIF) to establish a floor of new laboratories and offices providing dedicated space for co-location of 9 research groups in respiratory science and medicine. **Porter** and **Navani** developed the first cryoscopic biopsy service for interstitial lung disease in the UK with charitable and GSK funding. **Janes** is the lung theme lead in the CRUK Early Lung Cancer Detection Centre developing online pathology and imaging for research networks. **Renal Medicine** has acquired a new imaging suite with live cell and confocal imaging (£800,000).

UCL/UCLH and the NIHR BRC built a £2.5M GMP Radiopharmaceutical Production facility and invested in follow up capacity building to drive innovation in proof-of-concept studies for disease biomarkers, diagnostics and therapeutics, and accelerate clinical trials and translational imaging research. Major new investment in **Imaging** has funded multiple imaging modalities for clinical and pre-clinical research, including a £6M MRC Infrastructure Award for Image Guided therapy to **Lythgoe, Punwani** and **Emberton**; a £2M BRC-funded Imaging Trials Unit (**Punwani**); two 9.4T MRI systems for preclinical molecular MRI research (£2M award to **Walker-Samuel, Lythgoe**); a 3T MRI system for preclinical studies (£2M, **Punwani, Lythgoe**); £850,000 Wellcome funding to **Walker-Samuel, Lythgoe** for a preclinical MRI system for neurology and oncology; a £735,000 UCL CIF Award for Multimodal MRI to **Lythgoe, Walker-Samuel**; a £460,000 UCL CIF Award to **Lythgoe** for a PET/CT system; an ICON compact 1T MRI system for benchtop imaging of small rodents**,** an Optical Projection Tomographic scanner, an IVIS Spectrum for bioluminescence imaging in small animals (**Stuckey**, £400,000); NanoSPECT/CT and Mediso NanoScan PET/CT equipment for small animal imaging at different resolutions (**Lythgoe, Kalber**, £450K); and funding for a VisualSonics vevo2100 Ultrasound System for in-vivo small animal imaging to 30 μm resolution, photoacoustic imaging, and high-resolution episcopic microscopy to create 3D computer models at sub-micron resolution.

New infrastructural investment in **Cardiovascular Science** includes the £1M clinical research centre occupying the 4th floor 170 Tottenham Court Road, and £2M from UCL, UCLH Charity and the UCLH NIHR BRC for the Bloomsbury Centre for Clinical Phenotyping, operational 2017, equipped using a £776,000 BHF infrastructure award. In 2019, Children's Cardiovascular Diseases occupied a full floor in the Zayed Centre for Research into Rare Disease in Children. The MRC Unit for Lifelong Health and Ageing at UCL (MRC LHA) received £650,000 from UCL (to house **Captur**) and MRC investment supported LHA's move into refurbished offices at Torrington Place, coalescing all UCL's population cohort research.

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

4.1 Collaborations

4.1.1 National Collaborations

The results of a UoA1-wide survey conducted in July 2020 showed that 92% staff in this submission have been involved in national collaborations. UCL is a founder of the Francis Crick Institute, which opened in 2016 under Director Prof Sir Paul Nurse, employing 1,250 scientists with an operating budget of >£150M p.a.. UCL is an ideal founding partner because of its research excellence in Life and Medical Sciences, and the location of its main campus and NHS partners within 10 minutes' walk to the Crick. Several staff returned in this submission have senior group leader (**Swanton, Breuer, Bonfanti**) and early group leader (**Beale**) positions jointly with the Crick.

UoA1 units and staff (eg **Emberton, Enver, Hargrave, Herrero, Hochhauser, Jacques, Jamal-Hanjani, Janes, Lythgoe, Morris, Parrinello, Peggs, Pule, Punwani, Quezada, Stauss, Swanton, Walczak**), lead or are major partners in multiple national networks and consortia. Major examples include the Advanced radiotherapy Technologies Network (ART-NET), The Posthumous tissuE donAtion in CancEr (PEACE), The Cancer Immuno-Therapy Accelerator (CITA), CRUK radiation network award (RadNet), the CRUK Brain Cancer Centre of Excellence (BCoE), The CRUK-City of London Centre, and the CRUK Lung Cancer Centre of excellence (LCoE). The UCL CRUK Clinical Trials Centre leads phase I and II studies across the UK, with active recruitment from 17 Experimental Cancer Medicine Centres. **Punwani** is coordinator for the National Cancer Imaging Translational Accelerator involving UCL with the Universities of Glasgow, Manchester, Newcastle, Oxford, Cambridge, Imperial, KCL and ICR. UCL Partners with UCL's Cancer Institute, together with Queen's University Belfast, University of Leeds, Leeds Teaching Hospitals, Genomics England and IQVIA, leads the DATA-CAN: a new Health Data Research UK Hub for Cancer funded by Health Data Research UK to transform how cancer data from across the UK is used to improve patient care.

Peggs is Director of the National Institute for Health Research (NIHR) Blood and Transplant Research Unit (BTRU) in Stem Cells and Immunotherapies, an inter-disciplinary partnership between UCL, KCL, QMUL and NHS Blood and Transplant. **Beck** is Director of the Personal Genome Project UK; he leads the Epigenetics subdomain for the Genomics England Clinical Interpretation Partnership *(*GeCIP*); a*nd co-leads the International Human Epigenome Consortium EpiMap partnership. **Fielding** is Chief Investigator of the CRUK-funded UKALL14 (involving 70 NHS centres) and UKALL60+ studies (30 NHS centres), the UK's frontline researcher-initiated trials for Acute Lymphoblastic Leukaemia. **Vanhaesebrouck** leads the EU-funded Innovative Training Network for PhD Training in 'PI3K in health and disease'.

Breuer and **Castellano** are members of the COVID-19 Genomics UK Consortium (see **4.2.2**). **Hawkins, Pepys, Gillmore**, established the UK Amyloidosis Network (UKAN), the UK Amyloidosis Advisory Group (UKAAG) and the UK ATTR Amyloidosis Patient Association (UKATPA). In the UK Government's landmark 100,000 Genomes Project**, Swanton, Flanagan, Bridgewater** and **Thirlwell** are leads of Cancer Domains, **Jacques** and **Beales**, respectively, co-leads of the Childhood Solid Cancers and Paediatrics Domains, **Gale** and **Kleta** co-leads for the Renal domain, and **Chitty** led recruitment and analysis of ~26% of rare disease genomes from ~7,700 families in this project.

UoA1 staff are members of the NIHR Cardiovascular Network, **Humphries** co-established the UCL, Edinburgh, Bristol Consortium of Genetic Studies (UCLEB) with Bristol and Edinburgh Universities. ICS staff (**Clapp**, and Honoraries) are members of the UCL-wide PAH consortium, which is linked nationally through the National Cohort Study of Idiopathic and Heritable Pulmonary Arterial Hypertension (BRIDGE - project funded by BHF & MRC) and linked internationally through the Pulmonary Vascular Research Institute (PVRI), a global medical research charity fighting pulmonary disease.

With Newcastle University, **Copp** leads the Human Developmental Biology Resource, a Wellcome and MRC-funded collaborative resource, and **Livesey** leads the Wellcome's £10M collaborative Human Developmental Biology Initiative.

4.1.2 International Collaborations

Our survey showed that 85% of staff were involved in international collaborations, and 28% hosted visiting international researchers at UCL for a period of 12 months or more, funded by a competitive scheme from their own country. Since 2014 UCL's Global Engagement Office has awarded 73 grants to staff in UoA1 from its Global Engagement, Cities and other Funds, with a total value of £172,190, to foster international networking and collaboration. Since 2014, UoA1 researchers led 18 and were members of a further 37 international consortia funded by European Union FP7 or Horizon 2020 grants. For example, **Beck** is a co-lead, work-package lead or member of Horizon 2020 EU-STANDS4PM (WP lead), Horizon 2020 CETOCOEN-Excellence (member), NIH BioPath (member), Horizon 2020 MultipleMS (member), and NOCRC (WP lead).

UCL (lead, **Emberton**) with the Universities of Cambridge, Manchester, and Stanford and Oregon in the US, are partners with CRUK in the International Alliance for Cancer Early Detection (see **3.1.1**), to share ideas, technology and expertise in order to accelerate understanding of the earliest origins of cancer to detect and treat the disease before it emerges. UCL's CI is a major partner or lead in Hepatocellular Carcinoma Expediter Network (HUNTER), Innovative CAR Therapy Platform (INCAR), International Glioma Cellular Genetics Resource (GCGR), Multimodal clinical testing of prostate cancer patient plasma, and the Brain tumour award. Re-IMAGINE, STRATOSPHERE, and STAMPEDE are large international platform clinical trials led by UoA1 investigators (**Emberton, Attard**). GOS ICH is one of four members of the International Precision Child Health Partners with Melbourne, Boston and Toronto.

Fielding leads the CRUK program "personalising therapy in adult ALL" jointly with AV Moorman (Newcastle) a partnership involving the Wellcome Sanger Institute, Memorial Sloan Kettering and QMUL. In Cardiovascular Science, **Patel** co-leads an international consortium across >17 countries investigating Genetic and Non-Genetic Determinants of Subsequent Coronary Heart Disease (GENIUS-CHD). ICS has international partnerships with the Karolinska (Sweden); Medical University of Utrecht (Holland), and Yale (USA), Duke Medical School NUS, University of Brno, University of Cape Town (South Africa), Menzies Institute for Medical Research, University of Tasmania (Australia), University of Aarhus (Denmark), and inherited disease consortia with several multi-national Pharma collaborators.

The UCL-Yale Collaborative is a multi-disciplinary, transatlantic research, education, training and clinical collaboration between UCL/UCLP and Yale University/Yale-New Haven Hospitals, underpinned by a Framework Agreement signed by the Presidents of the two Universities and the CEOs of their hospitals, led by **Martin** until 2017.

4.2 Contribution to the research base, economy and society

4.2.1 Contribution to the research base

Our comprehensive survey of UoA1 staff in July 2020 shows that:

43.7% served on national (Research Council or similar) or international grants committees, and 86% have refereed research funding proposals;
28% are members of learned societies and 36% of professional bodies;
40% served on journal editorial boards, and 92% have refereed manuscripts for journals;
63% have participated in conference organisation, with 74% serving as conference programme chairs, 67% have given invited keynote lectures, and 95% given invited lectures;
82% have examined doctorates;
65% have engaged with industry through research or in advisory capacities, and 62% have taken steps to translate or commercialise their research for patient and societal benefit;
43% were members of expert boards or committees outside the university sector (e.g. NHS, regulatory, government, industry);
78% have directly engaged with non-academic users of research (industry, NHS, government), and 87% engaged with non-academic audiences or beneficiaries of research (e.g. schools, patient groups, media and cultural organisations).
In addition, UoA1 staff performed paid consultancy work valued at >£16.7M during the REF period.

Major contributions in these different areas are highlighted below.

Research Councils, Charities, and other funding bodies

Lomas was MRC's Deputy Chief Executive from January 2017 to March 2018, responsible for driving forward the MRC Delivery Plan and ensuring that the organisation remained a world leader in medical science in preparation for the creation of UK Research and Innovation (UKRI). **Lomas** was also a member of the BHF Board of Trustees, 2016-2019. **Swanton** is Cancer Research UK's Chief Clinician. **Rosenberg** is Scientific Adviser to the NIHR Office for Clinical Research Infrastructure, and is the NIHR CRN Hepatology National Specialty Lead. **Halligan** is a member of the NIHR Health Technology Assessment (HTA) Commissioning Board and the NIHR HTA Strategy Group. **Isenberg** is a member of The Board of Trustees and a non-executive director for Versus Arthritis (formerly Arthritis Research UK). **Fielding** is a member of the NIHR HTA Interventional Panel. **Smyth** is Chair of the MRC Clinical Training and Career Development Panel and clinical chair of the MRC Training and Careers Strategy Board and Overview Group. **Towers** is Chair of the Wellcome Expert Review Group in pathogen biology and transmission. During this REF period, UoA1 academics served on the grant awarding committee panels for the Wellcome (**Noursadeghi, Walker, Maini, Breuer, Lythgoe**), MRC (**Enver, Pillay x2, Mauri, Hochhauser, Morris**), BBSRC (**Pineda-Torra**), CRUK (**Khwaja, Stauss, Bridgewater**), and BHF (**Zachary**). **Elliott** is president of Cardiomyopathy UK.

Government

Lomas is Deputy Chair, Scientific Advisory Committee Genomics England 2013-. **Breuer** is Chair of the Department of Health Joint Committee on Vaccines and Immunisations (JCVI) human papillomavirus vaccine subcommittee, which oversaw introduction of three new human papillomavirus vaccine policies that between them are predicted to eradicate most HPV cancers in the UK, and Chair of the JCVI VZV vaccines subcommittee, which introduced a new vaccine predicted to prevent 98% of shingles. **Brown** is a member of the JCVI.

Learned societies, Editorial Boards

Williams is Chairman-Elect of the European Council on Hypertension of the European Society of Cardiology. **Lomas** is a member of the Council of the Academy of Medical Sciences. **Akbar** is President of the British Society of Immunology since 2019. **Martin** chaired the European Society of Cardiology Task force on stem cells and heart to 2018. In this REF period, **Maini, Breuer, Morris, De Coppi & Akbar** were elected Fellows of the Academy of the Medical Sciences (FMedSci). **Moonesinghe** represents the Academy of Medical Royal Colleges on the Board of the UK Clinical Research Collaborative (UKCRC). **Jalan** is Editor-in-Chief of the Journal of Hepatology (2015-present). **Grove** has been included in the World Economic Forum's Class of 2020 Young Scientists, a global list of exceptional researchers at the forefront of scientific discovery, one of 25 scientists from five continents, nominated for their research excellence, leadership potential and commitment to serving society. **McGranahan** was named as one of 30 EMBO Young Investigators for 2020, recognised for their scientific excellence and among the next generation of leading life scientists.

NHS

Powis (Professor of Renal Medicine, Honorary UCL appointment in UoA1) was appointed the National Medical Director of NHS England from 2018. **Cross** is Clinical Advisor to the National Children's Epilepsy Surgery Service. **Fielding** chairs the UK National Cancer Research Institute (NCRI) Adult ALL subgroup and a member of the UK NCRI Industry Adoption Panel. **Khwaja** is a member of the NCRI Haematological Oncology Clinical Studies Group. **Lomas** was non-executive director UCLH 2015-18, reappointed until 2021. **Burns** is Clinical Director Royal Free NHS Foundation Trust. **Stauss** is Governor of Royal Free NHS Foundation Trust. **Hurst** is UK COPD lead for National Asthma and COPD Audit Programme. **Janes** is Vice Chair of the Lung Cancer Clinical Excellence Group. **Denton** is a member of NHS England Rheumatology Clinical Reference Group. **Ehrenstein, Rahman** and **Giles** are members of Department of Health working groups and NHS England commissioning groups for rheumatological diseases. **Moonesinghe** is associate National Clinical Director for Elective and Critical Care at NHS England.

Regulatory authorities

Cross is Clinical Advisor to the update of the NICE guidelines for Childhood Epilepsy 2018-2021. **Navani** is a member of the NICE Committee for Lung Cancer.

Industry

Lomas was a member of the Steering committee, "Evaluation of COPD Longitudinally to Identify Predictive Surrogate Endpoints", for GSK to 2016, and is a member of the Trelegy COPD advisory board, GSK 2017-present, and of the Grants committee for the Grifols Alpha-one antitrypsin Laurell Training Award (ALTA) Grifols 2012-present.

NGOs, Other

Cross is Treasurer of the International League Against Epilepsy 2017-2021 (Secretary General 2013-2017), **Lomas** is Director of GMEC 2015- and MedCity Ltd. 2016-, member of the Board of Directors of the Crick Institute 2015-, and the Board of Directors Africa Health Research Institute 2016-. **Hurst** is lead of the multi-morbidity working group at Global Alliance for Chronic Disease.

4.2.2 Contribution to Economy and Society

New enterprises: spin out companies

UCL's TRO and UCLB commit support to the translation of research for societal and economic benefit, including small proof-of-concept grants worth >£4.5M for 41 projects led by UoA1 researchers. UoA1 staff performed consultancy work for industry and small or medium-sized companies worth £13M.

Since 2014, UCLB's Apollo and UCL Technology Funds (circa £100M) have provided support to enterprise activity led by UoA1 researchers, including £430K for 5 Proof-of-concept awards, £8.7M for 7 UCL Technology Awards, and £7.2M in the initial stages of spin-out companies. Staff in this submission are primary founders of spin-out enterprises that have collectively raised >£900M in private and other investment, and have generated a cluster of high-value companies centred on advanced therapies for human diseases, now employing >1000 people. Major examples are:

- Autolus Therapeutics Ltd, founded in 2014, by **Pule** (senior Vice-President & Chief Scientific Officer), with £30M investment from Syncona, followed by £99M in series B and C investment, to deliver advanced T-cell programming and manufacturing technology in the development of Chimeric Antigen Receptor (CAR) T cell therapies for haematological malignancies. Autolus launched on the NASDAQ stock exchange in June 2018, raising $160M (£123.6M) investment, now employing ~400 people, most in highly-skilled roles. Autolus is recognised as a UK industrial success story, featured in the government's Life Sciences Sector Deals published 2017 and 2018 as a case study for "Making the UK a global hub for advanced therapies manufacturing", and was one of a small number of biotech companies invited to discuss UK industrial strategy with then Secretary of State for Business, Energy and Industrial Strategy, Greg Clark.
- Orchard Therapeutics, founded by **Gaspar** (Honorary at UCL since 2019) and **Thrasher** to develop gene therapies for complex rare diseases, was spun out of GOS ICH in 2015, with **Gaspar** as Chief Scientific Officer. In 2018, a strategic agreement between GSK and Orchard secured development of GSK's portfolio of approved and investigational rare disease gene therapies by Orchard, and access for patients. Orchard raised $110M (£85M) Series B funding in December 2017, and in November 2018, $225 million (£173M) through its initial public offering (IPO) on NASDAQ, being valued at £1.3BN; Orchard currently employs >230 people in the UK and US.
- Achilles Therapeutics co-founded by **Swanton, Peggs, Quezada & Lowdell** launched in 2016, has raised £183M Series A, B and C investment to design therapies targeted at truncal tumour neo-antigens, and currently employs 130 mainly highly-skilled staff at its headquarters in Stevenage, UK.
- Freeline Therapeutics based on **Nathwani's** development of new therapies for haemophilia was founded in 2015, raised £91.8M Series B and C investment, $158.8M in an IPO on NASDAQ in August 2020, and now employs 200 staff in the UK, Germany and the US.

- **Stauss** and **Morris,** in partnership with scientists from KCL, and Hannover Medical School, co-founded Quell Therapeutics with £34M from Syncona Ltd in March 2019, and a further £1M from the UCL Technology Fund. Quell Therapeutics now has ~30 employees developing therapies which harness the suppressive capacity of T-regs to address several conditions of immune dysfunction utilising gene-modified cells.
- Yaqrit, founded by **Jalan** to develop novel therapies for liver disease, has raised £3.4M in Series A and other investment and employs 12 people.

Clinical trials

Investigators in UoA1 make pivotal contributions to large-scale clinical trial activity, and UCLH, GOSH and RFH are at the forefront nationally for patient recruitment in clinical trials, exemplars of which are described here. **Janes** is Chief Investigator of the SUMMIT Study delivering low dose CT lung cancer screening to 25,000 people in London and developing early cancer blood tests for 50,000 (UCL Sponsored/GRAIL funded), leading to building of 4 new CT screening centres screening 150 people a day. **Janes** also leads the FIM cell and gene therapy study TACTICAL (£2.9M MRC) and METEOR (Innovate - £1.65M) phase 1/2 studies delivering a therapy designed and manufactured at UCL, and is Chief Investigator in EARL – a first randomised controlled trial of a therapeutic intervention in early lung cancer, and of the Lung Screen Uptake Study showing the use of the Lung Health Check and Lung MOT were acceptable to patients, a model taken up by Manchester, Nottingham and Leeds in subsequent trials, and now adopted by NHS England for their CT Screening pilots. More than 20 other active clinical trials are led by or involve UoA1 investigators, including the landmark academic trials, PEACE (**Jamal-Hanjani**), TRACERx (**Swanton**) and DARWIN (**Swanton**), to develop criteria for stratified cancer treatment, and the ALLCAR19 and EU funded CARD (both **Peggs**) trials for CAR-T based immunotherapy. UoA1 staff lead or co-lead prominent multicentre clinical studies to develop novel therapeutics, early detection and risk identification: **Attard** is lead or co-lead for the PRIME, Re-IMAGINE (led by **Emberton**), STRATOSPHERE, PCF SELECET, and STAMPEDE clinical studies; **Swanton** leads the Bristol Myers Squibb-funded RUBICON-A Rule Book and Immune Atlas for Combination Therapy, and co-leads the NovoNordisk Foundation-funded Data-intensive complex systems approach, and EU FP7 PREDICT studies; **Yong** is lead or co-I for the UKMRA Myeloma XV TMG, RADAR, and 2019 Myeloma Early Detection CRUK Programme. **Morris** and **Stauss** led completion of one of the first T-Cell Receptor gene therapy trials in Europe. **Denton** led multiple academic or commercial clinical trials (ESOS, deSScipher, ZEBRA, Sclero-XIII, MINIMISE, Endothelin antagonist, IL6R blocker, LPA1 antagonist, PPAR agonist, IL13 blockade) advancing healthcare for systemic sclerosis. **Ehrenstein** is Chief Investigator for the multi-centre BEAT Lupus trial testing a novel therapeutic combination for lupus (rituximab plus belimumab), the first academic-led early phase interventional UK clinical trial in lupus for a decade.

Emberton, Moore, Kasivisvanathan led two landmark prostate cancer imaging trials: PROMIS and PRECISION. The Division of Surgery and Interventional Sciences on the Royal Free campus is the lead UK centre for clinical trials in surgery and peri-operative care. **Vaidya** led the TARGIT-IORT trial, which has established the superiority of single-dose intraoperative radiotherapy over several weeks of daily conventional radiotherapy, with reduced toxicity, reduced all-cause mortality, and improved quality of life, reduced travel time and hospital visits. **Hurst** is the International coordinating investigator for the NOVARTIS “SUNSET” trial, **Porter** is Chief investigator of a multi-centre study of a novel treatment for Interstitial Pulmonary Fibrosis in collaboration with Vicore, **Brown** is involved in two early phase vaccine trials for *S. pneumoniae* (funded by MRC and ImmunoBio). **Pinzani** and **Rosenberg’s** development of a new infrastructure for investigator-initiated clinical trials in Hepatology at Royal Free Foundation Trust since 2014, has resulted in UCL-Royal Free Hepatology rising from 13th position to 3rd nationally for clinical trial recruitment in hepatology.

Public Health and Public Policy

Response to COVID-19 Pandemic

UoA1 staff have played leading roles in the national and global effort to fight the COVID-19 pandemic**. Peacock** (UCL Infection & Immunity, Honorary) is Director and **Breuer** and **Castellano** are members of the COVID-19 Genomics UK Consortium, pivotal to rapid viral genomic sequencing and mapping the spread of COVID-19 and identifying new variants; **Breuer** led

establishment and coordinates work of the Consortium's London hospital hub, and leads with Imperial College, the COG-UK Hospital Onset COVID-19 Infections (HOCI) study to evaluate the benefit of rapid genomic sequencing in preventing hospital transmission of COVID-19. **Moonesinghe** is one of three chief investigators in a global clinical trial (COVID-19 Research Outcomes Worldwide Network (CROWN) Collaborative) to establish whether chloroquine, a widely prescribed anti-malaria drug, could prevent people from getting COVID-19.

Singer and **Lomas** co-led a UCL team with **Shipley** (UCL Engineering, returned in UoA12) and Mercedes Formula 1 engineers (Mercedes-AMG High Performance Powertrains), which produced modified CPAP (continuous positive airway pressure) machines, called UCL-Ventura, adding vital ventilation capacity for treatment of COVID-19 patients. This gained NHS regulatory approval and an order for 10,000 CPAP devices by the UK government in April 2020 (https://bit.ly/3qVkwUc). The UCL-Ventura breathing aid is treating COVID-19 patients in 110 NHS hospitals across the UK. Details required to make the device are available to download free from https://bit.ly/347EbXa, a research licensing website developed by UCLB to disseminate technologies helping the fight against COVID-19, and have been downloaded by more than 1,800 teams from 105 countries around the world and ~30 teams are manufacturing devices for testing in Brazil, Bulgaria, Canada, Colombia, Germany, India, Iran, Mexico, Russia, South Africa and the USA. **Singer** and **Lomas** were co-recipients of the Royal Academy of Engineering's President's Special Award for Pandemic Services in recognition of their work on CPAP devices.

Williams leads CAPACITY-COVID, a UK-wide collection of cardiovascular complications due to COVID-19 and part of an international registry, and 1 of 7 national flagship projects funded by the NIHR-British Heart Foundation Cardiovascular Partnership. **Porter** received £2M to lead two clinical trials from LifeArc's £10M fund supporting development of therapeutics for COVID-19: ATTRACT, in collaboration with Vicore Pharma, will test whether VP01 (Compound 21) can recalibrate the renin-angiotensin- system towards repair; and COVASE, in collaboration with the Crick Institute, investigates the ability of recombinant human deoxyribonuclease I to reduce hyperinflammation in the lungs of hospitalised COVID-19 patients.

Vaidya's TARGIT-IORT trial has informed recommendations in guidelines for treatment of breast cancer during the pandemic for the British Association of Cancer Surgery, German University Hospitals, and the Italian Association of Radiotherapy and Clinical Oncology. **Peacock** and **Powis** (Honoraries), are members of UK government's Scientific Advisory Group for Emergencies (SAGE), advising the government on the pandemic, and several staff and honorary academics in UoA1 are members of SAGE subgroups, including **Beale** (Public Health England Serology Working Group**),** and **Hopkins** (Honorary consultant, The Hospital Onset COVID-19 Working Group).

Singer, Pillay, Breuer, Lomas, Brown contributed to the written evidence submitted by UCL to the House of Commons Select Committees on Science and Technology and Health and Social Care Joint Inquiry, "Coronavirus: Lessons learnt". **Montgomery** chairs the National Emergency Covid Critical Care Committee (hosted by the Intensive Care Society), and co-authored National Covid Critical Care Guidelines.

Other Contributions

The prostate cancer imaging studies, PROMIS and PRECISION (**Emberton, Moore and Kasivisvanathan**) resulted in changed NHS England and NICE guidance and the European Association of Urology guidance. The PRECISION study won the British Medical Journal's 2019 Paper of the Year Award to **Emberton, Moore, Kasivisvanathan** and **Punwani. Ehrenstein's** BEAT lupus trial adopted by NIHR Translational Research Partnership, led to NHS England Commissioning recommending rituximab for patients with myositis 2015-16, and contributed to interim Commissioning Policy recommending rituximab for lupus in 2015 and 2019. **Singer** chairs the International Sepsis Forum, and co-led the 'Sepsis-3' international taskforce that redefined sepsis. **Groves, Halligan, Hutton, Lythgoe, Plumb, Punwani, Taylor, Walker-Samuel** all contributed to the Imaging Biomarker Roadmap Guidelines for Cancer Studies. **Halligan, Plumb, Taylor** were major contributors to the ECCO/ESGAR European guidelines on assessment of inflammatory bowel disease and indications for large bowel imaging. **Halligan, Taylor** contributed to European guidelines for rectal cancer imaging. **Halligan** is leading the ESGAR European guidelines for imaging anal sepsis. Work by **Halligan, Plumb, Taylor** comprised 9 of the 35 references in the Royal College of Radiologists CT colonography National Standard Document,

integral to the National Guidelines for the use of imaging in the National Bowel Cancer Screening Programme. **Taylor** was a member of the UK Department of Health working group on use of CT screening in asymptomatic individuals and lead author for CT colonography in the 2014 Department of Health publication, "Justification of Computed Tomography (CT) for Individual Health Assessment". **Punwani** was co-author of the White paper on National implementation of prostate MRI. The Institute of Sport, Exercise and Health was a partner in the Camden Active Spaces project which involved improving the playgrounds of several primary schools and measuring the impact on activity levels of children within those schools. **Harper** was appointed to the Nuffield Council of Bioethics working group on Genome Editing and advisor on IVF culture media to the MHRA. She is a key player in the development of the Human Fertilisation and Embryology web site on IVF add-ons and co-author of the consensus paper on add-ons. She co-founded the Fertility Education Initiative aiming to bring fertility awareness into the UK curriculum. **Humphries** co-directed the Department of Health funded UK-wide pilot for cascade testing of Familial Hypercholesterolaemia (FH), was the Lead Clinical Advisor for the recently published NICE guidelines on FH, and is project director for the Royal College of Physicians FH Audit.

Public Engagement

Data from the Higher Education Business and Community Interaction Survey for 2018/19 record that 156.5 days of UoA1 staff time were allocated to 119 public engagement events with a combined audience of >72,000 people. Research in UoA1 has benefited from major public engagement facilitated by the UCL Public Engagement team, resulting in numerous contributions of UoA1 staff to TV and Radio programmes, aired on major terrestrial free-to-air channels, focused primarily or exclusively on UCL-led research. Highlights include: a 1.5hr BBC2 documentary on immunotherapy for leukaemia (**Pule, Morris**); a 1hr BBC2 documentary on **Jalan and Mehta**'s work revealing the risks of alcohol for liver disease; widespread coverage in mainstream national media of **Emberton** and **Moore**'s work on MRI for Prostate cancer diagnosis (BBC, national press); and the major contributions of UoA1 staff and honorary academics to the national effort to combat the COVID-19 pandemic (**Powis, Breuer, Singer**). UoA1 researchers have also been at the forefront of promoting public awareness of advances in biomedical science: **Lythgoe** was Director of the Cheltenham Science Festival (2005-18) and is a member of the Wellcome Public Engagement Fellowship Committee. The Evening Standard's annual list of London's most influential people (https://www.standard.co.uk/news/the1000) features several staff returned in UoA1, including **Gupta, Williams, Enver**, and **Swanton**.